NIGERIAN INSTITUTE OF FOOD SCIENCE AND TECHNOLOGY (NIFST)

EAST CENTRAL CHAPTER

11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT (ReFoSTS)

5TH JUNE, 2025 || 10:00AM GMT

International Conference Centre, Institute of Management and Technology, Enugu.

THEME: Food Science and Technology: A Panacea for National Development.

BOOK OF PROCEEDINGS

1. IMPACT OF FOOD PROCESSING ON NUTRITIONAL CONTENT AND NATIONAL HEALTH.
2. POSITIONING FOOD PROCESSING FOR FOOD SECURITY AND NATIONAL DEVELOPMENT.
3. TECHNOLOGICAL INNOVATIONS IN FOOD PROCESSING.
4. FOOD TECHNOLOGY AND ENTREPRENEURSHIP: DRIVING ECONOMIC GROWTH.
5. REPOSITIONING FOOD SCIENCE AND TECHNOLOGY FOR FOOD SUFFICIENCY IN 21ST CENTURY.

EDITED BY: Odo, M.O., Agu, H.O., Ekwu, F.C., Nwadi, O.M.M., Obinna, V.O., Nwadike, S. Okogeri, O., Okoronkwo, C.N, Ikegwu,T.M., Ezegbe, C.C., David-Abraham,F.M, Ikegwu, O.J., Nwakalor, C.,Egbeonu, S., Nwigwe, I.C.

NIGERIAN INSTITUTE OF FOOD SCIENCE AND TECHNOLOGY

EAST CENTRAL CHAPTER

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT (ReFoSTS)

THEME:

FOOD SCIENCE AND TECHNOLOGY: A PANACEA FOR NATIONAL DEVELOPMENT

DATE: **THURSDAY, 5TH JUNE, 2025**

VENUE: **INTERNATIONAL CONFERENCE CENTRE, INSTITUTE OF MANAGEMENT AND TECHNOLOGY, ENUGU.**

EDITED BY:

ODO, M.O., AGU, H.O., EKWU, F.C., NWADI, O.M.M., OBINNA, V.O., NWADIKE, S., OKOGERI, O., OKORONKWO, C.N, IKEGWU, T.M., EZEGBE, C.C., DAVID-ABRAHAM, F.M, IKEGWU, O.J., NWAKALOR, C., EGBEONU, S., NWIGWE, I.C.

CHAPTER EXECUTIVES

s/n	Chapter Officers	Position	email
1	Mr. Peter Agbata	Chairman	uninova2010@gmail.com
2	Prof Charles Ishiwu	Vice Chairman	cn.ishiwu@unizik.edu.ng
3	Mr. Paul Chidolue	Secretary	chidoluepaul1@gmail.com
4	Dr. Jeremiah Igwe	Asst. Secretary	Igwejerry5324@gmail.com
5	Comr. Ahmed Omoaka Oyarebu	Pub. Secretary	ahmedoyarebu@gmail.com
6	Mrs. Ngozi Igwego	Fin. Secretary	igwegongozi@gmail.com
7	Josephine Chigbolum Ohuche	Treasurer	chijosey@gmail.com
8	Mr. Ikenna Nwigwe	- Asst. Pub. Secretary	nwigweikenna@gmail.com
9	Prof. Eucharia Onwurafor	- Welfare Secretary	Eucharia.onwurafor@unn.edu.ng
10	Dr. Onyekachi Ikegwu	- Ex Officio	ikegwukachi@gmail.com

ZONAL COORDINATORS

S/N	NAME	POSITION	EMAIL CONTACT
1	Prof. Eunice Uzodimma	Coordinator, Nsukka Zone	Eunice.uzodinma@unn.edu.ng
2	Comr. Oyarebu Ahmed Omoaka	Coordinator, Awka Zone	ahmedoyarebu@gmail.com
3	Dr. Innocent Ajawobu	Coordinator, Onitsha Zone	ajawobuinnocent@gmail.com
4	Prof. Charles Ishiwu	Coordinator, Enugu Zone	cn.ishiwu@unizik.edu.ng
5	Mr. Vincent Obinna	Coordinator, Afikpo Zone	vinoko43@gmail.com
6	Prof. Michael O. Odo	Coordinator, Abakiliki	odom1749@gmail.com

ADDRESS PRESENTED BY THE CHAIRMAN EAST CENTRAL CHAPTER OF NIFST, APOSTLE PETER, C. AGBATA ON THE OCCASION OF THE 11TH ReFoSTS HELD AT THE INTERNATIONAL CONFERENCE CENTRE, INSTITUTE OF MANAGEMENT AND TECHNOLOGY (IMT), ENUGU, ENUGU STATE ON THE 5TH DAY OF JUNE, 2025.

I am delighted to welcome you all on behalf of the executives of NIFST East Central Chapter, to the 11th ReFoSTS of the chapter. The Theme for this year ReFoSTS is "Food Science and Technology: A Panacea for National Development".

1. **BACKGROUND OF NIFST:**
   NIFST IN BRIEF:
   NIFST was established in June 1976 as body representing food professionals drawn from Academia, Research, Industry and Government in Nigeria with a Mission Statement: "To harness the abundance of talent and knowledge amongst food professional in Nigeria toward food sufficiency and good nutrition for the masses".
2. **EAST CENTRAL CHAPTER OF NIFST IN BRIEF:**
   In March 2005, the NIFST East Central Chapter was carved out from NIFST South East Chapter and subsequently inaugurated. The new chapter began with Prof E.C. Okoli as the Pioneer Chairman. The chapter member states includes; Anambra State, Enugu State and Ebonyi state. The chapter consists of six zones namely Abakaliki, Awka, Afikpo, Enugu, Nsukka and Onitsha zones.

I want to use this opportunity to thank the family of NIFST ECC for electing us to serve you. I shall strive with my team to serve you well. Be assured that by God's grace and your support, we will not fail in any of our assigned duties. ReFoSTS is usually a special moment for Food Scientists and Technologists, where we brainstorm on the way forward. However, this year ReFoSTS theme is unique because it is a panacea for National Development which means that the engine that will drive this development must be in good condition. It is my sincere desire that at the end of this conference, we must be well informed and equipped for the task ahead. Let use this opportunity to engage, network and build bridges between ourselves and the participants.

It has been observed that a one-day ReFoSTS is not enough to harness the complete knowledge and vast experience we share among ourselves during these conferences. It is my opinion that under my administration, we will be able to organize a two-day ReFoSTS conference in subsequent years as we progress in East Central Chapter with the help of our supporting partners. We want to sincerely appreciate extremely the ReFoSTS 2025 awardees: (i) Dr. John Onuora and (ii) Dr. Ijeoma Nzelu for their steadfastness in keeping the flag flying and their robust participation while mentoring young NIFSTers. We also appreciate your motherly and fatherly roles respectively in NIFST and we pray that you do not relent whenever NIFST calls.

We also appreciate the chairman and members of the Local Organizing Committee, Sub-committees' Chairmen and Chairladies, despite the short notice, they were able to do wonders with ReFoSTS 2025. We appreciate the Head of Department, Food Science and Technology, Institute of Management and Technology (IMT), Enugu for her resourcefulness towards the ReFoSTS, 2025. We also appreciate Prof. Dozie Ogbodo, the Rector, Institute of Management and Technology (IMT), Enugu for granting us access to host ReFoSTS 2025 in their International Conference Centre. May God reward you all abundantly.
We also appreciate our supporting partners who have been pivotal in some of the key areas of success recorded in various ReFoSTS programs. We will not fail to recognize; BLISCO Food and Beverages Limited, Nnewi, Gemstone Table Water, Umuoji, International Breweries, Onitsha, KP Food and Beverages, Ogidi, Chitis Foods, Enugu, Chief's Palate Ltd etc.

May God continue to grant you all success in your various businesses and establishments. As we declare the conference open, let us all pay rapt attention as we learn and imbibe.

Finally, we will start the planning of ReFoSTS 2026 on time. Before the end of the day, we will announce the LOC Chair for ReFoSTS 2026.
Once again, you are all welcome to the coal city state.
Wishing everyone a wonderful ReFoSTS conference day in Enugu, the Coal City State of Nigeria.

APOSTLE PETER C. AGBATA FNIFST, CFSN
CHAPTER CHAIRMAN
NIFST ECC

EDITORIAL COMMENT

It is with heart full of joy that I wish to present the proceedings of the 11th Regional Food Science and Technology Summit (ReFoSTS) of Nigerian Institute of Food Science and Technology (NIFST) East Central Chapter slated for June, 5, 2025 in Enugu with a theme: Food Science and Technology: A Panacea for National Development. A theme carefully chosen to reiterate the position of Food Scientists in developing Nigerian economy. The committee to organize this year's summit was inaugurated at the first quarterly chapter meeting of the institute held at IMT, Enugu in March, 2025. This left the Planning Committee with less than three months to plan and execute the conference.

The editorial sub-committee made up of twelve dedicated NIFSTERS swung into action by calling for papers for the conference's technical session. At the initial stage, it seemed as if we may not receive any paper but the committee was not deterred.

However, a total of fifty-three (53) extended abstracts from scholars across the entire nation were received and reviewed. This sub-committee was delighted at the quality and level of research going on in our institutions. The extended abstracts covered all aspects of Food Science and Technology including agribusiness to buttress the significance of this year's theme. It is worthy to note that only about 6 % of the papers submitted could not meet the standard required signifying the relevance of our research output.

The editorial committee observed with dismay that greater numbers of contributors sent in their papers very late. We urge future authors to always submit their research findings early for proper review. Nevertheless, I most sincerely thank the editorial committee as well as good spirited NIFSTERS who assisted in the review process.

I appreciate in no small measure the NIFST-East Central chapter executive for their unalloyed support in this exercise as the website hoisted in the course of this 11th ReFoSTS has come to stay. I want to also thank the editorial committee secretary- Mr. Nwigwe Ikenna C. for his dedication I wish all the authors happy presentation.

Prof. Michael O. Odo

Chairman, Editorial Committee

REVIEWERS

1. Prof. Michael O. Odo
2. Mr. Ikenna Chijindu Nwigwe
3. Prof. Okogeri Otu
4. Prof. Helen O. Agu
5. Mr. Vincent O. Obinna
6. Dr. Chioma N. Okoronkwo
7. Dr. Theophilus M. Ikegwu
8. Mr. Somadina Egbonu
9. Mrs. Sylvia Nwadike
10. Dr. Clement Ezegbe
11 Dr. Chizoba Nwakalor
12 Prof. Francis C. Ekwu
13 Prof. Folusho David-Abraham
14 Dr. John O. Ikegwu
15 Dr. Oluchukwu M. M. Nwadi

TABLE OF CONTENTS

PAPER NO.	TITLE AND AUTHOR(S)	PAGE
CHAPTER 1: FISH, MEAT AND DAIRY PRODUCTS.		
11	**Development of probiotic yoghurt analogue using tiger nut and malted sorghum milk blends** Uwandu, A.C[1] and Okoli, E.C	67 - 71
13	**Innovative Processing of Yoghurt: Physicochemical Properties of Greek Yoghurt Derived from Blends of Cow Milk and Rice Milk** Elochukwu, C. U.	79 - 83
18	**Effect of malting periods on the physicochemical and sensory properties of Milk Analogue from Mungbean grain** *Onwurafor, E.U., Akamelu, S.M. and Okafor, E.N.	104 - 108
29	**Determination of Level of Heavy Metals in Canned Fish Sold in Central Market of Kaduna Metropolis, Nigeria** Ozioko E.N. *Ozioko P.C. and Momoh, R.	164 - 167
30	**Proximate Evaluation of Yoghurt from Soy-Cow Milk Blends, Preserved with Coconut Husk Extract** *Udo-Ezika, O.N. Ikegwu, T.M. and Omologbe, F.	168 - 173
32	**Physical Properties of Stored Street Vended *Glycine Maxima* from Five Local Governments Areas in Ebonyi State: A Preliminary Study** Isirue, P.N., Chimdi, G O; *Isirue, A.M.C., Aroh, K.E. and Isirue, J. I	
37	**Storage Stability of Smoked Catfish Treated with *Syzygium Aromaticum* Ethanolic Extract** *Aniagor, E.N., Eze, C.M., Amonyeze, A.O. and Nduka, O.C.	200 - 203
CHAPTER 2: CEREALS, COMPOSITE, FLOURS AND BAKED PRODUCTS		
04	**Probiotic Potentials of *Akamu* (Pap) and *Efu Nkwo* (Fermented Tomatoes): A Review** *Obinna, V.O., Okereke H.C. and Oganezi, N.C.	31 - 34
21	**Functional and Sensory Evaluation of Weaning Food Produced from Malted Sorghum Enriched with Soybean, Unripe Plantain, Crayfish and Termites.** *Chidolue, P.U., Ojokoh, E., Egege, J.N.	120 - 125

22	**Physical properties of yellow maize-based snacks enriched with orange fleshed sweet potato and soybean wastes** *Odieze, I. E and Asogwa, I.S	126 - 131
24	**Proximate and sensory qualities of bread produced from blends of locally cultivated and commercial wheat flours** *Asogwa, I.S., Ezenwuba, C.J., Odieze, I. E.	138 - 142
28	**Quality Evaluation of Foods (Complementary) Produced from Rice, Sorghum and Brisket Bone Blends.** *Michorji, C.M., Ikegwu, T. M. and Omologbe, F.	154 - 157
36	**Effect of Baobab Seed Flour Inclusion on the Mineral and Phytochemical Properties of Wheat and Tigernut Residue Biscuits** *Odo, J.E, Ugwu, K., Lazarus, C. C., Asogwa, I.S. and Chime, A.J	195 - 199
39	**Mineral and Sensory Properties of Breads Produced from the Blends of Wheat Flour and Flaxseed Flour** Obarisagbon, I. and *Okechukwu, N.G	209 - 214
40	**Effects Of Fermentation on the Proximate Composition of Chin-Chin Produced from Brown Rice, Wheat and Kidney Beans Flour** Obarisagbon, I. and *Okechukwu, N.G	215 - 222
44	**Sensory and Proximate Evaluation of Dry-Milled *Pap* Produced from Maize, Sorghum, Millet and Tiger Nut Flours** *Ani, C.P., Mapamile, A.D., Oyarebu, A. O., and Khoza, M	240 - 245
47	**Functional Properties of Maize-Date Pap Fortified with Palm Oil** *Udeze, M. E. Ikegwu, T. M. and Omologbe F.	260 - 265
CHAPTER 3: LEGUME PROCESSING AND PRODUCTS.		
05	**Effect of Malting and Extrusion on the Nutritional Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends** *Azuka, E. C., Nnamocha, T., Okafor, G. I and Boesch, C.	35 - 40
06	**Effect of Malting and Extrusion on the Mineral Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends** *Azuka, E. C., Nnamocha, T., Okafor, G.I and Boesch, C	41 - 45
17	**Phytochemical Composition and Antioxidant Properties of Bread Enriched with Groundnut Testa** *Uchegbu, N. N. and Amaefuna, B. C.	100 - 103
CHAPTER 4: ROOTS AND TUBER PROCESSING.		
07	**Effect of Incorporation of Plantain Peel and Okara Flours on the Micronutrient of Dough Meal from Yellow Cassava-Maize Blends.** *Onwuchekwa, A.I, Amonyeze, A. O, Aniemena, C. C and Chiaha, E.	46 - 49

26	**Micronutrient Composition and Molar Ratio of Minerals in Orange-Fleshed Sweet Potato/Soybean Complementary Food Enriched with Crayfish.** * Ijeomah, O.C., Ben-Okoro, O.U. and Asomugha, V.U.	149 - 153
42	**Physico-Chemical Properties of Aerial Yam, Finger Millet and Pro Vitamin A Cassava Flour Blends.** *Mbam, N.J., Ekwu, F.C and Odo, M.O.	228 - 233
CHAPTER 5: FRUITS AND VEGETABLES PROCESSING.		
03	**Quality Characteristics and Antioxidant Activities of Liquid Food Dyes Produced from Three Different Pigmented Foods (Beetroot – *Beta vulgaris*, Turmeric – *Curcuma longa* and Hibiscus – *Hibiscus sabdariffa*)** *Mbah, U. C, Udenta, E. A. and Mustapha, A. O.	23 - 30
08	**Effects of Processing Methods on the Proximate Composition of *Uziza* (*Piper Guineense*) Seed Flour** *Ifediba, C. M. Ikegwu, T. M. and Omologbe F.	50 - 54
14	**Proximate Analysis of Cooked and Raw Jackfruit Seed Flour** Eneasato, O.S.	84 - 88
20	**Physicochemical Characteristics of Fresh and Stored Juice from Zobo (*Hibiscus sabdariffa*), Date Palm (*Phoenix dactylifera L.*), Ginger (*Zingiber officinale*) and Cloves (*Syzygium aromaticum*).** *Orji, R. N, Chima, J. U. and Ayodele, E. A.	116 - 119
33	**Effect of Different Drying methods on Nutrient Composition of Fluted Pumpkin Leaves *(Teifairia occidentalis)*** *Okoye O. I., Okoye F.U. and Nwafor C. C	183 - 187
38	**Proximate and Micro-Nutrients Composition of Pumpkin Seed, Leaf, Pulp, and Peel Powders** *Obeta, N. A., Efobi K. B., Oba, B. N. and Ezugwu, C. O.	204 - 208
CHAPTER 6: NUTRITION.		
01	**Analyzing the Impact of Lifestyle Characteristics of Hypertensive Adults in South-East (Nigeria).** *Benneth I. C, Onyeji, G. N, Francis, C. A	12 - 17
09	**Proximate Composition and Sensory Qualities of Weaning Foods Produced from Blends of Rice (Mas 2401) and Soybean** Nwakunite L. C., *Oyarebu A. O., Ezeh M. C., Udoh O. B. and Ezeasor, Q.U.	55 - 61

15	**Formulation and Evaluation of Nutrients Values and Sensory Properties of Complementary Diet from Millet (*Pennisetumglaucum*), Soybeans (*Glycine max)*, Groundnut (*Arachishypogaea*) and Date palm (*Phoenix dactylifera L.*) for children (6-24 months)** *Sa'eedu, A.M., Haruna, H., Osagede, E.A., Daniel C.S., Anda, S.A.D., Sulaiman, L.A., Ishaq, R.A., Ejembe, P.A., Agboola, F.O., and Sale, A.	89 - 93
CHAPTER 7: FOOD ENGINEERING, WATER AND MISCELLANEOUS		
02	**Preservation of Nutrients of High Moisture Perishables Through Controlled Solar Drying** Abur T. B.	18 - 22
10	**Storage Stability of Extruded Foods: A Mini-Review** *Nwadi, O.M.M. and Okonkwo, T.M.	62 - 66
12	**Cornsilk: A By-Product with Potential Utilization in Food Industries** Okorafor-Nwosu, A. Anigbogu, C.B. Anukwuorji, E.O. and *Kolawole, O.O.	72 - 78
16	**Role of Artificial Intelligence in Foodservice Systems/Operation: A Review** *Nwigwe, I. C. and Nwankwegu, R. O.	94 - 99
19	**Design, Construction and Evaluation of 5-Liter Capacity Process for Refining of Soy Bean Oil** *Okoyeuzu, C. F., Nwaogwugwu, J. N., Nduka, O. C., Nwankwo, C. S. Okoronkwo, N. C. and Eze, J. I.	109 - 115
23	**Entrepreneurial Exploration in Food Business Operations Using Innovative Business Model Strategies for Sustainable Food Businesses: A Review** *Oyarebu, A.O., Agbadua, S. A., Agbata P. C. and Nwabugwu K. T.	132 - 137
25	**Agricultural Products and Packaging, Panacea for Food Safety: The Agribusiness Approach**. Okpeke, A. G.	143 - 148
27	**Assessment of Meaning Construction on Food Labels of Selected Processed Foods** *Olayinka, O. O. and Arasi, A. S.	158 - 163

31	**Chemical Composition of Seasoning Cubes Produced from Ginger, Turmeric, Rosemary, Nutmeg, and Clove** *Agu, H. O., Ekeh, M. J., Mba, J. C. and Okolo, C.A.	174 - 177
34	**Evaluation of The Toxicity and Hepatoprotective Effect of Tea Produced from Ixora Red Flower, using a Rat Model.** *Ezugwu, C. O., Obeta, N. A. and Ezeh, C. I.	188 - 191
35	**Narratives Exploring Food Security through Literary Representations of Agricultural Innovation, Technology, and National Development in African Literature: A Study of Yellow-Yellow and Oil on Water** *Adeleke, K. J. and Adediran, O. B.	192 - 194
41	**Structural Insights into Novel Metal-Peptide Complexes Via DFT-Based Geometrical Optimization and Experimental X-Ray Diffraction** *Igbokwe, C. J, Nwadi,, O.M.M., Duan, Y., Zhang, H.	223 - 227
43	**The Role of Agrovoltaic Technology in Food Security and Safety in Nigeria: A Review** *Ani, C.P; Oyarebu, A. O., Mapamile, A.D, Agu, R. I	234 - 239
45	**De-Emphasizing Unwholesome-refinement of Traditional Foods, towards Improving National Health** Undie, J. B., Omang, C. E. and John, E. G	245 - 249
46	**Advances in Sustainable Food Packaging Technology: A Review** *Salaudeen, O. H., and Atoo, T. S.	250 - 259
48	**Effect of soaking time on the proximate composition and anti-nutrient properties of fermented African oil bean seed** **Ewunonu O.C**	265 – 269
49	**Quality Evaluation of Energy Bar Produced from Tiger Nut, Groundnut and Beniseed Flavoured with *Uziza* Seed Powder.** *Ikegwu, T. M, Okafor, M. O. and Omologbe F.	270 - 275

Analyzing the Impact of Lifestyle Characteristics of Hypertensive Adults in South-East (Nigeria).

*Benneth I. C[1], Onyeji, G. N[2], Francis, C. A[3]

[1]Department of Nutrition and Dietetics Alex-Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State Nigeria. [2]Department of Nutrition and Dietetics David Umahi Federal University of Health Sciences, Uburu, Ebonyi State Nigeria. [3]Department of Agriculture, Alex-Ekwueme Federal University, Ndufu-Alike, Abakaliki, Ebonyi State Nigeria.

Corresponding Author's E-mail: ihuoma.benneth@funai.edu.ng

ABSTRACT

Hypertension is one of the major risk factors affecting the global burden of disease especially cardiovascular diseases. This study was conducted to assess the impact of lifestyle on hypertensive adults aged 50-70 years in South East Nigeria. Seven hundred and twenty hypertensive adults were selected using a sampling procedure. Data was collected with a validated questionnaire on demographic variables, socio-economic characteristics, personal and medical history, lifestyle characteristics. Validated sphygmomanometer was used to assess Blood Pressure, classified as normal SBP<120mmHg and DBP<80mmHg, pre-hypertension: SBP of 120-139mmHg and/or DBP of 80-89mmHg and hypertension SDP ≥ 140mmHg and/or 90mmHg. SPSS and Chi square test were used to analyze the data. Mean age of the respondents was 59.3±6.3 and 59.7% were females. About 40.3% of the participants took alcohol, out of which 36.4%, 36.4%, 12.2% and 7.5% took beer, palm wine spirit and hard liquor respectively. Majority of the respondents (89.3%) had never smoked any tobacco product. About 82.4% reported that they were involved in regular physical activity (PA). About half (54.3%) had physical activity for less than 75 minutes per day. Being physically active, reducing tobacco and alcohol intake can improve the health of hypertensive individual.

Key words: Hypertension, Adults, Lifestyle Characteristics

1.0 Introduction

In Nigeria, hypertension is the most common form of cardiovascular disorder, occurring in 86.4% of patients with cardiovascular disorders and in 38% of the adult population (Odili *et al.*, 2020). The prevalence of hypertension was highest in South-East Nigeria (52.8%) when compared to other geo-political zones (North- Central, 20.9%; North-East, 27.5%; North-West, 26.8%, South-South, 44.6% and South- west, 42.1%). Hypertension has been defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg on the average of two or more readings taken at each of two or more visits after initial screening (American Heart Association 2021). It affects people of all age groups, sex and socio-economic classes (Amir *et al.*, 2020); however, it is highly prevalent among the elderly (Raji *et al.*, 2017). The poor health outcomes associated with uncontrolled hypertension include myocardial infarctions, strokes, dementia, renal failures and kidney diseases (Dzudie *et al.*, 2021). Hypertension is also identified as a key modifiable risk factor for cardiovascular morbidity and mortality (Oguanobi, 2021). Changes in lifestyle, such as physical activity, weight reduction and dietary modifications are the main approaches for the prevention and management of hypertension (Unger *et al.*, 2020). Lifestyle changes have shown to have a favorable effect on prevention and treatment of hypertension, emphasizing on alcohol and sodium intake,

smoking cessation, physical activity level and dietary pattern (Bruno *et al.*, 2018). The role of regular physical activity in preventing cardiovascular disease is well recognized and increased physical activity has been revealed to be effective in the treatment of high blood pressure in several studies (Oseni *et al.*, 2024). The American College of Cardiology and the American Heart Association recommend adults engage in at least 150 minutes of moderate-intensity aerobic exercise per week (Piercy, *et al.*, 2018). The aim of this study is to analyze the impact of lifestyle characteristics of hypertensive adults in South-East Nigeria.

2.0 Materials and Methods

In Abia and Ebonyi State, South-East Nigeria a cross-sectional and descriptive study was conducted to evaluate the impact of lifestyle on hypertensive adults. A total of 720 participants with systolic blood pressure (SBP) ≥140mmHg and/or diastolic blood pressure (DBP) ≥ 90mmHg residing in Abia and Ebonyi State Nigeria were selected using a five-stage simple random sampling technique.

The sample size was determined using an appropriate formula for cross-sectional studies, considering a 5% margin of error and a 95% confidence level, based on the estimated population of teachers in the area.

2.1 Sample Size Determination

2.1.1 Subjects and sample size- Minimum sample size was determined using the formula for cross–sectional studies (Frankfort-Nachimias and Nachimias, 1992).

$$n = \frac{Z^2pq}{d^2}$$

Where: Where Z is the Z score value at 95% confidence interval (CI) = 1.96

n = minimum sample size when sample frame is more than 10,000.

Z = 1.96

d = 0.05 (5% degree of accuracy desired)

p = 30.6% (0.306). Prevalence of hypertension as reported by Adeloye (2021).

q = 1-p (69.4).

The estimated proportion of success (of accepting the various null hypotheses) = 50%

Therefore,

$$n = \frac{Z^2pq}{d^2}$$

$$n = \frac{1.96^2\ (0.306)\ (0.694)}{0.05^2}$$

$$n = \frac{3.8416\ (0.212364)}{0.0025}$$

n= 326.33

Ten percent (10.0 %) of the minimum sample size calculated using the above formula was introduced to compensate for attrition.

Thus, 10.0% of 326.33 = 32.6

326.33+32.6 = 358.93. The sample size (n) for the study was approximated to 360 (Three hundred and sixty) citizens for each state. For the two (2) states, it was a total of 720 (360 x 2) participants. Data was collected with a structured and validated questionnaire on demographic variables, socio-economic

characteristics, personal and medical history, lifestyle characteristics, Validated sphygmomanometer was used to assess Blood Pressure, classified as normal SBP<120 mmHg and DBP<80 mmHg, pre-hypertension: SBP of 120-139 mmHg and/or DBP of 80-89 mmHg, stage 1 hypertension: SBP of 140-159 mmHg and/ or DBP of 90-99 mmHg and stage 2 hypertension: SBP ≥ 160 mmHg and/or DBP ≥ 100 mmHg. SPSS and Chi square test were used to analyze the data.

3.0 Results and Discussion

Table 1 provides information on the lifestyle characteristics of the respondents. The respondents' type of physical activities was more of walking which is done within a short duration of <75 minutes/day. This indicates that older adults were not very active and this can pre-dispose them to overweight/obesity and hypertension. This agrees with Hayes *et al*., (2022) indicating that as people grow older, they are more likely to become less physically active and develop hypertension. This is similar to Ayogu and Nwodo, (2021) and Adeke *et al*., (2022) who reported that low physical activities, alcohol consumption were associated with hypertension. Tobacco intake was low (10.7%) among the participants in the present study. This is similar to the study by Adeke *et al*, (2022) who reported that 4.1% and 35.4% consumed tobacco and alcohol respectively. The low tobacco consumption in this study could be connected to the age of the study participants which is above the school age when tobacco consumption is learnt as a behavior due to peer pressure and stress (Leshargie *et al*., 2019) while the high alcohol consumption could have originated from the low socio-economic status of the people, religion, belief and cultural standards in the study area. Li *et al.,* (2024) in China reported that smoking and drinking had the strongest association with the prevalence of hypertension. Also, a study in Ogun State, Nigeria, (Bolajoko *et al*., 2019) observed that blood pressure had a positive correlation with tobacco smoking and alcohol drinking. Interventions addressing smoking cessation, alcohol moderation, and increased physical activity could be an effective action for blood pressure control. However, several control strategies have been adapted to control tobacco and alcohol consumption in different parts of the world (Jiang *et al*., 2022). Being physically active, quitting tobacco and reducing alcohol intake can help improve the health of hypertensive patients (WHO, 2023).

Table 1: Lifestyle Characteristics of the Respondents

	Intervention (N=360)		Control (N=360)		Aggregate (N=720)	
Do you smoke	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
No	316	87.8	327	90.8	643	89.3
Yes	442	12.2	33	9.2	77	10.7
Frequency of smoking						
Do not smoke	316	87.8	327	90.8	643	89.3
Daily	24	6.7	10	2.8	34	4.7
twice a week	12	3.3	14	3.9	26	3.6
4 times a week	8	2.2	9	2.5	17	2.4
Quantity of cigarette/day						
Do not smoke	316	88.1	327	90.8	643	89.3
<10 sticks/day	20	5.6	13	3.6	33	4.6
10-20 sticks/day	21	5.8	15	4.2	36	5.0
>20 sticks/day	3	.6	5	1.4	8	1.1
Do you take alcohol?						
No	211	58.6	219	60.8	430	59.7
Yes	149	41.4	141	39.2	290	40.3
Describe Quantity taken						
No response	213	59.2	219	60.8	432	60.0
>14 bottles of beer/21 shot of spirit/10 glasses of wine	27	7.5	20	5.6	47	6.5
7-14 bottles of beers/10-20 shots of spirits/7-10 glasses of wine	44	12.2	34	9.4	78	10.8
<7 bottles of beer/10 shots of spirit and 7 glasses of wine	76	21.1	87	24.2	163	22.6
Do you engage in regular Physical Activities?						
No	69	19.2	58	16.1	127	17.6
Yes	291	80.8	302	83.9	593	82.4
Duration of activities/week						
No response	97	26.9	102	28.3	199	27.6
<75 minutes	152	42.2	159	44.2	311	43.2
75-120 minutes	65	18.1	60	16.7	125	17.4
120-150 minutes	30	8.3	23	6.4	53	7.4
>150 minutes	16	4.4	16	4.4	32	4.4

4.0 Conclusion and Recommendation

Lifestyle modification was observed to have positive relationship with hypertension. Interventions and strategies that improve lifestyle characteristics of hypertensive individuals can reduce the burden of hypertension In Nigeria.

References

Adeke, A.S., Chori, B.S., Neupane, D., Sharman, J.E., Odili, A.N. (2022). *Socio-demographic and lifestyle factors associated with hypertension in Nigeria: results from a country-wide survey. Journal of Human Hypertension, 38,* 365 – 370.

American Heart Association (2021). *Blood pressure guidelines.* Retrieved from https://www.heart.org/en/health-topics/high-blood-pressure. Retrieved on 24 April, 2025.

Amir, A., Ebrahim F, Michael J. G, Parivash K, Faezeh F, Razieh C. (2020). *Effect of different dietary approaches compared with a regular diet on systolic and diastolic blood pressure in patients with type 2 diabetes: A systematic review and meta-analysis*. Diabetes Research and Clinical Practice, Volume 163, 108.

Ayogu, R.N.B, and Nwodo C.J. (2021). *Epidemiological characteristics of hypertension, impaired fasting capillary glucose and their comorbidity: a retrospective cross-sectional population-based study of rural adolescents in Southeast Nigeria*. BMJ Open*;* 11: e041481

Bolajoko, O.O. Odunuga B. A. and Salami O.E (2019). *Assessment of Body Composition, Smoking and Alcohol as Risk Factors to Hypertension among Adults in Abeokuta, Ogun State, Nigeria.* Journal of Dietitians Association of Nigeria. Volume 10: 2141-8209.

Bruno, C. (2018). *Lifestyle and Hypertension: An Evidence-Based Review*. Journal of Hypertension and Management. 4.

Dzudie, A., Njedock, N., Boombhi, J., Ba, H., Amougou, S. N., Kamdem, F., Barche, B., Nzali, A., Njomou, A., Ngwasiri, C., Geh, M. M., Azabji, M., Mefire, A. C., Njamnshi, A. K., Kingue, S., Empana, J. P., Sobngwi, E., Etoundi Ngoa, L. S., and Kengne, A. P. (2021). *Association between measures of adiposity and blood pressure levels in adult Cameroonians*. Health science reports, 4(2), e259.

Frankfort-Nachimias C and D Nachimias. (1992). *Research methods in social Sciences: Fourth Edition*. Published by *Edward Arnold Ltd, Kent, England*; 97- 426.

Hayes, P., Ferrara, A., Keating, A., McKnight, K., andO'Regan, A. (2022). *Physical Activity and Hypertension*. Reviews in cardiovascular medicine, 23(9): 302.

Jiang, X., Jackson, L. J., Syed, M. A., Avşar, T. S., and Abdali, Z. (2022). *Economic evaluations of tobacco control interventions in low- and middle-income countries: a systematic review.* Addiction (Abingdon, England), *117*(9), 2374–2392.

Leshargie, C.T., Alebel, A., Kibret, G.D., Birhanu, M.Y., Mulugeta, H., Malloy, P. *et al.*, (2019), *The impact of peer pressure on cigarette smoking among high school and university students in Ethiopia: A systemic review and meta-analysis'*, *PLoS One* 14(10): e0222572.

Li, G., Liu, L., Liu, D., Yu, Z., Golden, A. R., Yin, X., Cai, L. (2024). *Tobacco exposure and alcohol drinking prevalence and associations with hypertension in rural southwest China: A cross-sectional study*. Tobacco Induced Diseases, 101; 22.

Odili, A. N., Chori, B. S., Danladi, B., Nwakile, P. C., Okoye, I. C., Abdullahi, U., Nwegbu, M. N., Zawaya, K., Essien, I., Sada, K., Ogedengbe, J. O., Aje, A., and Isiguzo, G. C. (2020). Prevalence, Awareness, Treatment and Control of Hypertension in Nigeria: Data from a Nationwide Survey 2017. *Global heart*, *15*(1), 47

Oguanobi N.I (2021). *Management of hypertension in Nigeria (2021). The barriers and challenges*. Journal of Cardioly and Cardiovascular Medicine; 6: 023-025.

Oseni, T. I. A., Ahmed, S. D., Eromon, P. E., Fuh, N. F., Omoregbe, I. N. (2024). *Physical activity, obesity and risk of atherosclerotic cardiovascular diseases among patients with hypertension and diabetes attending a teaching hospital in Edo State, Nigeria.* PloS one; *19*(8): e0307526.

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., and Olson, R. D. (2018). *The Physical Activity Guidelines for Americans*. JAMA, 320(19), 2020–2028.

Raji R.Y, Taiwo A., Oye G. (2017). *Awareness of hypertension and its impact on blood pressure control among elderly Nigerians: report from the Ibadan study of aging*. Pan African Medical Journal; *27:190*

Unger, T., Borghi, C., Charchar, F., Khan, N. A., Poulter, N. R., Prabhakaran, D., Ramirez, A., Schlaich, M., Stergiou, G. S., Tomaszewski, M., Wainford, R. D., Williams, B., andSchutte, A. E. (2020). *2020 International Society of Hypertension Global Hypertension Practice Guidelines. Hypertension*, 75(6), 1334–1357.

WHO, (2023). *Hypertension*. https://www.who.int/news-room/fact-sheets/detail/hypertension. (Retrieved on May 2, 2025).

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT -East Central Chapter

Preservation of Nutrients of High Moisture Perishables Through Controlled Solar Drying

Abur T. B.

Department of Mechanical/Production Engineering, Faculty of Engineering and Engineering Technology, Abubakar Tafawa Balewa University, Bauchi.

Corresponding Author's Email: tbabur@atbu.edu.ng

ABSTRACT

Drying methods are known for preservation and shelf-life elongation of products. However, these methods could affect the nutrient content of dried products negatively. The effect of solar and open sun drying on the quality of tomatoes compared to fresh slices is presented. Fresh, solar and open sun-dried samples were analysed for vitamin C, iron, calcium, potassium and phosphorus using recommended standard by the Society for Analytical Chemistry. Tomatoes slices dried under solar radiation of 458 to 679W/m^2 in the month of August characterised with poor sky conditions showed a decreased nutritional composition for open sun drying and good nutrient retention capability for those dried under a solar cabinet dryer depicting similarity to fresh slices and in agreement with values found in literature. This suggests that the development of a solar cabinet dryer with auxiliary heating source through systematic design approach and parameters optimisation for controlled drying in nutrient retention in high moisture crops as a valid tool.

Keywords: Controlled **s**olar drying, perishables, nutrient retention, tomatoes slices

1.0 Introduction

Nutritional value of dried products (quality) is of vital importance in promoting the usage of solar dryers as a means of food preservation. Tomatoes are good sources of antioxidant lycopene, vitamins, also containing high levels of minerals, phosphorus, folate including potassium which are linked to health benefits such as helping the body system as immune boosters, reducing risk of heart diseases and cancer (Adenipekun and Oyetunji, 2010).

Solar drying is more viable in countries within the tropics where solar radiation is available in substantial amount throughout the year (Ismail *et al.,* 2015). Various forms of solar dryers ranging from indirect, direct, mixed mode, solar tunnel with and without auxiliary heating source have proven effective in the solar drying and preservation of crops **(**Abur *et al*., 2014). Sensory attributes such as colour, texture, flavour, taste and nutritive contents of fruits and vegetables are often affected by the type of solar drying and thus, resulting in low market value (Mu'azu *et al*., 2012; Abur *et al.,* 2014)**.** For retaining sensory attributes and nutrients, solar drying under verified temperature and solar type is necessary. Review of literature have suggested indirect solar cabinet and solar tunnels dryers as having superior performance compared to other forms of solar dryers for drying of perishables **(**Abur *et al*., 2014**).** Osunde and Musa (2007) assessed changes in nutritional values of freshly sun-dried tomatoes, sweet pepper and okra grown in Minna. The study showed that adult's intake of carotene and ascorbic acid from dried tomato, pepper and okra, which are used in most Nigerian diet at non-production seasons, will be inadequate after cooking compared to recommended daily allowances. Awogbemi and Ogunleye (2009) studied the effect of solar drying on the quality of amaranthus (tete in local language), vernonia (ewuro) and fluted pumpkin (ugu) vegetables. Proximate and microbial load analysis carried out on the vegetable samples after each day of drying for a total of 5 days showed that the nutritional composition of the fresh vegetable and their microbial load decreases with each day of drying.

The use of forced convectional dryers fitted with temperature regulators is advantageous in preserving nutrient content and prevent product moisture re-absorption but are less cost effective and contribute to environmental degradation. The use of solar cabinet dryers prevents the negative impact of direct solar radiation on product, minimise dirt, dust and insects' infection but falls short of maintaining the drying chamber temperature above the ambient. This often leads to favourable conditions for colour degradation, texture and flavour changes, nutrient depletion and microbial growth **(**Emmanuel and Olajide, 2012).

The work developed a solar dryer cabinet dryer with sensible heat storage material beneath the collector to maintain the drying chamber temperature above the ambient during solar off-peak periods and thus curb the negative impact of fluctuation and non-uniform solar drying.

2.0 Materials and Methods

2.1 Materials

Fresh harvested and healthy tomatoes bought at Yelwa Tundu market, Bauchi were sliced with a stainless knife to a thickness of approximately 3 mm and measured into drying trays of the solar cabinet dryer and for open sun drying in the month of August, 2020. A digital thermometer (CE K type) capable of measuring temperature in the range of -50 to 1350°C was attached for monitoring the drying chamber temperature, while a digital weight balance used for observing sample weight at an hourly basis. The solar radiation was also monitored through a solar meter.

2.2 Methods

2.2.1 Design and optimisation approach of solar dryer

The solar dryer dimensions and system characteristics were obtained through a parametric study carried out using a program written in MATLAB utilising thermodynamics equations relating to the various components of the developed solar dryer to establish the collector area and its efficiency as well as depth of air passage and mass of crop. Some of the variables involved in the study include tilt angle, glazing number, wind speed, and insulating materials.

The collector area for single glazing obtained from system parametric studies was optimised in addition to the gravel bed thickness. The process also included determining the drying chamber variables of volume, vertical distance between successive trays and clearance between tray two and the chimney using TRNSYS 16 software. The software component of a tank with nodes was selected to represent the drying chamber, while the nodes serve as the drying tray. The drying chamber (tank) air flow inlet size at the base was adjusted to the equivalent of the solar collector air outlet size. Modifications were then made for the tank volume, tray width, vertical distance between successive trays, clearance between tray two and the chimney, gravel bed thickness as well as the solar collector area until desired results obtained. These results included the product drying temperature not exceeding 70°C as well as a minimum gravel bed temperature of 40°C for both optimum (March) and design (August) months considering system characteristics.

2.2.2 Description of the solar cabinet dryer

Two trays, 4mm singled glazed solar cabinet dryer incorporated with gravels beneath the 1mm aluminium absorber plate for supplementary heat supply during off peak solar radiation located at the Centre for Industrial Studies, CIS of the Abubakar Tafawa Balewa University Bauchi is experimented. The heater is lagged with sawdust of 50mm thickness to decrease the thermal losses through the bottom. The dryer has a collector area of 1.5m^2, tilted at 13.01° to the horizontal for maximal solar absorptivity with an air gap height of 50 mm.

2.2.3 Proximate analysis

Three samples namely fresh, solar and open sun dried were analysed for vitamin C, iron, calcium, potassium and phosphorus. Vitamin C concentration was determined by means of titration method, phosphorus by

UV-spectrometric approach, while those of iron, calcium and potassium were carried out using elemental analysis by atomic absorption spectrometry (AAS) all at the Chemistry Department of Abubakar Tatari Ali Polytechnic, Bauchi.

Figure 1: UV-Spectrophotometer (Model 752N)/ Flame atomic absorption spectrophotometer (Model AA320N) (L-R) (Author, 2020)

3.0 Results and Discussion

The results of the analysis showed no significant ($p<0.05$) variation between fresh, solar cabinet dried slices and literature values. However, iron, vitamin C, phosphorus and potassium exhibit a closer resemblance in values to those of fresh slices than calcium but with no significant difference. There exists a significant difference between those of open sun dried, fresh and standard value found in literature as a result of depleted nutrients in the open sun drying method (Table 1). The lost in nutrient for open sun method could be attributed to oxidative destruction in the presence of heat, light, oxygen, moisture and metal ions (Patience *et al.,* 2021) while, the ability of the solar dried slices to retain a good percentage of the product nutrient is due to its controlled drying environment such as temperature**,** absence of dust, re-absorption of moisture etc. The positive correlation of the result in this study is a clear indication of the effectiveness of the solar cabinet dryer to preserve nutritive values of dried product. This work is similar to those of Mu'azu *et al.*, (2012) who dried tomatoes slices in a forced convection indirect solar dryer in Maiduguri-Nigeria while Khandezod *et al.,* (2024) reported solar dried slices maintained good nutritional status of dehydrated tomato slices during storage period.

Table 1: Nutrients of fresh, solar dried and open sun-dried tomatoes slices (100 g)

Nutrients and vitamin	Fresh	Solar-dried	Open- dried	Literature value
Calcium, mg	9.1	8.06	6.1	10
Phosphorus, mg	26.9	25.4	15.9	24
Potassium, mg	243.6	234.8	210.4	236
Iron, mg	0.32	0.28	0.19	0.27
Vitamin C, mg	14.3	12.4	8.5	13.7

Source: Author, 2020

4.0 Conclusion

The comparative results of fresh, open sun and solar dried products of the tomatoes slices indicate a strong linear relationship between the fresh, solar dried and literature values for the nutrient contents of the tomatoes slices. This shows the suitability of the systematically developed controlled solar cabinet dryer for preserving nutrients contents of high moisture contents crops sensitive to temperature. The similarities in proximate values of solar dried and fresh samples of tomatoes strongly suggest that the development of solar dryers through the use of program design parametric study, optimization and simulation as a valid tool.

Reference

Adenipekun, C.O. and Oyetunji, O. J. (2010). *Nutritional Values of Some Tropical Vegetables*. Journal of Applied Biosciences. 35: 2294-2300.

Awogbemi, Omojola and Ogunleye, I. Olusola (2009). *Effects of Drying on the Qualities of Some Selected Vegetables*. International Journal of Engineering and Technology. 1: 409-414.

Benjamin Ternenge Abur, Habou Dan-Dakouta and Gerry Egbo (2014). *Food Security: Solar Dryers and Effective Food Preservation*. International Journal of Advanced Engineering Research and Studies. 3:166-171.

Emmanuel Dayo Fagbohun and Olajide Sunday Faleye (2012). *Effect of Storage on Chemical Composition and mycoflora of okra (Abelmoschus esculentus)*. International Journal of Biosciences. 2: 83-89.

Gutti Babagana, Kiman Silas and Mustafa B. G. (2012). *Design and Construction of Forced/Natural Convection Solar Vegetable Dryer with Heat Storage*. ARPN Journal of Engineering and Applied Sciences. 7:1213-1217.

Ismail Isa Rikoto, Mohammad Bashir Abdurrahman, Mohammad Hassan Idris, Mahmoud Muhammad Garba and Mohammed Kabiru Halidu (2015). Design, Construction and Installation of 250-Liter Capacity Solar Water Heating System at Danjawa Renewable Energy Model Village. *International Journal of Engineering Sciences*. 4(**3**): 39-44.

Osunde, Z. D. and Musa Makama, A.L. (2007). Assessment of Changes in Nutritional Values of Locally Sun-Dried Vegetables. *AU J.T*. 10(**4**): 248-253.

Patience Natumanya, Hannington Twinomuhwezi, Victory S. Igwe, Sarvarian Maryam, and Chinaza G. Awuchi (2021). Effects of Drying Techniques on nutrient retention and Phytochemicals in Selected vegetables (2021). *European journal of Agriculture and Food Sciences*. 3(**2**), 5-14.

Khandezod, S. V., Sonkamble, A. M., Ravankar, D. S. and Patil, S. R. (2024). Nutritional Quality of Dehydrated Tomato Slices as Influenced by Drying Methods. *International Journal of Advanced Biochemistry Research*. 8(**6**), 41-43.

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT -East Central Chapter

Quality Characteristics and Antioxidant Activities of Liquid Food Dyes Produced from Three Different Pigmented Foods (Beetroot – *Beta vulgaris*, Turmeric – *Curcuma longa* and Hibiscus – *Hibiscus sabdariffa*)

*Mbah, U. C[1], Udenta, E. A.[2] and Mustapha, A. O.[1]

[1]Department of Food Technology, Institute of Management and Technology, Enugu. [2]Department of Nutrition and Dietetics, University of Nigeria, Nsukka, Enugu.

*Correspondence email: umbah@imt.ed.ng

ABSTRACT

This study determined the quality characteristics and antioxidant characteristics of liquid food dyes produced from pigmented foods. Raw materials were separately processed into powder and dyes individually extracted from the powder using Soxhlet apparatus, methanol and concentrated in water bath. Hibiscus, beetroot and turmeric dyes were coded samples A, B and C respectively, synthetic dyes coded D, E, for yellow, red respectively, and F for Vitamin C standard solution controls. Results showed acceptable pH values ranging from 3.51±0.02 to 6.57±0.13, total titratable acidity (0.14±0.02 to 0.98±0.04%), flavonoid 2.53±0.57 to 289.87±0.37mg/100g, sugar 5.40±0.21 to 24.75±0.35%, color intensity at 5.05% from 0.63±0.00 to 1.71±0.00% and dispersibility 15.00±1.41 to 104.00±4.24 seconds. For DPPH and FRAP antioxidant activity, all samples were detected at 75µg/ml % inhibition with Sample C values dominating in both parameters, except Sample B which was detected at 150µg/ml % inhibition in DPPH. Plant products can be used to effectively produce organic food dyes as possible alternatives for synthetic dyes.

Keywords: Food Dyes, Quality characteristics, Antioxidant activity, Health benefits.

1.0 Introduction

Appetite appeal is influenced by color which is one of the quality characteristics associated with sensory evaluation of food. Enhancing visual attraction towards a food product has led to the use of many artificial colors in food industries (Alim-un-Nisa *et al*., 2021). Food dyes or colorants, are substances that impart color to foods, they may conceal unacceptable colors, enhance existing colours, replace lost colors, homogenize color, extending it over time or to increase or reduce the natural intensity of food color making it more vibrant (Durazzo *et al*., 2022). Food dyes are commonly used in processed foods such as sweets, chewing gums, cereals, candies, sodas and beverages, pastries, meat products, dairy products, chocolate coatings, spices, condiments and pharmaceuticals and as additives to enhance their appeal. Changes in the colour of these products may indicate quality changes as color generates certain product expectations and identity (Clydesdale, 2007). Synthetic food colors have been used to achieve these effects in processed foods. Synthetic food dyes are chemicals that originate from coal tar derivatives, they are petroleum-based chemicals (Dey and Nagababu, 2022). Several studies have linked artificial food colors to different medical conditions, such as Autism and hyperactivity in children (Bakthavachalu *et al.,* 2020; de Oliveira *et al.,* 2024; Ramamurthy *et al*., 2025), cancers (Kara *et al*., 2025), gastrointestinal disorders, respiratory disorders, allergies (Bigwood *et al*., 2008; Silva *et al*., 2022) and physiological dysregulations (El-Wahab and Moram, 2013; Merinas-Amo *et al*., 2019).

The demand for safer natural foods additives which will not predispose consumers to diseases, or raise health concerns has led to research and use of natural dyes to replace artificial dyes, while raising awareness on the effects of artificial dyes used in food on health. Natural plant and animal pigment are considered safe to use due to their non-carcinogenic, non-toxic and biodegradable nature (Alegbe and Uthman, 2024;

Di Salvo *et al*., 2023; Yadav *et al.,* 2023). Pigmented foods such as tomatoes, carrot, purple cabbage, spinach, beetroot, turmeric and hibiscus. may be used. There are certain setbacks in the use of these natural dyes, which has been attributed to their cost, instability and purity specification (Olas *et al*., 2021). Despite the stated challenges, there is need to explore more on the health benefits of the locally available natural pigmented foods in their use for food dye production.

2.0 Materials and Methods

2.1 Source of Raw Materials

The beetroots, turmeric and hibiscus were purchased from *Ogbete* main market, Enugu in Enugu State.

2.2 Sample Preparation

2.2.1 Extraction of Dye from Beetroot (*Beta vulgaris*)

The beetroot dye was produced using the method described by Alim-un-Nisa *et al.* (2021) with slight modifications. The beetroots were sorted, washed thoroughly and peeled. They were sliced into 2mm thickness, oven dried at 50°C for 10 hours and milled. The Beetroot powder was wrapped with filter paper and inserted into the Soxhlet apparatus and set up for extraction for 5 hours using methanol as the solvent. It was then concentrated in a water bath for 4 hours at 68°C, cooled and stored for analysis.

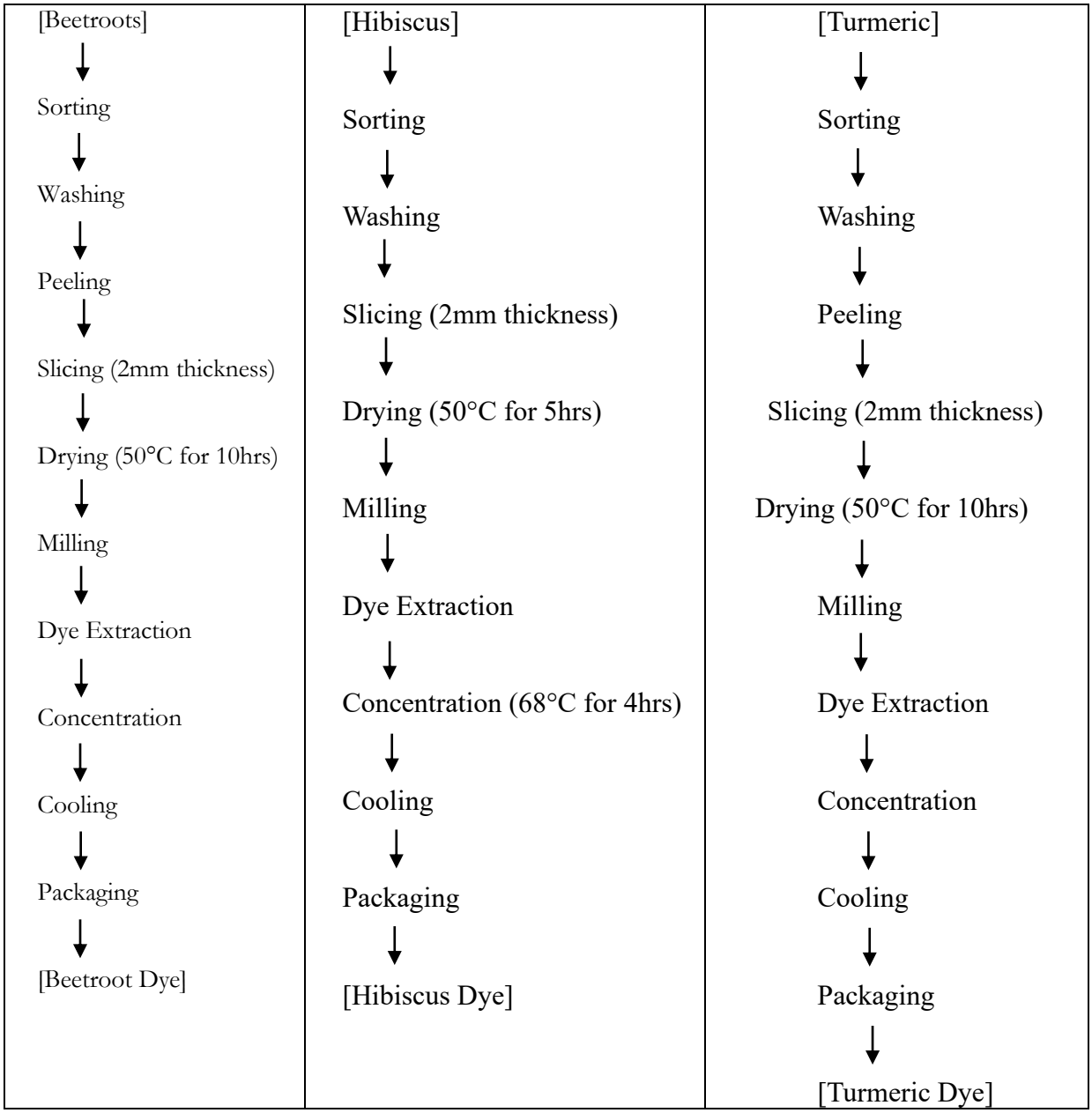


Fig 1: Production of Beetroot Dye (Alim-un-Nisa *et al.*, 2021), Hibiscus Dye (Kumar Jha *et al.*, 2015) and Turmeric Dye (Manasa *et al.*, 2023)

2.2.2 Extraction of Dye from Hibiscus (*Hibiscus sabdarifa*)

The Hibiscus dye was produced following the method described by Kumar Jha *et al.* (2015) with slight modifications. The Hibiscus leaves were sorted, washed and sliced into 2mm thickness; oven dried at 50°C for 5hrs and milled. The Hibiscus powder was wrapped with filter paper and inserted into Soxhlet apparatus and set up for extraction for 5 hours using methanol as solvent. The dye was then concentrated in water bath for 4 hours at 68°C, cooled and stored for analysis.

2.2.3 Extraction of Dye from Turmeric Rhizome (*Curcuma longa*)

The turmeric dye was produced using the method described by Manasa *et al.* (2023) with slight modifications. Turmeric rhizomes were sorted, washed, peeled and sliced into 2mm thickness, oven dried at 50°C for 10hrs and milled. The turmeric powder was wrapped with filter paper and inserted into the

Soxhlet apparatus and set up for extraction for 5 hours using methanol as solvent. The dye was concentrated in water bath for 4 hours at 68°C, cooled and stored for analysis.

The Vitamin C standard solution used as control was prepared using the method described by Belete *et al.* (2023)

2.3 Physicochemical Characteristics

2.3.1 pH Determination

This was done using a Hanna pH meter (Hanna Instruments, Model HI96107, Italy).

2.3.2 Titratable Acidity Determination

This was determined using the alkaline Titrimetric method Ogbeide *et al.* (2021)

2.3.3 Sugar Content (Brix) Determination

The sugar content was measured using a refractometer, with the corresponding calculations as described by Oti, (2016).

2.3.4 Flavonoid Determination

This was done using the method described by Kogoya *et al.* (2024).

2.3.5 Determination of Colour Intensity

The absorbance was determined at 445nm for an optical wavelength of 1cm as described by (Bekele *et al.*, 2024)

2.3.6 DPPH Free Radical Scavenging Activity (RSA)

This was determined using the method described by Sharma and Bhat (2009).

2.3.7 Ferric Reducing Antioxidant Power (FRAP)

This was determined using the method outlined by Xavier *et al.* (2017)

2.3.8 Statistical Analysis

The data collected were subjected to one way Analysis of Variance (ANOVA), using SPSS software (SPSS, 2010). Separation of means was done using Duncan's New Multiple Range Test at 5% probability level.

3.0 Results and Discussion

3.1 Physicochemical Composition of the Food Dyes

Table 1 shows the physicochemical properties of the dye samples, which had acceptable values for pH in agreement with Ojileh and Okechukwu (2023). For titratable acidity, Ebiringa and Onyeneke (2019) reported similar values (0.52 – 0.68%). The samples showed high flavonoid values which would contribute significantly to the Recommended Daily Allowance for flavonoid (Ladeji *et al.,* 2004), which is beneficial to health (Nan *et al.,* 2022). The color intensity was in line with 0.87% synthetic food dye reported by Dilrukshi *et al.* (2019). Although the sugar content does not pose a disadvantage to the dye, it can be used in the classification of the dye samples (Mosotho and Limpho, 2015). The low values recorded is in agreement with Sakhare *et al.* (2019). Ebiringa and Onyeneke (2019) reported that it takes food color less than 20 minutes to disperse in water, which is in line with the findings of this study, except for sample C which took a longer time. This could be attributed to higher concentrations of bioactive molecules when sample was analyzed. In comparison to the control samples, there were significant differences ($p<0.05$) between the samples, although some showed similarities as seen on the table below.

Table 1: Physicochemical Composition of the Food Dyes

Samples	pH	Total Titratable Acidity (%)	Flavonoids (mg/100ml)	Color Intensity (5.05% Extraction)	Sugar (%)	Dispersibility (S)
A	3.66^{d}±0.01	0.87^{b}±0.04	262.54^{c}±1.32	1.64^{b}±0.00	5.40^{d}±0.14	15.00^{d}±1.41
B	3.51^{e}±0.02	0.98^{a}±0.02	251.33^{d}±0.57	1.64^{b}±0.00	5.15^{d}±0.21	21.00^{c}±1.42
C	6.04^{b}±0.03	0.16^{d}±0.01	288.52^{b}±0.02	1.71^{a}±0.00	15.10^{b}±0.14	104.00^{a}±4.24
D	5.37^{c}±0.01	0.14^{d}±0.02	2.53^{e}±0.57	0.63^{c}±0.00	24.75^{a}±0.35	30.00^{b}±2.83
E	6.57^{a}±0.13	0.41^{c}±0.06	289.87^{a}±0.37	1.64^{b}±0.00	10.00^{c}±0.00	18.00^{cd}±1.41

Values are mean±standard deviation from duplicate determinations. Means in the same column bearing same superscript are not significantly different ($p>0.05$).

Sample A = Hibiscus Dye, Sample B = Beetroot Dye, Sample C = Turmeric Dye, Sample D = Yellow dye (Control), Sample E = Red dye (control).

3.2: Antioxidant Activity

3.2.1 Percentage Inhibition for DPPH and FRAP

In the table below, the DPPH antioxidant activity of Samples A and C dye were detected at 75µg/ml % inhibition while Sample B was detected at 150µg/ml % inhibition, all differing significantly ($p<0.05$). All samples were detected at 75µg/ml in FRAP, with sample C domination in both parameters. This was similar to the findings of Mohasen *et al.* (2019). Sample F (Vitamin C- ascorbic acid Standard solution) served as the positive control, this is a standard solution used for antioxidant activity calibration for FRAP and DPPH in samples, that is the Vitamin C equivalent antioxidant capacity.

Table 2: Percentage Inhibition for DPPH and FRAP

Samples	75µg/ml		150µg/ml		300µg/ml		600µg/ml		12.5 mg/ml	25 mg/ ml	50 mg/ ml
	DPPH	FRAP	DPPH	FRAP	DPPH	FRAP	DPPH	FRAP	DPPH	DPPH	DPPH
A	13.76^{c}±0.36	21.13^{b}±0.12	28.63^{c}±0.57	30.09^{b}±0.20	43.87^{c}±0.36	44.01^{b}±0.99	57.62^{c}±0.26	53.60^{b}±0.12	0	0	0
B	ND	16.67^{d}±0.12	5.63^{d}±0.41	27.66^{c}±0.42	19.79^{d}±0.21	42.34^{c}±0.18	34.27^{d}±0.26	51.55^{c}±0.16	0	0	0
C	20.48^{b}±0.92	27.7^{a}4±0.09	33.61^{b}±0.25	40.41^{a}±0.22	49.28^{b}±0.87	52.99^{a}±0.15	62.35^{b}±0.26	57.33^{a}±0.17	0	0	0
D	ND	5.74^{f}±0.05	ND	17.97^{f}±0.15	ND	30.56^{e}±0.12	ND	44.43^{e}±0.93	13.83^{b}±0.26	24.12^{b}±0.91	62.31^{b}±1.12
E	ND	13.58^{e}±0.05	ND	22.51^{d}±0.12	ND	37.79^{d}±0.34	ND	49.00^{d}±1.24	ND	ND	ND
F	23.29^{a}±0.36	17.91^{c}±0.01	44.02^{a}±0.24	19.58^{e}±0.42	63.29^{a}±0.26	21.49^{f}±0.21	76.14^{a}±0.26	28.31^{f}±0.19	79.67±0.28	83.13±1.06	90.71^{a}±0.24

Values are mean±standard deviation from duplicate determinations. Means in the same column bearing same superscript are not significantly different ($p>0.05$).

Sample A = Hibiscus Dye, Sample B = Beetroot Dye, Sample C = Turmeric Dye, Sample D = Yellow dye (Control), Sample E = Red dye (control), Sample F = Vitamin C Standard Solution (to measure antioxidant activity as control), ND = Not Detected.

4.0 Conclusion

The results shows that organic food dyes can be effectively produced from plant products which can be used to replace chemical food dyes, as they show better results in most parameters analysed, with antioxidant properties, without the associated health concerns of chemical dyes. Further studies are still required to standardize the dyes as well as determine their biological activity.

References

Alegbe, E. O., and Uthman, T. O. (2024). A review of history, properties, classification, applications and challenges of natural and synthetic dyes. In *Heliyon*, 10(13). Elsevier Ltd.

Alim-un-Nisa, Hina, S., Kalim, I., Saeed, M. K., Ahmad, I., Zahra, N., Mazhar, S., Masood, S., Ashraf, M., Syed, Q. U. A., and Shad, R. (2021). Quality Assessment and Application of Red Natural Dye from Beetroot (*Beta vulgaris*). *Pakistan Journal of Agricultural Research*, *34*(3), 552–558.

Bakthavachalu, P., Kannan, S. M., and Qoronfleh, M. W. (2020). Food Color and Autism: A Meta-Analysis. In M. M. Essa and M. W. Qoronfleh (Eds.), *Personalized Food Intervention and Therapy for Autism Spectrum Disorder Management* (pp. 481–504). Springer International Publishing. https://doi.org/10.1007/978-3-030-30402-7_15

Bekele, N., Abewaa, M., Mengistu, A., Adino, E., Takele, T., Yilma, M., Temesgen, T., and Angassa, K. (2024). Optimization of natural dye extraction from the root of Rumex abyssinicus plant using response surface methodology. *Results in Chemistry*, *8*. https://doi.org/10.1016/j.rechem.2024.101577

Belete, A., Yisak, H., Chandravanshi, B. S. and Yaya, E. E. (2023). Ascorbic acid content and the antioxidant activity of common fruits commercially available in Addis Ababa, Ethiopia. *Bulletin of Chemical Society of Ethiopia,* 37(2), 277-288. https://dx.doi.org/10.4314/bcse.v37i2.3

Bigwood, T., Hudson, J. A., Billington, C., Carey-Smith, G. V., and Heinemann, J. A. (2008). Phage inactivation of foodborne pathogens on cooked and raw meat. *Food Microbiology*, *25*(2), 400–406.

Clydesdale, F. M. (2007). Color perception and food quality. *Journal of Food Quality*, *14*, 61–74.

de Oliveira, Z. B., Silva da Costa, D. V., da Silva dos Santos, A. C., da Silva Júnior, A. Q., de Lima Silva, A., de Santana, R. C. F., Costa, I. C. G., de Sousa Ramos, S. F., Padilla, G., and da Silva, S. K. R. (2024). Synthetic Colors in Food: A Warning for Children's Health. In *International Journal of Environmental Research and Public Health* (Vol. 21, Issue 6). Multidisciplinary Digital Publishing Institute (MDPI).

Dey, S., and Nagababu, B. H. (2022). Applications of food color and bio-preservatives in the food and its effect on the human health. In *Food Chemistry Advances* (Vol. 1, pp. 1–13). Elsevier Ltd. https://doi.org/10.1016/j.focha.2022.100019

Dilrukshi, P. G. T., Helani, M. A., Buddhika, G. Silva, P. G. and De-Silva, S. M. (2019). Identification of synthetic food colors in selected confectionaries and beverages in Jaffna district, Sri Lanka. *Journal of Food Quality* 2019(1) https://doi.org/10.1155/2019/7453169

Di Salvo, E., Lo Vecchio, G., De Pasquale, R., De Maria, L., Tardugno, R., Vadalà, R., and Cicero, N. (2023). Natural Pigments Production and Their Application in Food, Health and Other Industries. In *Nutrients* (Vol. 15, Issue 8). MDPI.

Durazzo, A., Carocho, M., Heleno, S., Barros, L., Souto, E. B., Santini, A., and Lucarini, M. (2022). Food dyes and health: Literature quantitative research analysis. *Measurement: Food*, *7*. https://doi.org/10.1016/j.meafoo.2022.100050

Ebiringa, D. C and Onyeneke, E. N (2019). Proximate compositions, physicochemical and organoleptic properties of drinks produced from Beetroot and roselle. *Journal of Agriculture and Food Sciences,* 17(1), 38 - 53.

El-Wahab, H. M. F. A., and Moram, G. S. E.-D. (2013). Toxic effects of some synthetic food colorants and/or flavor additives on male rats. *Toxicology and Industrial Health*, *29*(2), 224–232. https://doi.org/10.1177/0748233711433935

Kara, S. G., Yuzbasioglu, D., Avuloglu-Yilmaz, E., and Unal, F. (2025). Do the azo food colorings carmoisine and ponceau 4R have a genotoxic potential? *Toxicology Research*, *14*(2). https://doi.org/10.1093/toxres/tfaf033

Kogoya, E., Simaremare, E. S., Sadaqa, E., Meliana Nadeak, E. S., and Mangiwa, S. (2024). Determination of total contents of flavonoids and phenolic fractions Pandanus julianettii Martelli. *Malaysian Journal of Pharmaceutical Sciences*, *22*(2), 1–10.

Kumar Jha, C., Kumar, R., Kumar, V., and Rajeswari, D. (2015). Extraction of natural dye from marigold flower (Tageteserectal.) and dyeing of fabric and yarns: A focus on colorimetric analysis and fastness properties. *Scholars Research Library Der Pharmacia Lettre*, *7*(1), 185–195. www.scholarsresearchlibrary.com

Ladeji, O., Akin, C. U. and Umaru, H. A. (2004). Level of antinutritional factors in vegetables commonly eaten in Nigeria. *African Journal of Natural Sciences,* 7(3), 71 – 73.

Manasa, P. S. L., Kamble, A. D., and Chilakamarthi, U. (2023). Various Extraction Techniques of Curcumin─A Comprehensive Review. *ACS Omega*, *8*(38), 34868–34878. https://doi.org/10.1021/acsomega.3c04205

Merinas-Amo, R., Martínez-Jurado, M., Jurado-Güeto, S., Alonso-Moraga, Á., and Merinas-Amo, T. (2019). Biological effects of food coloring in in vivo and in vitro model systems. *Foods*, *8*(5).

Mohasen, A. F., Ahmed, H. S. S. and Abdelazim, S. A. A. (2019). Evaluation of red pigment extracted from beetroot. *Current Science International,* 8 (04): 930-941

Mosotho, J. G. and Limpho, V. M. (2015). Determination and comparison of physicochemical properties of home-made juices in Lesotho and commercial juice available in the local markets. *American Chemical Science Journal,* 5(3), 247 – 252.

Nan, S., Tongfei, W., Quan, G., Sian, L., Li,W. and Biao, J. (2022). Plant Flavonoids: classification, distribution, biosynthesis and antioxidant activity. *Food Chemistry,* 383.

Ogbeide, U. M., Irene, D. E., and Okeri, H. A. (2021). Assessment of pH, titratable acidity, and caffeine content of some brands of energy drinks. *Journal of Science and Practice of Pharmacy*, *8*(1), 441–446.

Ojileh, P. C and Okechukwu, Q. N. (2023) Value-added Hibiscus drink with Date juice. *Food Processing and Technology.* 53(3), 545 – 553.

Olas, B., Białecki, J., Urbańska, K., and Bryś, M. (2021). The Effects of Natural and Synthetic Blue Dyes on Human Health: A Review of Current Knowledge and Therapeutic Perspectives. In *Advances in Nutrition* (Vol. 12, Issue 6, pp. 2301–2311). Oxford University Press.

Oti, W. J. O. (2016). Using Refractometer to Determine the Sugar Content in Soft Drinks Commonly Consumed in Abakaliki, Nigeria. *IOSR Journal of Applied Chemistry*, *9*(7), 89–91.

Ramamurthy, K., Dharshan, S. S., Ashok, K., Rajagopal, R., Alfarhan, A., Choi, K. C., Guru, A., and Arockiaraj, J. (2025). Auramine O, food dye induces cognitive impairment, anxiety, alters synaptic transmission and neural growth in zebrafish model. *Journal of Environmental Sciences*.

Sakhare, K. S., Sawate, A. R., Kshirsagar, R. B. and Taur, A. T. (2019). Studies on physical and chemical composition of Beetroot (*Beta vulgaris L.*). *International Journal of Chemical Studies.* 7(2), 283 - 285

Sharma, O. P., and Bhat, T. K. (2009). DPPH antioxidant assay revisited. *Food Chemistry*, *113*(4), 1202–1205.

Silva, M. M., Reboredo, F. H., and Lidon, F. C. (2022). Food Colour Additives: A Synoptical Overview on Their Chemical Properties, Applications in Food Products and Health Side Effects. *Foods*, *11*(3).

Xavier, J., Reddy St Joseph, J., Reddy, J., and Jobi Xavier, C. (2017). A study on antioxidant and antibacterial activities of the fruit and seed extracts of two different cultivars of Momordica charantia Linn. *Journal of Pharmacognosy and Phytochemistry*, *6*(6).

Yadav, S., Tiwari, K. S., Gupta, C., Tiwari, M. K., Khan, A., and Sonkar, S. P. (2023). A brief review on natural dyes, pigments: Recent advances and future perspectives. In *Results in Chemistry* (Vol. 5). Elsevier B.V.

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT -East Central Chapter

Probiotic Potentials of *Akamu* (Pap) and *Efu Nkwo* (Fermented Tomatoes): A Review

*Obinna, V. O[1], Okereke H. C. [2] and Oganezi, N. C. [3]

[1]Department of Food Science and Technology, Akanu Ibiam Federal Polytechnic, Unwana Ebonyi State Nigeria. [2]Department of Microbiology, Abia State University, Uturu Abia State, [3]Department of Food Science and Technology, Abia State University, Uturu Abia State

*Corresponding Author's Email: vinoko43@gmail.com

ABSTRACT

Probiotics are live bacteria that, when taken in the proper forms and amounts, are good for your health. In recent years, probiotics have been the focus of interesting studies, with results showing their antibacterial properties, ability to modulate immune responses, and role in maintaining gastrointestinal health. Probiotics are known to human kind since ages as they are important component in fermented milk products; however the use of probiotics in non-dairy product is a novel method for the delivery of probiotics. Delivery of probiotics through non-dairy products will be beneficial for consumers who are lactose intolerant and also, those who abhor milk products due to religious reasons, who are deprived of benefits of probiotics by dairy products. Hence, this review strove to examine the probiotic potentials of *akamu* (pap) and *efu nkwo* (fermented tomatoes). The unexpected prevalence of *Lactobacillus* species, especially *L. plantarum* and *L. casei*, highlights the rich microbial diversity inherent in these traditional food products. This newfound understanding suggests that indigenous fermented foods could serve as readily accessible and abundant sources of beneficial probiotic bacteria.

Key words: probiotics, *akamu*, gastrointestinal health, deprived, diversity

Introduction

Probiotics are live bacteria that, when taken in the proper forms and amounts, are good for your health (Sánchez, *et al*., 2017). In recent years, probiotics have been the focus of interesting studies, with results showing their antibacterial properties, ability to modulate immune responses, and role in maintaining gastrointestinal health (Sánchez, *et al*., 2017). Research highlights the wide range of potential health benefits that probiotics may offer. According to research, maintaining and repairing a healthy gut microbiota—which is essential for proper food digestion and absorption—is one of the main roles of probiotics (Fei, *et al*., 2023). Additionally, probiotics have been shown to improve the immune system's resistance to infections and inflammatory diseases.

Probiotics are known to human kind since ages as they are important component in fermented milk products; however, the use of probiotics in non-dairy product is a novel method for the delivery of probiotics. Delivery of probiotics through non-dairy products will be beneficial for consumers who are lactose intolerant and also, those who abhor milk products due to religious reasons, who are deprived of benefits of probiotics by dairy products (Goderska *et al*., 2022).

The intriguing potential benefits of probiotics for human well-being and health have drawn a lot of interest in scientific research. When consumed in sufficient quantities, probiotics—live microorganisms—offer several health advantages. Interest in them has increased due to their potential to support immune system function, boost healthy intestinal function, and even fight infectious diseases (Obinna, 2018). As our

understanding of the intricate relationship between gut microbiota and general health continues to expand, investigating probiotics from unconventional sources presents an interesting new avenue for investigation.

According to FAO/WHO probiotics are "live microorganisms which when administered in adequate amounts confer a health benefit to the host". The administration of probiotics results in the prevention of a number of physical conditions and diseases and the prophylaxis and treatment of others. A number of health benefits have been observed relatively consistently in clinical studies of intestinal diseases, including: prevention of antibiotic associated diarrhea, reduction of duration of active diarrhea, reduction of respiratory tract infection incidence; increased eradication rates of anti-Helicobacter pylori therapy; prevention of severe necrotizing enterocolitis; symptom alleviation in irritable bowel syndrome; prevention of *Clostridium difficile*-associated diseases; extension or induction of remission periods in Irritable Bowel Disease patients; prevention of pouchitis after ileal pouch anal anastomosis; relieve of childhood constipation; and prevention of atopic dermatitis in infants (Lee *et al.,* 2013).

Probiotics from traditional sources—such as yoghurt and fermented milk products—have been extensively studied (Okereke *et al*., 2016), but there is still a wealth of microbial variety in unconventional dietary sources that has not been fully investigated. Many tribes all throughout the world have traditionally used fermented foods—like *efu nkwo* (fermented tomatoes), *Ogiri* (African locust bean), *akamu* (pap) and *Nono* (fermented milk) — into their traditional diets. In addition to their purported health benefits, they are highly valued for their nutritional content. These foods acquire their unique aromas, textures, and potentially even health advantages from the natural fermentation processes that promote the growth of beneficial microbes (Okereke *et al*., 2016).

Probiotic Potentials of *Akamu*

Akamu (Igbo), *Ogi* (Yoruba) or Pap is a Nigerian corn (*Zea mays*) meal made from wet corn starch. It has a distinctive sour taste that makes people crave for it. It is processed from dry white or yellow corn. *Akamu* can also be produced from millet or sorghum (Obinna, 2018). *Akamu* is prepared by soaking clean maize grains in water for 2-3 days. The grains are washed and ground to a paste. The paste is sieved to smooth slurry which is allowed to settle and the supernatant decanted. The slurry is mixed with hot water with stirring until it forms a gel which serves as food (Nwokoro and Chukwu, 2012).

According to Obi and Okoronkwo (2022), *akamu* is consumed by adults and children as breakfast meals, and it also serves as a weaning diet. After 5–6 months, breast-feeding is no longer sufficient to satisfy the nutritional requirements of the growing infant. Beginning from this period, the child needs solid foods to meet increasing nutritional needs. This period is the weaning period and in Nigeria, *akamu* is introduced gradually to the child's diet to supplement nutrition.

Ideally, *akamu* consists of a heterogenous mixture of microorganisms and they according to Obi and Okoronkwo (2022), Obinna (2018) and Nwokoro and Chukwu (2012) include: *Aspergillus niger, Aspergillus oryzae, Penicillium citrinum, Candida utilis, Candida tropicalis, Mucor mucedo, Rhizopus stolonifer, Rhizopus microsporus*t, *Rhizopus oligosporus, Saccharomyces cerevisiae, Corynebacterium sp., Lactobacillus planatarum, Lactobacillus fermentum, Leuconostoc mesenteroides, Clostridium bifermentans and Staphylococcus aureus*, *Lactobacillus delbrueckii, Lactobacillus amylovorus, Pseudomonas alkaligenes, Bacillus licheniformis, Pseudomonas aeruginosa, Bacillus cereus,* and *Bacillus subtilis.*

Probiotic Potentials of Tomatoes

Tomato (*Lycopersicun esculentum*) has long been used as food both in cooked as well as raw form. The deep red colouration of ripened tomato fruit is due to the presence of lycopene, a form of β- carotenoid pigment which forms the precursor of Vitamin A and hence is of great nutritional value. It is a rich source of water and its composition includes 95%. Today with an increased number of ailments of vision, these fruits, which are rich in carotenoid pigments, are of prime importance in minimizing the problems related to vision. Also, tomato forms a major food component because of its wide distribution and application in a number of food stuffs be it Asian or European dish. Tomato finds a wide arena of cultivation with highest in China followed by USA, Turkey, India and Egypt. But there is a huge loss of tomato across the globe

due to microbial spoilage. Since it is composed mostly of water, microbes grow best using it as its substrate (Gosh, 2009).

The microorganisms implicated in tomatoes according to Obeng *et al.,* (2018) include: *Bacillus sp., Citrobacter sp., Citrobacter koseri, Lactobacillus planatarum, Lactobacillus fermentum, Enterobacter doacae, Klebsiella oxytoca, Klebsiella pneumonia, Proteus mirabilis, P. aeruginosa, Shigella sp.*

Probiotics Ecology of Locally Fermented Indigenous Foods

The unexpected prevalence of *Lactobacillus* species, especially *L. plantarum* and *L. casei*, highlights the rich microbial diversity inherent in these traditional food products. This newfound understanding suggests that indigenous fermented foods could serve as readily accessible and abundant sources of beneficial probiotic bacteria (Ogbuonye, 2018; Oranusi *et al.*, 2013).

In the real world, this discovery matters as it opens up new avenues for leveraging traditional diets to promote health and well-being. Harnessing the probiotic potential of *Lactobacillus* species from indigenous fermented foods offers a sustainable and culturally appropriate approach to improving gut health and immunity.

Furthermore, it presents opportunities for developing locally sourced and economically viable probiotic products, catering to diverse populations worldwide. Overall, this surprise finding underscores the importance of exploring and preserving traditional food-ways for their potential contributions to global health and nutrition (Oranusi *et al.*, 2013).

Conclusion

The review concludes that *akamu* (pap) and *efu nkwo* (fermented tomatoes) are not just nutritionally beneficial to the health of the consumers but also confer to the consumers probiotic benefits.

References

Fei, Y., Chen, Z., Han, S., Zhang, S., Zhang, T., Lu, Y., Berglund, B., Xiao, H., Li, L. and Yao, M. (2023). "Role of prebiotics in enhancing the function of next-generation probiotics in gut microbiota." *Critical Reviews in Food Science and Nutrition*, *63*(8): 1037-1054.

Ghosh, A. (2009). Identification of microorganisms responsible for spoilage of tomato (*Lycopersicon esculentum*) fruit. *Journal of Phytology (6)*: 414–416

Goderska, K., Dombhare, K. and Radziejewska-Kubzdela, E. (2022). Evaluation of probiotics in vegetable juices: tomato (*Solanum lycopersicum*), carrot (*Daucus carota subsp. sativus*) and beetroot juice (*Beta vulgaris*). *Arch Microbiol* **204**, 300. Available at: https://doi.org/10.1007/s00203-022-02820-1 (Accessed: 16 May 2025)

Lee, I-C. Tomita, S. Kleerebezem, M. and Bron, P. (2013). The quest for probiotic effector molecules—Unravelling strain specificity at the molecular level. Pharmacological Research 69:61– 74.

Nwokoro, O. and Chukwu, B. C. (2012). Studies on *Akamu*, a traditional fermented maize food. Revista chilena de nutrición *Reviews in Children Nutrition 39(4)*: 180 – 184

Obeng, F. A.; Gyasi, P. B.; Olu-Taiwo, M. and Ayeh-kumi, F. P. (2018). Microbial Assessment of Tomatoes (*Lycopersicon esculentum*) Sold at Some Central Markets in Ghana. *BioMedical Research International.* 2018, Article ID 6743826. Available at: https://doi.org/10.1155/2018/6743826 (Accessed: 16 May 2025).

Obi, C. N. and Okoronkwo, W. O. (2022). Production, Microbiol*ogi*cal and Proximate Analysis of Akamu produced from different Varieties of Maize. *Nigerian Journal of Microbiology, 36(1)*: - 6001 – 6012

Obinna, V. O. (2018). *Clostridium deficile* and Probiotics. *Journal of Probiotics and Health* 6(1):10000196 DOI:10.4172/2329-8901.1000196

Obinna, V. O. (2018). Comparative studies of sensory attributes of *akamu* produced from yellow maize with pure and mixed microbial cultures. *Journal of Food Science and Nutrition 1*: 54.

Ogbuonye, E. O. (2018). Chemical and Microbial Evaluation of '*Ogiri*' (A Locally Fermented Food Condiment) Produced from Kersting Groundnut Seeds. *Science Arena Publications Specialty Journal of Biological Sciences. 4 (2)*: 7 – 13

Okereke, H. C., Okereke, J. I., and Ajunwa, V. C. (2016). The microbiol*ogi*cal analysis of fresh and probioticated fruit juices with *Lactobacillus casei*. *Journal of Pathology, Ethno-Medicine and Parmacology 1*:44 – 52

Oranusi S., Braide W. and Chinakwe E. (2013) Probiotic Carrier Potential, Sensory Properties and Microbial Quality of Ugba (Pentaclethra macrophylla) and *Ogiri* (Ricinus communis). *International Journal of Microbiology Research*, ISSN: 0975-5276 and E-ISSN: 0975- 9174, 5(5): 476 – 481.

Sánchez, B., Delgado, S., Blanco-Míguez, A., Lourenço, A., Gueimonde, M. and Margolles, A. (2017). "Probiotics, gut microbiota, and their influence on host health and disease." *Molecular Nutrition and Food Research*, *61*(1): 1600240.

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT -East Central Chapter

Effect of Malting and Extrusion on the Nutritional Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends

*Azuka, E. C. [12], Nnamocha, T.[3], Okafor, G. I[2] and Boesch, C [a]

[1] School of Food Science and Nutrition, University of Leeds, United Kingdom, [2]Department of Food Science and Technology, University of Nigeria, Nsukka, [3]Department of Food Science and Technology, University of Agriculture and Environmental Sciences, Umuagwo

* Corresponding author's Email: chinenye.azuka@unn.edu.ng

ABSTRACT

The nutritional properties of extrudates are influenced by the applied processing conditions and extrusion variables. Knowledge of the combined impact of malting and extrusion on the nutritional properties of malted-extruded foods which has more nutritional value in non-extruded form is lacking. Malted pigeon pea and brown rice flours were processed into blends and extruded under various conditions of feed moisture level (15– 20), feed composition (8 - 30%), and barrel temperature (100-130°C), and analysed using Response Surface Methodology with a Box-Behnken design. The nutritional factors considered were protein, ash, fat, soluble and insoluble dietary fibre, available carbohydrate and resistant starch. The protein content of extrudates increased (16.41- 23.63%) with increased malted feed composition. Fat content of the extrudates increased (2.00- 3.00 %) with increased barrel temperature. The ash content ranged from (1.19- 2.02 g/100g) with increased malted feed composition and barrel temperature. The resistant starch ranged from 0.02- 0.50 g/100g with their highest values occurring at increased malted feed composition. The results showed that malting and some extrusion variables had a significant effect on the nutritional quality of the extrudates.

Keywords: Malting; brown rice; pigeon pea; resistant starch; soluble and insoluble dietary fibre

1.0 Introduction

The call for sustainability which incorporates improved food security and nutritional quality is therefore necessary as processing methods that improve the nutritional quality of underutilized foods are explored. Malting is a valuable technique that enhances nutritional quality, decreases anti-nutritive chemicals, improves mineral bioavailability, and enhances the functional qualities of cereals and pulses (Nkhata *et al,* 2018; Tiwari and Singh, 2020). Pigeon pea (*Cajanus cajan*), is an underutilized legume grown in tropical and subtropical regions. It is a good source of plant-based protein (18- 26 %) [Akubor, 2017; Adepeju *et al*., 2015], and also a rich source of carbohydrates, minerals, vitamins and dietary fibre essential for growth and development (Abebe, 2022; Haji *et al.* 2024). It is an excellent source of polyphenolic compounds, has lower lipid content free of cholesterol (Tiwari *et al*, 2013). Malted pigeon pea exhibits more bioactive compounds than un-malted counterparts, (Uchegbu and Ishiwu, 2016).

Rice is the seed of the genus Oryza and the grass family Poaceae (Oko, 2011). Brown rice contains a large amount of dietary fibre, vitamin E, B vitamins (B_1, B_3 and B_6), minerals and gamma-aminobutyric acid (GABA) more so than other types of rice. Although brown rice has a high nutritious content, it is not commonly eaten as a staple diet due to its dark color and tough texture. (Wu *et al*., 2013). Malted brown rice has a softer texture than regular brown rice due to the weakening of the rice kernel and starch granule during the malting process which results in softer, quicker-cooking rice that retains more nutrients (Han *et al*., 2016). It has been noted that the bioactive compounds obtained during malting of grains reduce

drastically following conventional heat treatment (Uchegbu *et al*., 2017) which led to exploring the use of extrusion cooking as a heat treatment in this study. Extrusion cooking is a high temperature short time (HTST) complex food processing technique that requires precise management of various factors to enhance the quality of food (Bordoloi and Ganguly, 2014; Zambrano *et al.,* 2022; Azuka *et al.,* 2025). The objective of this study was to assess the combined effect of malting and extrusion on the nutritional properties of the extrudates from flour blends of malted brown rice and pigeon pea which has more nutritional properties in their non-extruded form.

2.0 Materials and Methods

2.1 Acquisition of raw materials

The brown rice (*Oryza sativa glaberrima,* FARO 44 variety) was obtained during 2020 harvest season from the National Cereal Research Institute in Badeggi Bida, Niger State, Nigeria. The Red Pigeon pea (*Cajanus cajan L.*) [50 kg] was obtained at *Ogige* market in Nsukka LGA in Enugu State, Nigeria. The raw materials were cleaned by winnowing and sorted to remove impurities and were then packaged in 'ziploc' bags. They were subsequently stored at room temperature (30 ^{0}C) until they were needed. The brown rice and pigeon pea were malted and processed into flour blends using Box-Behnken design and thereafter subjected to different extrusion conditions as described by Azuka *et al.* (2025)

2.1.2 Designing formulations using Response Surface Methodology

Minitab software was utilized to establish a Response Surface Methodology (RSM) in a three-factor Box-Behnken design. The operating ranges and three standardized levels were determined following multiple preliminary trials and operating ranges; feed moisture level: 15-20 (X_1), barrel temperature 100-130 ^{o}C, (X_2) and feed composition: 8-30 % (amount of pulse combined with malted and un-malted rice flour- X_3), were the independent variables considered.

2.1.3 Nutritional composition analysis of extrudates

Protein, ash, fat, and moisture of the extrudates were determined according to method of AOAC (2010).

2.1.4 Determination of available carbohydrate

Megazyme kit K-ACHDF was employed to determine the available carbohydrate of the flour samples by following the company's protocol

2.1.5 Determination of resistant and digestible starch

Resistant and digestible starch of the pulverized extrudates were carried out using the Megazyme Kit, K-RAPS and protocol.

2.2 Statistical Analysis

The measurements were done with 3 replicates, and reported as the mean value ± standard deviation. An ANOVA was conducted using Minitab software, with significance set at $p < 0.05$. The results from the Box-Behnken design were analyzed to assess the impact of feed moisture level, feed blend composition, and barrel temperature as well as the impact of malting on the nutritional properties of the extrudates

3.0 Results and Discussion

The protein composition of the extrudates varied between 16.41- 23.63 % as shown in Table 1. Samples with a low malted feed composition (8 %) exhibited a significant low ($p < 0.05$) protein concentration (16.41- 17.50 %), due to a reduced amount of pigeon pea. The protein content of malted pigeon pea was 41.17 g, which was higher than that of un-malted pigeon pea (18- 26 %) reported by Akubor, (2017) and Adepeju *et al.* (2015). The fat content of the extrudates varied between 2.00- 3.00 g. Samples with lower malted feed composition (8 %) had the highest fat concentration (3 %) but the fat content significantly $p < 0.05$ declined with increased incorporation of malted feed composition (pigeon pea). At high barrel temperature there was a corresponding increase in the fat content though not significant ($p > 0.05$). This phenomenon could be as a result of enhanced fat extraction at elevated temperatures (Raj and Singh, 2024). There was a significant decrease ($p < 0.05$) in fat content (Table 2) with increase in feed moisture at increased malted pigeon pea composition.

Table 1: Nutritional composition of extrudates (g/100g)

Runs	Design Points (X_1, X_2, X_3)	Protein	Fat	Ash	moisture	Available Carbohydrate (g/l)	Digestible Starch (g/100g)	Resistant Starch (g/100g)
1	(15, 100, 19)	20.22± 0.12	2.50± 0.00	1.68± 0.02	8.79± 0.00	65.10± 10.19	6.74± 0.78	0.03± 10.19
2	20, 100, 19)	20.30± 0.37	2.60± 0.14	1.33± 0.02	10.00± 0.00	76.77± 1.34	6.76± 0.55	0.03± 1.34
3	(15, 130, 19)	20.13± 0.12	2.85± 0.07	1.86± 0.02	7.40± 0.28	64.62± 8.88	6.58± 0.56	0.04± 8.88
4	(20, 130, 19)	19.43± 0.00	2.50± 0.14	1.62± 0.04	9.80± 0.00	72.15± 0.84	6.55±0.61	0.03± 0.84
5	(15, 115, 8)	16.41± 0.18	3.00± 0.00	1.22± 0.09	8.30± 0.13	64.20± 8.51	6.92± 0.26	0.04± 8.51
6	(20, 115, 8)	16.59± 0.06	2.80± 0.00	1.19± 0.08	9.60± 0.00	58.00± 3.43	6.81± 0.51	0.04± 3.43
7	(15, 115, 30)	22.66± 0.49	2.40± 0.00	2.02± 0.01	6.80± 0.85	61.56± 14.93	6.24± 0.80	0.03± 14.93
8	(20, 115, 30)	23.63± 0.25	2.00± 0.00	1.80± 0.01	9.20± 0.28	66.78± 0.08	6.18± 0.66	0.03±0.08
9	(17.5, 100, 8)	16.94± 0.43	2.40± 0.00	1.26± 0.14	7.90± 0.14	78.39± 1.14	6.79± 1.01	0.03± 1.14
10	(17.5, 130, 8)	17.50± 0.00	3.00± 0.00	1.18± 0.00	8.20± 0.84	65.70± 16.05	6.94± 0.74	0.02± 16.05
11	(17.5, 100, 30)	22.40± 0.00	2.40± 0.00	1.72± 0.02	8.10± 0.14	68.04± 0.63	6.75± 0.12	0.50± 0.63
12	(17.5, 130, 30)	23.58± 0.81	2.55± 0.07	1.77± 0.17	7.80± 0.28	61.50± 1.64	6.41± 0.06	0.03± 1.64
13	(17.5, 115, 19)	19.60± 0.13	2.75± 0.21	1.62± 0.01	8.30± 0.14	66.40± 1.69	6.69± 0.16	0.03± 1.69
14	(17.5, 115, 19)	19.43± 0.12	2.45± 0.07	1.73± 0.03	8.00± 0.28	65.05± 18.38	6.77± 0.21	0.03± 18.38
15	(17.5, 115, 19)	19.47± 0.18	2.60± 0.14	1.64± 0.01	8.10± 0.14	75.45± 0.38	6.74± 0.25	0.04± 0.38
16	BRF	11.71± 0.06	2.95± 0.07	1.16± 0.00	12.29± 0.14	89.64± 13.23	7.29± 0.02	2.73± 0.15
17	GBRF	12.12± 0.17	2.90± 0.00	0.93± 0.01	10.50± 0.42	91.98± 6.11	7.24± 0.03	2.43± 0.13
18	PPF	41.17± 0.31	0.25± 0.21	3.71± 0.11	6.70±0.14	62.40± 12.54	0.28± 0.04	21.56± 0.74
	Control (D-Glucose)					93.94± 0.75		

Key (X1, X2, X3) (X1= Feed moisture, X2 = Extruder barrel Temperature X3= Feed Composition). GBRF= Germinated brown rice flour; BRF= brown rice flour; PPF= Germinated pigeon pea flour. Triplicate runs were carried out in all design point and average reported

Table 2: Analysis of variance of the nutritional properties of the developed quadratic model for germinated rice–pigeon pea blend

Source	Protein p-value	Fat p-value	Ash p-value	Moisture p-value
Model	0.001	0.218	0.017	0.009
X_1 (feed moisture)	0.848	0.197	0.049	0.000
X_2 (barrel temperature)	0.676	0.141	0.232	0.001
X_3 (feed composition)	0.000	0.023	0.001	0.291

The extrudate ash content ranged from 1.19 to 2.02 g. An increase in the malted feed composition resulted in a significant ($p < 0.05$) increase in the ash content of the extrudates. The elevated ash level in the extrudates might be attributed to the increased addition of malted pigeon pea, which is abundant in minerals. The moisture content of the feed had no significant ($p > 0.05$) effect on the ash content and the ash content increased as the barrel temperature increased though not significantly $p > 0.05$. Higher temperatures lead to degradation of organic compounds which causes an elevation in the inorganic compounds which represents ash content of a sample during analysis. The moisture content of the extrudates varied between 6.80 -10.00g. An increase in feed moisture levels resulted in a corresponding significant ($p < 0.05$) increase in extrudate moisture content at low barrel temperature. The total amount of available carbohydrate which included D-glucose, D-fructose, and digestible starch, varied between 58.00- 78.39 g in samples that were extruded at a feed moisture level of 17.5, barrel temperature of 100˚C, malted feed composition of 8% and a feed moisture level of 20, barrel temperature of 115 ^{0}C, and feed composition of 8% respectively. The extrudates had a digestible starch level ranging from 6.18 to 6.94 g as shown in Table 2. The extrudates produced at a feed moisture level of 20, a barrel temperature of 115˚C, and a feed composition of 30 % had the lowest value of digestible starch. On the other hand, the extrudates produced at a feed moisture level of 17.5 %, a barrel temperature of 130˚C, and a feed composition of 8 % had the highest value of digestible starch. The addition of malted peas resulted in a decrease in the rate of digestible starch. The digestibility of the starch molecule was not significantly affected by variations in barrel temperature and feed moisture. The digestibility rating of malted pigeon pea was the lowest, measuring 0.28/100g. The samples exhibited a range of resistant starch content, varying from 0.02 to 0.50g. The limited presence of resistant starch in some of the extrudates may be attributed to the relatively low amount of malted pigeon pea, which contains the highest quantity of resistant starch (21.56g). The resistant starch content was highest in the sample that was extruded with a feed moisture level of 17.5, a barrel temperature of 100˚C, and a malted feed composition of 30%. The digestibility value of pigeon pea was the lowest. Malting demonstrated a positive relationship between resistant starch levels and the increase in feed composition. The barrel temperature and feed moisture did not have a significant ($p > 0.05$) impact on the resistant starch content of the samples.

3.1 Optimization of the extrudate quality

Conditions of the optimization process to maximize extrudate protein, ash, and to minimize, fat and moisture content in malted brown rice-pigeon pea extrudates was set up. By applying the desirability function, the best optimum independent variables for X_1, X_2 and X_3 were 15, 109.39 ^{o}C and 30 g/100g, respectively for optimal extrudate quality. At these combinations, optimum protein (22.55 %) and ash (1.98 %) were obtained, while minimum fat (2.43 %) and moisture (7.29 %) were also obtained, and optimal desirability was 0.71which indicated that a greater number of the optimized responses were within the acceptability limits.

4.0 Conclusion

Extrudates produced from malted pigeon pea and brown rice flour blends showed significant improvements in nutritional characteristics due to malting process and extrusion processing conditions. The extrudates increased in protein level with increased malted feed composition. The fat content increased with increased barrel temperature. The ash content increased with increased malted feed composition and barrel temperature. The soluble, insoluble dietary fibre, resistant starch, increased with increased malted feed composition which were highly desirable. The digestible starch increased with reduction in malted feed composition. More utility for underutilized crops which employ advanced processing methods for food production, is essential and encouraged as they are cheaper and affordable.

Refernces

Adepeju, A. B., Abiodun, O. A., Ikuomola, D. S. and Esani, Y. O. (2015). Effects of inclusion of pigeonpea flour on the nutritional, functional and sensory characteristics of snacks from breadfruit flour. *European Journal of Basic and Applied Sciences* 2(2): 43– 51.

Akubor, P. (2017). Effect of processing methods on the chemical composition and functional properties of pigeon pea seed. *Asian Journal of Advances in Agricultural Research* 2(2): 1–8.

Azuka, C., Onwuchekwa, A., Nwosu, A., Holmes, M., Boesch, C., Okafor, G. (2025). The Effects of Malting and Extrusion on the Functional and Physical Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends. *Foods* 28;14(3):422. doi: 10.3390/foods14030422. PMID: 39942015; PMCID: PMC11816902.

Bordoloi, R., and Ganguly, S. (2014). Extrusion technique in food processing and a review on its various technological parameters. *Indian Journal of Scientific Research and Technology*, *2*(1), 1-3.

Haji, A., Teka, T., Yirga Bereka, T., Negasa Andersa, K., Desalegn Nekera, K., Geleta Abdi, G., Lema Abelti, A. and Makiso Urugo, M. (2024), Nutritional Composition, Bioactive Compounds, Food Applications, and Health Benefits of Pigeon Pea (*Cajanus cajan* L. Millsp.): A Review. *Legume Science* 6: e233.

Han, A., Jinn, J.-R., Mauromoustakos, A., and Wang, Y.-J. (2016). Effect of Parboiling on Milling, Physicochemical, and Textural Properties of Medium- and Long-Grain Germinated Brown Rice. *Cereal Chemistry Journal 93*(1:, 47-52.

Nkhata, S. G., Ayua, E., Kamau, E. H., and Shingiro, J.-B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science andamp; Nutrition 6*(8): 2446-2458.

Oko, A. O., and Ugwu, S. I. (2011). The proximate and mineral compositions of five major rice varieties in Abakaliki, South-Eastern Nigeria. *International Journal of Plant Physiology and Biochemistry*, *3*(2), 25-27.

Raj, T., and Singh, V. (2024). Natural deep eutectic solvents (NADES) assisted deconstruction of oil-cane bagasse for high lipid and sugar recovery. *Industrial Crops and Products 210*: 11812

Songtip, P., Jangchud, K., Jangchud, A., Tungtrakul, P., Piyachomkwan, K., and Development, M. K. D. o. P. (2013). *Development of Extruded Snacks from Germinated Khao Dawk Mali 105 and Hom Nin Brown Rice Flour Fortified with Xanthones*. Kasetsart University.

Tiwari, S. and Singh A. (2020) Nutritional potential of developed ready-to-use multinutrient malt mix.*AGBIR* 36(1):11-13

Uchegbu, N. N., and Ishiwu, C. N. (2016). Germinated Pigeon Pea (*Cajanus cajan*): a novel diet for lowering oxidative stress and hyperglycemia. *Food Science and Nutrition*, *4*(5), 772-777.

Uchegbu, N. N., Okoli, E. C., and Onwurafor, E. U. (2017). Antioxidant Properties of Steamed Paste (Moin-Moin) Made from Sprouted Pigeon Pea Flour as Influenced by Heat Treatment. *American Journal of Food Technology 13*(1): 42-47.

Wu, F., Yang, N., Touré, A., Jin, Z., and Xu, X. (2013). Germinated Brown Rice and Its Role in Human Health. *Critical Reviews in Food Science and Nutrition 53*(5): 451-463.

Zambrano Y, Contardo I, Moreno MC, and Bouchon P. (2022). Effect of extrusion temperature and feed-moisture content on the microstructural properties of rice-flour pellets and their impact on the expanded product. *Foods* 11(2):198.

Effect of Malting and Extrusion on the Mineral Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends

*Azuka, E. C. [12], Nnamocha, T.[3], Okafor, G. I[2] and Boesch, C [a]

[1] School of Food Science and Nutrition, University of Leeds, United Kingdom, [2]Department of Food Science and Technology, University of Nigeria, Nsukka, [3]Department of Food Science and Technology, University of Agriculture and Environmental Sciences, Umuagwo

* Corresponding author's Email: chinenye.azuka@unn.edu.ng

ABSTRACT

The mineral properties of extrudates are influenced by the applied processing conditions and extrusion variables. Knowledge of the combined impact of malting and extrusion on the mineral properties of malted-extruded foods is lacking. Malted pigeon pea and brown rice flours were processed into blends and extruded under various conditions of feed moisture level (15 – 20), feed composition (8 - 30%), and barrel temperature (100 - 130 °C), and analysed using Response Surface Methodology with a Box-Behnken design. The minerals evaluated were iron, zinc, calcium, magnesium, potassium, manganese and copper. All the minerals excluding iron, manganese and magnesium increased with increased incorporation of malted feed composition. The iron content (0.47– 4.47 mg/L) decreased with increase in barrel temperature and feed moisture. The zinc (0.18– 0.20 mg/l) content increased with increase in barrel temperature but there was no effect of feed moisture. The magnesium content (8.37– 9.13 mg/l) increased with decrease in feed moisture and there was no effect of barrel temperature. The calcium (1.33- 2.50 mg/l), manganese (0.15-0.19 mg/l), and copper (35.31 -64.64 μg/L) content decreased with increase in barrel temperature. Results showed that malting and some extrusion variables had a significant effect on the mineral quality of the extrudates.

Keywords: Malting; brown rice; pigeon pea; Box-Behnken design; minerals

1.0 Introduction

Based on the need to enhance food security and maintain nutritional quality, it is essential that processing methods that improve the nutritional quality of underutilized foods is explored. Malting is a simple beneficial technique that enhances nutritional quality, decreases anti-nutritive chemicals, improves mineral bioavailability, and enhances the functional qualities of cereals and pulses (Nkhata *et al.,* 2018; Tiwari and Singh, 2020). Pigeon pea (*Cajanus cajan*), is an underutilized annually grown legume that is a good source of minerals mainly copper and plant-based protein and also a rich source of carbohydrates, vitamins and dietary fibre (Haji *et al.,* 2024). Malted pigeon pea exhibits more secondary metabolites than its counterparts (Uchegbu and Ishiwu, 2016). Rice is the seed of the monocot plant belonging to the genus Oryza and the grass family *Poaceae* (Oko, 2011). Brown rice contains a large amount of dietary fibre, vitamin E, B vitamins, minerals and gamma-aminobutyric acid (GABA). However, malting has been confirmed to enhance the nutritional value, palatability, and texture of brown rice (Patil and Khan 2011). It has been noted that the bioactive compounds obtained during malting of grains reduce drastically following conventional heat treatment (Uchegbu *et al*., 2017), thus exploring extrusion cooking a high temperature short time (HTST) complex food processing technique to minimize these losses was crucial. The effect of malting and extrusion on the mineral properties of malted-extruded foods is lacking. The objective of this study was to assess the combined effect of malting and extrusion on the mineral properties of the extrudates from flour blends of malted brown rice and pigeon pea.

2.0 Materials and Methods

The brown rice (*Oryza sativa glaberrima,* FARO 44 variety) was obtained during 2020 harvest season from the National Cereal Research Institute in Badeggi Bida, Niger State, Nigeria. The Red Pigeon pea (*Cajanus cajan L.*) [50 kg] was obtained at Ogige market in Nsukka LGA in Enugu State, Nigeria. The raw materials underwent cleaning by winnowing and sorting to remove impurities and were then packaged in ziploc bags. The brown rice and pigeon pea were malted and processed into flour blends using Box-Behnken design and thereafter subjected to different extrusion conditions as described by Azuka *et al.* (2025)

2.1 Designing formulations using Response Surface Methodology

Minitab software was utilized to establish a Response Surface Methodology (RSM) in a three-factor Box-Behnken design. The operating ranges and three standardized levels were determined following multiple preliminary trials and operating ranges; feed moisture level: 15-20 (X_1), barrel temperature 100-130°C, (X_2) and feed composition: 8-30 % (amount of pulse combined with malted and un-malted rice flour- X_3), were the independent variables considered.

2.2 Mineral content determination

2.2.1 ICP-OES Analysis

A Thermo Scientific iCAP7400 ICP-OES (Ryl *et al.,* 2022) was used. The analysis was used in radial mode. Samples were analysed undiluted. Appropriate internal standard was added to each dilution.

2.3 Statistical analysis

The analysis was done with 5 replicates, and reported as the mean value ± standard deviation. An ANOVA was conducted using Minitab software, with significance set at $p < 0.05$. The results from the Box-Behnken design were analysed to assess the impact of feed moisture level, feed blend composition, and barrel temperature as well as the impact of malting on the mineral properties of the extrudates.

3.0 Results and Discussion

Table 1 showed the mineral content of extrudates from flour blends of malted rice and pigeon pea. The iron content (0.47– 4.47 mg/L) of the extrudates decreased significantly ($p < 0.05$) with increase in barrel temperature and moisture content of the extrusion variables. There was no significant ($p > 0.05$) effect of malted feed composition on the extrudates (Table 2). Different researchers reported a decrease in iron while malting sorghum, foxtail, and chickpea (Laxmi, 2015; Ogbonna *et al.*, 2012) as shown in Table 1 where malted brown rice was 0.16 mg/L against the value of 0.73 mg/L in un-malted brown rice, supporting the claims of Laxmi (2015) and Ogbonna *et al.* (2012). The zinc content of the extrudates ranged from 0.18 – 0.20 mg/l. There was a significant difference ($p < 0.05$) in zinc content with increase in barrel temperature and malted feed composition but there was no significant effect ($p > 0.05$) of feed moisture on the zinc content of the extrudates. The calcium content of the extrudates ranged from 1.33- 2.50 mg/l. The calcium content of the extrudates increased significantly ($p < 0.05$) with increase in feed composition, decrease in barrel temperature with no significant effect ($p > 0.05$) from feed moisture (Table 2). Pigeon pea is rich in dietary elements including calcium (57—276 mg/100g) as reported by Wu *et al.* (2024). This may have contributed to the increase in the calcium level of extrudates with increase in feed composition in the extrudates. A decrease in calcium while malting sorghum, foxtail, and chickpea has been reported (Laxmi, 2015; Ogbonna *et al.*, 2012). In Table 1, the result showed the malted brown rice calcium level of 0.44 mg/L against the value of 0.88 mg/L in un-malted brown rice, supporting the claims of Laxmi (2015) and Ogbonna *et al. (*2012).

Table 1: Mineral content of extrudates from flour blends of malted rice and pigeon pea

Runs	Design Points (X_1, X_2, X_3)	mg/L						µg/L
		Fe	Zn	Ca	Mg	K	Mn	Cu
1	(15, 100, 19)	4.47	0.19	1.61	8.72	36.14	0.19	55.62
2	20, 100, 19)	1.94	0.19	1.57	8.43	33.30	0.17	49.77
3	(15, 130, 19)	0.72	0.20	2.06	9.13	39.77	0.16	46.04
4	(20, 130, 19)	0.47	0.19	1.96	8.67	37.48	0.16	45.75
5	(15, 115, 8)	1.32	0.19	1.36	8.60	24.28	0.17	36.99
6	(20, 115, 8)	0.78	0.19	1.41	8.37	24.94	0.17	35.31
7	(15, 115, 30)	1.64	0.20	2.47	8.78	45.18	0.16	50.29
8	(20, 115, 30)	0.62	0.19	2.47	8.61	43.18	0.15	64.64
9	(17.5, 100, 8)	1.82	0.18	1.33	8.63	28.17	0.18	54.28
10	(17.5, 130, 8)	0.51	0.19	1.42	8.48	26.26	0.16	40.18
11	(17.5, 100, 30)	1.64	0.19	2.07	9.05	45.01	0.16	60.02
12	(17.5, 130, 30)	0.60	0.20	2.50	8.80	43.44	0.15	49.57
13	(17.5, 115, 19)	0.79	0.20	2.07	9.00	40.14	0.16	45.47
14	(17.5, 115, 19)	0.66	0.20	2.11	8.75	37.48	0.16	42.98
15	(17.5, 115, 19)	0.76	0.20	2.05	8.74	39.11	0.16	51.78
16	BRF	0.73	0.20	0.82	8.71	18.15	0.21	34.51
17	GBRF	0.16	0.14	0.44	4.59	12.21	0.09	38.48
18	PPF	0.30	0.23	5.57	9.58	118.01	0.11	100.41
19	MILLIQ water	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Key (X1, X2, X3) (x1= Feed moisture, X2 = Extruder barrel Temperature X3= Feed Composition). GBRF= Germinated brown rice flour; BRF= brown rice flour; PPF= Germinated pigeon pea flour. Triplicate runs were carried out in all design point and average reported

Table 2: Analysis of variance of the mineral properties of the developed quadratic model for germinated rice–pigeon pea blend

Source	Fe p-value	Zn p-value	Ca p-value	Mg p-value	K p-value	Mn p-value	Cu p-value
Model	0.030	0.016	0.000	0.431	0.003	0.001	0.218
X_1 (feed moisture)	0.02	0.217	0.724	0.102	0.520	0.002	0.727
X_2 (barrel temperature)	0.003	0.007	0.002	0.677	0.520	0.000	0.083
X_3 (feed composition)	0.965	0.005	0.000	0.098	0.000	0.000	0.022

The magnesium content of the extrudates ranged from 8.37 – 9.13 mg/l. There was increase in magnesium content of the extrudates with increase in malted feed composition and decrease in feed moisture but there was no statistical significance $p > 0.05$. There was no significant $p > 0.05$ effect of barrel temperature on the magnesium content of the extrudates. The Potassium content (24.28 – 45.18 mg/l) of the extrudates increased significantly $p < 0.05$ with increasing malted feed composition. This could be as a result of high content of potassium (1104 mg/100g) in pigeon pea as reported by Wu *et al.* (2024) and 1845–1941 mg/100g as reported by Amarteifio *et al.* (2002). There was no significant $p > 0.05$ effect from feed moisture and barrel temperature on potassium content. The manganese content of the extrudates ranged from 0.15 - 0.19 mg/l. The manganese content of the extrudates decreased significantly $p < 0.05$ with increase in malted feed composition, barrel temperature and feed moisture variables. This could be as a result of low content of manganese in the malted pigeon pea (0.11 mg/l). The manganese content of the malted brown rice decreased after malting. Malting could enhance reduction of manganese in both cereals and legumes. The copper content of the extrudates ranged from 35.31 - 64.64 μg/L. The copper content of the extrudates increased significantly $p < 0.05$ with increasing levels of the malted feed composition. This is as a result of high content of Cu 100.41 μg/L in malted pigeon pea which is high compared to the copper content of un-malted pigeon peas (0.93 - 1.23 μg/L) as reported by A'yuni *et al., (*2022). The copper content reduced with increase in barrel temperature though not significant $p > 0.05$.

3.1 Optimization of the extrudate quality

By applying the desirability function, the best optimum independent variables for X_1, X_2 and X_3 were 15, 109.39 °C and 30 g/100g, respectively for optimal extrudate quality. At these combinations, optimum 1ron (2.39 mg/L), zinc (0.20 mg/L), calcium (2.32 mg/L), magnesium (8.85 mg/L), potassium (44.77 mg/L), manganese (0.16 mg/L) and copper (51.64 μg/L) were obtained. The optimal desirability was 0.71which indicated that a greater number of the optimized responses were within the acceptability limits.

4.0 Conclusion

Extrudates produced from malted pigeon pea and brown rice flour blends showed significant nutritional characteristics due to malting process and extrusion processing conditions. The zinc, calcium and potassium increased with increased malted feed composition which is highly desirable. It is recommended that extrudates of malted-brown rice and pigeon pea flour blends, should be extruded using the optimum independent variables and its nutrient digestibility, availability, and overall sensory acceptability evaluated for an acceptable eating quality. More utilization of underutilized crops employing advanced processing methods for food security and nutritional sustainability is essential and encouraged as they are low-cost and will be affordable for the poor to contribute in ending hunger and achieving food security which is the goal 2 of the SDGs.

References

A'yuni, N. R. L., Marsono, Y., Marseno, D.W. and Triwitono, P. (2022). Physical characteristics, nutrients, and antinutrients composition of pigeon pea (Cajanus cajan (L.) Millsp.) grown in Indonesia. *Food Research 6*(2): 53 - 63.

Amarteifio, J. O., Munthali, D. C., Karikari, S. K., and Morake, T. K. (2002). *Plant Foods for Human Nutrition 57*(2): 173-177.

Azuka, C, Onwuchekwa A, Nwosu A, Holmes M, Boesch C, Okafor G. (2025). The Effects of Malting and Extrusion on the Functional and Physical Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends. *Foods*. 14(3):422.

Haji, A., Teka, T., Yirga Bereka, T., Negasa Andersa, K., Desalegn Nekera, K., Geleta Abdi, G., Lema Abelti, A. and Makiso Urugo, M. (2024), Nutritional Composition, Bioactive Compounds, Food Applications, and Health Benefits of Pigeon Pea (*Cajanus cajan* L. Millsp.): A Review. *Legume Science* 6: e233.

Laxmi G, C. N., and Richa S. (2015). The Impact of Malting on Nutritional Composition of Foxtail Millet, Wheat and Chickpea. *Journal of Nutrition and Food Sciences 5*(5): 407.

Nkhata, S. G., Ayua, E., Kamau, E. H., and Shingiro, J.-B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science and Nutrition 6*(8): 2446-2458.

Oko, A. O., and Ugwu, S. I. (2011). The proximate and mineral compositions of five major rice varieties in Abakaliki, South-Eastern Nigeria. *International Journal of Plant Physiology and Biochemistry*, *3*(2), 25-27.

Patil, S. B., and Khan, M. K. (2011). Germinated brown rice as a value-added rice product: A review. *Journal of Food Science and Technology 48*(6): 661-667.

Ryl, A., Szylińska, A., Bohatyrewicz, A., Jurewicz, A., Pilarczyk, B., Tomza-Marciniak, A., and Rotter, I. (2022). Relationships between indicators of metabolic disorders and selected concentrations of bioelements and lead in serum and bone tissue in aging men. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*:3901-3911.

Wu, J., Zhou, Q., Zhou, C., Cheng, K. W., and Wang, M. (2024). Strategies to promote the dietary use of pigeon pea (Cajanus cajan L.) for human nutrition and health. *Food Frontiers*, *5*(3), 1014-1030.

Tiwari, S. Singh A. (2020) Nutritional potential of developed ready-to-use multi-nutrient malt mix.*AGBIR* 36(1):11-13.

Uchegbu, N. N., and Ishiwu, C. N. (2016). Germinated Pigeon Pea (Cajanus cajan): a novel diet for lowering oxidative stress and hyperglycemia. *Food science and nutrition*, *4*(5), 772-777.

Uchegbu, N. N., Okoli, E. C., and Onwurafor, E. U. (2017). Antioxidant Properties of Steamed Paste (Moin-Moin) Made from Sprouted Pigeon Pea Flour as Influenced by Heat Treatment. *American Journal of Food Technology 13*(1): 42-47.

Effect of Incorporation of Plantain Peel and Okara Flours on the Micronutrient gf Dough Meal from Yellow Cassava-Maize Blends.

*Onwuchekwa, A. I, Amonyeze, A. O, Aniemena, C. C and Chiaha, E.

Department Of Food Science and Technology, Faculty of Agriculture, University of Nigeria, Nsukka

*Corresponding Authors Email address: amarachi.onwuchekwa@unn.edu.ng

ABSTRACT

The study investigates the effect of incorporating plantain peel and okara flour on the micronutrient composition of dough meals formulated from blends of yellow cassava and maize flour blends. Composite flours were formulated with varying substitution levels of plantain peel (0-20%) and okara (0-15%) in a yellow cassava maize blend (60:40) and coded respectively as MCPO 1 (95:0:5), MCPO 2 (95:5:0), MCPO 3 (85:10:5), MCPO 4 (75:15:10), MCPO 5 (65:20:15). The formulated flour blends were analysed for micronutrients content (iron, calcium, potassium, Vit A, Vit C) using the standard method of AOAC methods. The data obtained were subjected to one way analysis of variance (ANOVA) and significance difference at ($p<0.05$) using SPSS version 22. The results obtained from the blends of cassava –maize blend incorporated plantain peel and okara flour showed a significant difference ($p<0.05$) on the micronutrient composition ranging (0.26-2.85mg/100g)vitamin A (0.06-0.11mg/100g) vitamin C, (250.51-1775.21mg/100g) potassium, (1.81-1.96mg/100g) in Iron, and Calcium (62.25-99.86mg/100g)showing an increase with increased level of the plantain peel flour(PPF) and okara flour (OKF). The study reveals that incorporating plantain peel and Okara flour could improve the micronutrient composition of the dough meal. A more nutritionally and improved dough meal from flour blends of yellow cassava, and maize incorporated plantain peel and okara was produced and accepted.

Keyword: Micronutrient, Okara, Plantain peel, Dough Meal, nutritional enhancement

1.0 Introduction

Micronutrient deficiencies, particularly in iron, zinc, vitamin A, and calcium, remain a global public health challenge, especially in developing countries where staple foods like maize and cassava dominate diets (FAO, 2023). These staples are often low in essential micronutrients, contributing to conditions such as anemia, stunted growth, and impaired immune function (WHO, 2024). Yellow cassava, rich in provitamin A carotenoids, has emerged as a promising ingredient to address vitamin A deficiency (Njie *et al.,* 2022). Cassava (*Manihot esculenta*) and maize (*Zea mays l.*) are one of the most common ingredients used for preparing fufu meals. These ingredients are good source of carbohydrates but offer little in the way of other essential nutrients like protein, essential vitamins, and minerals, thereby making it not nutritionally balanced (Morgan and Choct, 2016). Maize contains higher amount of protein and other micronutrient when compared to cassava flour. The challenge of malnutrition in regions where these meals are consumed regularly has prompted the need to improve the nutritional content. However, its micronutrient profile can be further enhanced by incorporating nutrient-dense agricultural by-products like plantain peel and okara.

Plantain peel, a by-product of Musa paradisiaca processing, is rich in dietary fibre, minerals (iron, calcium, and potassium), and antioxidants (Fatima *et al.,* 2023). Okara, a soy pulp residue from soymilk production, is high in protein, fibre, and minerals such as zinc and magnesium (Li *et al.,* 2024). Both by-products are underutilized, often discarded as waste, despite their potential to enrich food products (Odeyemi and Afolabi, 2025). Incorporating these into dough meals a staple in many African diets could improve nutritional quality and promote sustainable food systems (Temba *et al.,* 2025).

Dough meals mostly consumed across West Africa and beyond, are starchy and mainly from cassava. They are prepared by mixing flours with water and cooking (Akinjisola *et al.,* 2024). This meal is nutritionally imbalance and needs to improve its nutritional value by addition of other plant flour to help enrich its nutritional content (Bamidele *et al.,* 2015). Previous studies have explored composite flours for dough meals, focusing on proximate composition and sensory properties (Famakin *et al.,* 2016; Ukeyima *et al.,* 2021). In order to improve the nutritional imbalance in fufu-meal – addition of other plant crop like maize flour, soy meal, unripe plantain, moringa seed, etc. has been incorporated into the meal (Badejo *et al.,* 2022). However, there is limited research on the micronutrient enhancement of yellow cassava-maize dough meals using plantain peel and okara. This study aims to evaluate the effect of plantain peel and okara flour incorporation on the micronutrient composition (iron, zinc, calcium, magnesium, and vitamins A and C) of dough meals, with implications for addressing micronutrient deficiencies and utilizing agricultural by-products.

2.0 Materials and Methods

2.1 Raw Material Collection and Preparation

Yellow cassava roots (*Manihot esculentaCrantz,* TMS 01/1371) and maize grains (*Zea mays L.*) were sourced from a local market in Nike market Enugu state, Nigeria. Cassava roots were peeled, grated, fermented for 48 hours, and dried at 60°C for 24 hours to produce flour (AOAC, 2020). Maize grains were cleaned, milled, and sieved (60-mesh). Unripe plantain peels were collected after peeling from the whole plantain bunch. The Plantain peels were washed, sliced, dried at 50°C for 18 hours, and milled into flour (Fatima *et al.,* 2023). The okara was obtained from a soymilk production, was dried at 55°C for 12 hours and milled (Li *et al.,* 2024).

2.2 Formulation of Composite Flours

A yellow cassava-maize base blend (60:40) was adopted. Plantain peel flour and okara was incorporated at varied ratio levels of 0-20 %. Flours were mixed thoroughly, sealed in airtight containers, and stored at 27°C prior to analysis.

2.3 Experimental Design and Data Analysis

The experiment was laid out in a Completely Randomized Design (CRD). Data obtained were subjected to Analysis of Variance (AVOVA) using the Statistical Product for Service Solution (SPSS) version 22. Duncan's New Multiple Range Test (DNMRT) was used to compare the treatment means. Statistical significance was accepted at $p<0.05$.

Table 1: Formulation Of Maize-Cassava Incorporation with Plantain Peel Flour (PPF)And Okara Flour (OKF) Blend..

Sample Codes	MCF (%)	PPF (%)	OKF (%)
MCPO 1	95	5	0
MCPO 2	95	0	5
MCPO 3	85	5	10
MCPO 4	75	10	15
MCPO 5	65	15	20

Where MCPO: Maize, Cassava, Plantain peel, and Okara, MCPO 1: 95% Maize-Cassava Flour, 5% Plantain Peel Flour and 0% Okara Flour, MCPO 2: 95% Maize-Cassava Flour, 0% Plantain Peel Flour and 5% Okara Flour, MCPO 3: 85% Maize-Cassava Flour, 10% Plantain Peel Flour and 10% Okara Flour, MCPO 4: 75% Maize-Cassava Flour, 10% Plantain Peel Flour and 15% Okara Flour, MCPO 5: 65% Maize-Cassava Flour, 15% Plantain Peel Flour and 20% Okara Flour

3.0 Results and discussion

Table 2 shows the result of the micronutrient composition of dough meal produced from maize-cassava flour, plantain peel flour and okara flour. The effect of plantain peel and okara flour inclusion showed a significant increase ($p<0.05$) on all the micronutrient studied. The sample blend containing (95% Yellow cassava: maize flour: 5% plantain peel, 0% okara) recorded a significant lower value of the micronutrient content iron (1.18 mg/100 g), calcium (62.25 mg/100 g), potassium (250.51 mg/100 g), vitamin A (0.26 µg/100g), and vitamin C (0.09 mg/100 g) when compared to the other blends. Incorporation of plantain peel and okara from 5-20% significantly ($p < 0.05$) increased all micronutrients. The blend with 15% plantain peel and 20% okara exhibited the highest values: iron (1.96 mg/100 g), calcium (99.86 mg/100 g), potassium (1775.21 mg/100 g), vitamin A (2.85 ug/100g), and vitamin C (0.16 mg/100 g). The result obtained from this study was relative to the study by Mayomi and Aderinola (2024) stating an increasing effect in the micronutrient contents of the flour with the substitution of the plantain peel. The low Vitamin C contents levels observed in the blends with increase substitution of the plantain peel and okara were relatively low across all samples, ranging from 0.06 mg/100g to 0.11 mg/100g. This shows that okara and plantain peel flour are not good sources of Vitamin C. An appreciable increase of the micronutrient potassium, iron and calcium content presents this meal as healthy and beneficial for both adults and children.

4.0 Conclusion

The study successfully evaluated the micronutrient composition of dough meal produced from maize-cassava incorporated unripe plantain peel and okara flour. The outcome of the study indicates that inclusion of plantain peel flour and okara in yellow cassava maize dough meals significantly improved the micronutrient composition of the flour vitamin C, A, potassium, calcium and Iron content. This study has shown the potential of agricultural by products from plantain root and soybean milk in developing a sustainable, nutrient rich foods

Table 2: Micronutrient composition of dough meal produced from maize-cassava flour, plantain peel flour and okara flour

Sample	Vit A (ug/100g)	Vit C (mg/100g)	K (mg/100g)	Fe (mg/100g)	Ca (mg/100g)
MCPO 1	$0.26^{a}\pm0.00$	$0.09^{a}\pm0.00$	$250.51^{a}\pm1.00$	$1.81^{a}\pm0.02$	$62.25^{a}\pm0.63$
MCPO 2	$0.50^{b}\pm0.02$	$0.09^{a}\pm0.00$	$558.31^{b}\pm5.53$	$1.83^{a}\pm0.00$	$63.04^{a}\pm0.02$
MCPO 3	$1.07^{c}\pm0.07$	$0.10^{a}\pm0.01$	$819.50^{c}\pm9.56$	$1.95^{b}\pm0.01$	$68.84^{b}\pm0.25$
MCPO 4	$2.02^{d}\pm0.00$	$0.11^{a}\pm0.00$	$1169.09^{d}\pm1.41$	$1.94^{b}\pm0.00$	$81.22^{c}\pm0.48$
MCPO 5	$2.85^{e}\pm0.02$	$0.16^{a}\pm0.06$	$1775.21^{e}\pm0.00$	$1.96^{b}\pm0.00$	$99.86^{d}\pm3.45$

Values are means ± standard deviation of 2 replicate determination. Means with the same superscripts in a column are not significantly ($p> 0.05$) different.

MCPO 1: 95% Maize-Cassava Flour, 5% Plantain Flour and 0% Okara Flour, MCPO 2: 95% Maize-Cassava Flour, 0% Plantain Peel Flour and 5% Okara Flour, MCPO 3: 85% Maize-Cassava Flour, 5% Plantain Peel Flour and 10% Okara Flour, MCPO 4: 75% Maize-Cassava Flour, 10% Plantain Peel Flour and 15% Okara Flour, MCPO 5: 65% Maize-Cassava Flour, 15% Plantain Peel Flour and 20% Okara Flour

References

Akinjisola, T.D., Olumurewa J.A.V., Bamisile O.B. and Omole R.A. (2024). Quality Characteristics of Dough Meal Formulated from Unripe Plantain, Soymeal, Moringa Seed, and Marugbo Leaf. *Obese.* 2(1):4.

AOAC. (2010). Official Methods of Analysis. Association of Official Analytical Chemists. 19th Edition, Washington DC

Badejo, A.A., Oduola T., Falarunu J.A. and Olugbuyi A.O. (2022). Physicochemical Composition and Invitro Antioxidative Properties of Flour Blends from Pro-Vitamin A Cassava, Quality Protein Maize and Soybean Cake for Dough Meal. *Journal of Culinary Science and Technology*. 21(5):1-18.

Bamidele, O. P., Fasogbon, M. B., Oladiran, D. A., and Akande, E. O. (2015). Nutritional composition of fufu analog flour produced from Cassava root (*Manihotesculenta*) and Cocoyam (*Colocasiaesculenta*) tuber. *Food science and nutrition*, 3(6), 597–603.

Fatima, A., Khan, M. and Ahmad, S (2023). Nutritional and antioxidant potential of plantain peel flour in food applications. *Journal of food Processing and Preservation*, 47(4)e12456

Li, Y., Zhang, X. and Wang, Q (2024) Okara as a sustainable ingredient: nutritional composition and applications in functional Foods. *Food Chemistry*, 425:139456

Mayomi, P.T., and Aderinola, T.A. (2024). Proximate, mineral, amino acid composition, and bioactive properties of dough meals supplemented with African walnut flour. *Food Science and Engineering*, 5(2), 404-417.

Morgan, N.K. and Choct M. (2016). Cassava: Nutrient composition and nutritive value in poultry diets. *Animal Nutrition*, 2(4):253-261

Njie, D., Maiziya-Dixon, B. and Alamu, E. O. (2022). Nutritional evaluation of provitamins A. Cassava based products. *Global journal of Science frontier Research,* 22(3),45-52

Odeyemi, O. and Afolabi, W. (2025). Valorization of agricultural by products for food security in sub-Saharan Africa *Journal of Food Science*, 19(1),23-34

Temba, G., De Mast, Q. and Kimambo, A (2025). Traditional African diets and non-communicable disease prevention: Evidence from Tanzania. *The Guardian Global Development*

Ukeyima, M., Agoh, P. and Ochelle, P.O (2021). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *Sematic scholar*

Uzairu, S. M. and Kano M. K. (2021). Assessment of phytochemical and mineral composition of unripe and ripe plantain (Musa paradisiaca) peels. *African Journal of Food Science*, 15(3), 107-112.

WHO (2024). Micronutrient deficiencies. Global health perspectives. World Health Organization

Effects of Processing Methods on the Proximate Composition of *Uziza* (*Piper Guineense*) Seed Flour

*Ifediba, C. M.[1] Ikegwu, T. M.[1] and Omologbe F.[1]

1.Department of Food Technology, Nnamdi Azikiwe University, Awka, Anambra State.

*Corresponding author: ifedibacynthia22 @gmail.com

ABSTRACT

Uziza (*Piper guineense*) is a spice commonly used in West African cuisine, particularly in Nigeria, where it is valued for both its distinctive flavor and medicinal properties. This research aimed to investigate the effect of different processing methods on the proximate properties of *Uziza* (*Piper guineense*) seed flour. The research was designed using a factorial design (2×3) with Minitab software (version 21.0). The results were generated automatically to give six (6) samples, while a control was included to minimize experimental error. Findings from the study indicated that processing methods like toasting and roasting significantly influenced the nutritional and functional properties of the flour. Toasting at 150°C for 5 min resulted in higher protein and ash contents, while roasting at 220°C for 15 min increased carbohydrate and fat content. The proximate analysis showed that moisture content ranged from 7.39% to 11.06%, protein content from 6.45% to 7.97%, fat content from 3.01% to 4.05%, fibre content from 2.11% to 2.85%, ash content from 4.13% to 5.76%, and carbohydrate content from 69.39% to 75.25%. Significant differences were observed among the samples, with sample 00A2 having the highest carbohydrate content (75.25%) and sample 00B2 the lowest (69.39%). The processing conditions play a crucial role in determining the optimal nutritional potential guiding it's use in food industries.

Keywords: *Uziza*, Proximate, roasting, toasting

1.0 Introduction

Traditional societies are known for using herbs to cure sicknesses, although many of their belief systems remain unverified scientifically (Dibulo, 2016). To validate these claims, it is important to conduct bioassays and determine the biological value of these local herbs. In recent years, there has been growing interest in natural remedies for various health concerns (Chinonso, 2008). One herb gaining popularity for its numerous health benefits is *Uziza* (Nkem, 2013). Its distinctive flavor and medicinal properties have made *Uziza* a widely used herb in traditional medicine for centuries (Harbone, 2018).

Piper guineensis, commonly referred to as African black pepper or Ashanti pepper, belongs to the Piperaceae family. It is similar to *Piper nigrum*, the true pepper of commerce used to produce black and white pepper (Anyanwu and Nwosu, 2014). This plant has over 700 species throughout tropical regions worldwide. *Piper guineensis* is reported to treat intestinal diseases, bronchitis, cough, rheumatism, infertility in women, and low sperm count in men (Dibulo *et al.*, 2017). The plant is a climbing vine that grows up to 20 meters and bears peppery berry fruits (Ogbonna *et al.,* 2015). In Nigeria, it is known by various names such as *Uziza* in Igbo, *Iyere* in Yoruba, and *Odusa* in Ibibio.

Uziza (*Piper guineense*) is a spice commonly used in West African cuisine, particularly in Nigeria, where it is valued for both its distinctive flavor and medicinal properties. The seed of *Uziza* is known for its pungent, peppery taste, which has made it a staple in traditional recipes and herbal remedies. The plant belongs to the *Piperaceae* family and is similar to the true pepper of commerce, *Piper nigrum*, from which black and white pepper are derived (Anyanwu and Nwosu, 2014).

Historically, *Uziza* has been utilized in traditional medicine to treat a variety of ailments (Chima, 2016). It has been reported to be effective in managing intestinal diseases, bronchitis, cough, rheumatism, infertility in women, and low sperm count in men.

Processing methods can significantly impact the physicochemical properties of plant materials, influencing their nutritional value, bioactive compound contents, and overall quality. Common processing techniques for spices and herbs include drying, roasting, and milling. Each method can alter the chemical composition and physical characteristics of the final product. For instance, drying can affect the moisture content and shelf life, while roasting can enhance flavor but may lead to the loss of heat-sensitive nutrients (Besong *et al.,* 2016).

Given the wide usage of *Uziza* in both culinary and medicinal applications, it is crucial to understand how different processing methods affect its physicochemical properties. This knowledge can help optimize processing techniques to preserve or enhance the desirable qualities of *Uziza* seed flour, making it more effective and appealing for various uses.

Research on the impact of processing methods on the properties of *Uziza* seed flour is limited (Nwosu, 2014). However, existing studies on other spices and herbs suggest that processing can significantly alter both physical and chemical attributes. For instance, drying methods can influence the color, texture, and nutrient content of plant materials, while milling can affect particle size and distribution, which in turn impacts solubility and bioavailability of nutrients (Ogbonna *et al.,* 2015).

Understanding these effects is particularly important for *Uziza*, given its dual role in food and medicine. Optimizing processing methods can enhance its functionality, ensuring that the final product retains its health benefits and flavor profile. This research aims to fill the gap in knowledge by systematically studying how different processing techniques affect the physicochemical properties of *Uziza* seed flour.

2.0 Materials and Methods

The raw material used in the study include *Piper guineensis* seeds of high quality. The material was purchased from 'Ose' market, Onitsha, Anambra State.

2.1 Preparation of Raw Materials

Uziza seeds were processed according to Anyanwu and Nwosu (2014). The *Uziza* seeds were subjected to different processing methods after carefully removing the seeds from the pods. The seeds were blanched, toasted, and, roasted and then ground to flour. The *Uziza* flours were packaged in low-density polyethylene bag and kept in a desiccator.

3.0 Results and Discussion

3.1 Proximate Composition of *Uziza* Seed Flour (*Piper guineense*)

The results of proximate composition showed that there were significant differences ($p<0.05$) in the ash, crude fibre, protein, carbohydrate, moisture and fat contents of the flours are shown in Table 1.

The moisture content of the *Uziza* seed flour varied significantly ($p<0.05$) from 7.79 to 11.06 %. The sample 00B2 (150°C, 5 mins Toasting) exhibited the highest moisture content (11.06%), while the sample 00A2 (220°C, 15 mins Roasting) had the least (7.39%). There was significant difference ($p<0.05$) in the moisture content of the *Uziza* seed flour. Due to the fact that the products were all formulated with heat treatment at different times, all the samples had moisture content below 13%, which was within the standards for dry food samples according to Obadina *et al.* (2014). The moisture content of any food is an index of its water activity (Steel and Torrie, 2012). It is also used as a measure of stability and susceptibility to microbial contamination (Frazier and Westhoff, 2013).

The protein content of the *Uziza* seed flour ranged from 6.45 to 7.97 %. Sample 00B2 (150°C, 5 mins Toasting) had the highest value (7.97%), whereas sample 00A2 (220°C, 15 mins Roasting) recorded the least value (6.45%). There was significant difference ($p<0.05$) in the protein content of the *Uziza* seed flour. According to Asaolu *et al.* (2012), a diet is nutritionally satisfactorily if it contains a high calorie value and a

sufficient amount of protein. When compared with the value of 7.82 % reported by Ojinnaka *et al.* (2016), the control sample, an observed decrease in protein content at increasing roasting and toasting (temperature and time) could be attributed to denaturation of protein as a result of the heat applied and polymerization of amino acid during the processing operation. Similar findings were observed by Santos *et al.* (2018) that protein content of roasted *Uziza* (*Piper guineense*) seed flour decreased as roasting conditions increases.

The fat content ranged from 3.01 to 4.05 %. There were significant differences ($p<0.05$) between the samples. The sample 00A2 showed the highest amount at 4.05%, while sample 00A1 had the least value at 3.01%. When compared with the value of 3.16% reported by Ojinnaka *et al.* (2016), the fat content was within the same range, although with an increased fat content shown by the sample roasted 220˚C for 15 mins. The fat content of the seed flour obtained in this study suggests that the *Uziza* seed flour could be a good source of energy, enhanced taste and acceptability. Fat is an important nutrient in diet due to its ability to store and promote the absorption of fat-soluble vitamins in the body (Reddy and Jialal, 2022).

The fibre content varied, ranging from 2.11 to 2.85%. There was a slight significant difference in the samples, as sample 00B2 had the least value of 2.11% while sample 00A4 had the highest value of 2.85 %. It was observed that the fibre content increased as the temperature and time increased. The high fibre content observed could help improve the nutritional profile of the tested seed sample. High fibre content in the diet could help improve digestion of food, control serum lipids and glycemic index, thereby reducing the risk associated with high cholesterol and chronic heart diseases (Chen *et al.,* 2020). The result obtained support the observation of Ahmed *et al.* (2020) who reported an increase in the crude fibre content in roasted Sesame seed flour.

Ash content varied from 4.13 to 5.76 %. There were significant differences in the samples ($p<0.05$). Sample 00B2 had the highest level at 5.76%, while sample 00A2 reported the lowest at 4.13%. Obatolu *et al.* (2007) had similarly reported an increased ash content in flour from roasted yam bean. The observed increase in ash content could be attributed to decomposition of organic matter due to elevated temperatures thus concentrations of the inorganic contents of the sample and these samples had high ash content which indicates that they will have a high mineral content.

The carbohydrate content ranges from 69.39 to 75.25 %. There were significant differences in the samples as sample 00A2 had the highest percentage at 75.25 % and sample 00B2, which had the lowest value at 69.39%. It was observed that the carbohydrate content of the *Uziza* seed flour increased as the temperature and time increased. These findings are in agreement with Ogechukwu and Ikechukwu (2017) for roasted *Uziza* (*Piper guineense)* increased the extractability of the carbohydrates.

Table 1: Proximate analysis of *Uziza* seed flour (*Piper guineense*)

Sample Code	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
00A1	$8.43^{c}\pm0.47$	$6.74^{c}\pm0.02$	$3.01^{d}\pm0.01$	$2.46^{c}\pm0.06$	$4.48^{c}\pm0.49$	$74.47^{ab}\pm0.80$
00B2	$11.06^{a}\pm0.06$	$7.97^{a}\pm0.11$	$3.73^{ab}\pm0.04$	$2.11^{d}\pm0.01$	$5.76^{a}\pm0.05$	$69.39^{d}\pm0.18$
00B3	$9.17^{b}\pm0.15$	$6.70^{d}\pm0.02$	$3.16^{c}\pm0.02$	$2.46^{c}\pm0.04$	$4.76^{b}\pm0.04$	$73.48^{ab}\pm0.26$
00A3	$10.77^{ab}\pm0.64$	$7.64^{b}\pm0.03$	$3.43^{b}\pm0.04$	$2.61^{b}\pm0.02$	$5.00^{ab}\pm0.03$	$70.97^{b}\pm0.11$
00A4	$10.16^{ab}\pm0.21$	$7.64^{b}\pm0.03$	$3.70^{ab}\pm0.03$	$2.85^{a}\pm0.05$	$5.12^{ab}\pm0.02$	$70.31^{c}\pm0.37$
00A2	$7.39^{d}\pm0.41$	$6.45^{e}\pm0.03$	$4.05^{a}\pm0.05$	$2.74^{ab}\pm0.02$	$4.13^{d}\pm0.04$	$75.25^{a}\pm0.55$

Values are means± S.D of triplicate results (n=3). Values with different letters in the same column are significantly different ($p<0.05$).

Key: 00A1 is 200°C and 10 mins toasting, 00B2 is 150°C and 5 mins toasting, 00B3 is 200°C and 5 mins toasting,00A3 is 180°C and 15 mins roasting, 00A4 is 180°C and 10 mins roasting and 00A2 is 220°C and 15 mins roasting.

4.0 Conclusion

The results of the study on the proximate, properties of *Uziza* seed flour (*Piper guineense*) indicate that different processing methods (toasting and roasting at varying temperatures and times) significantly influence the nutritional and functional quality of the flour. Proximate analysis revealed notable differences in the moisture, protein, fat, fibre, ash, and carbohydrate contents. Toasting at 150°C for 5 minutes (Sample 00B2) had the highest protein (7.97%) and ash content (5.76%), while roasting at 220°C for 15 minutes (Sample 00A2) led to the highest carbohydrate content (75.25%) and fat content (4.05%). Furthermore, the processing conditions play a crucial role in determining the optimal nutritional potential guiding it's use in food industries.

References

Ahmed, I. A. M., Al Juhaimi, F. Y., Osman, M. A., Al Maiman, S. A., Hassan, A. B., Alqah, H. A. and Ghafoor, K. (2020). Effect of oven roasting treatment on the antioxidant activity, phenolic compounds, fatty acids, minerals, and protein profile of sesame (Mesembryanthemum forsskalei hochst) seeds. *Journal of Food Science and Technology* 13(1): 109-825.

Anyanwu, C. and Nwosu, G. (2014). Assessment of the antimicrobial activity of aqueous and ethanolic extracts of *Piper guineense* leaves. *Journal of Medicinal Plants Research* 8(9): 436–440.

Asaolu, S. S., Adefemi, O. S., Oyakhilome, I. G. and Ajibulu, K. E. (2012). Proximate and mineral composite of Nigeria leafy vegetables. *Journal of Food Research* 1(3): 214-218.

Besong, S. A., Umeh, S. and Eze, V. (2016). The botanical properties and uses of *Piper guineensis*. *Plant Research Journal* 12(4): 231-244.

Chen, Y., Lin, H., Lin, M., Zheng, Y. and Chen, J. (2020). Effect of roasting and in vitro digestion on phenolic profiles and antioxidant activity of water-soluble extracts from sesame. *Food Chemistry and Toxicology* 1(1): 12-39.

Chima, S. (2016). Historically studies the utilization of *Uziza* in traditional medicine to treat a variety of ailments. *Indian Journal of Pharmacology* 7: 30-32.

Chinonso, E. (2008). Herbal remedies and traditional medicine: An overview. *African Journal* of *Traditional Medicine* 5(2): 98-110.

Dibulo, P. (2016). Known for the use of herbs to cure sicknesses. *Journal of Medical Research* 8(10): 337-439.

Dibulo, P., Okeke, T. and Okechukwu, M. (2017). Therapeutic potential of Piper guineensis. *International Journal of Medicinal Plants* 10(1): 50-59.

Frazier, W. C. and Westhoff, D. C. (2013). *Food Microbiology* (3rd ed.). McGraw-Hill Book Company, New York, 293-303.

Harbone, I. B. (2018). The medicinal properties of *Uziza*. *Journal of Herbal Medicine* 34(3): 202-213.

Nwosu, J.O. (2014). Research on the impact of processing methods on the properties of *Uziza* seed flour being limited. *European Journal of Medicinal Plants* 7: 34-39.

Obadina, A. O. Babatunde, B. O. and Olotu I. (2014). Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. *Journal of Food Science and Nutrition* 2(6): 676-681.

Obatolu, V. A. Fasoyiro, S. B. and Ogunsunmi, L. (2007). Processing and functional properties of yam beans *(Sphenostylis stenocarpa). Journal of Food Process and Preservation* 31(2): 240-249.

Ogbonna, C. C., Okafor, C. E. and Adeyemi, T. O. (2015). Studies on the climbing vine that grows up to 20 meters and bears peppery berry fruits. *International Journal of Pharmacy and Pharmaceutical Research 6*(1), 368-384.

Ogechukwu, I. and Ikechukwu, C. (2017). Observed that roasted *Uziza* increased the extractability of carbohydrates. *Innovative Food Science Emerging Technology* 3 (1): 399-406.

Ojinnaka, C. M., Ajienka, J. A., Abayeh, O. J. (2016) Formulation of Best-Fit Hydrophile/Lipophile Balance-Dielectric Permittivity Demulsifiers for Treatment of Crude Oil Emulsions. *Egyptian Journal of Petroleum* 25: 565-574.

Reddy, P. and Jialal, I. (2022). Biochemistry, fat-soluble vitamins. In *StatPearls (Internet)*. StatPearls Publishing. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK53 4869/?utm source= chatgpt.com. Accessed, 25 February, 2025

Santos, R. M., Okafor, J. C., and Adeyemi, T. O. (2018). Observed that the protein content of *Uziza* flour decreased as roasting conditions increased. *Global Journal of Pure and Applied Sciences* 6: 321-324.

Steel, R. G. D. and Torrie, J. H. (2012). *Principles and procedures of statistics: A biometrical approach* (2nd ed.). McGraw-Hill.

Proximate Composition and Sensory Qualities of Weaning Foods Produced from Blends of Rice (Mas 2401) and Soybean

Nwakunite L. C.[1], *Oyarebu A. O.[2], Ezeh M. C.[1], Udoh O. B[1]. and Ezeasor, Q. U[2].
[1]Department of Food Technology, Federal Polytechnic, Oko, Anambra State. [2]Technical Division, National Board for Technology Incubation, Technology Incubation Centre, Nnewi

*Corresponding Author's email: ahmedoyarebu@gmail.com

ABSTRACT

The purpose of this study was to determine the proximate composition and sensory qualities of weaning foods produced from blends of local rice and soybean flours. Flours were produced from fermented local grains and toasted soybean seeds. Weaning foods were formulated by mixing rice flour and soybeans flour, in the ratios of 60:40 (M11), 70:30 (M22), 80:20 (M33), 50:50 (M44) and 100:0 (M55). The proximate compositions of the samples were determined using standard analytical methods while a 9-point Hedonic scale was used to evaluate their sensory qualities. The values obtained for proximate composition ranged from 10.70% in 60:40 to 14.80% in 100:0 for moisture, 3.96% in 60:40 and 70:30 to 6.90 in 50:50 for protein, 16.00% in 60:40 to 22.00% in 100:0 for ash, 1.89% in 50:50 to 2.88% in 60:40 for crude fibre, 11.00% in 100:0 to 17.00% in 50:50 for crude fat and 43.51% in 100:0 to 49.96% to 60:40 for carbohydrate. The sensory evaluation results showed no significant difference ($p > 0.05$) in the colour of the samples. However, all other quality attributes varied significantly ($p < 0.05$). The overall acceptability scores of the samples were 7.40 (60:40), 6.58 (70:30), 7.32 (80:20), 7.94 (50:50) and 6.56 (100:0). In conclusion, locally sourced rice (MAS 2401) and soybean could be an alternative for production of weaning food.

Keywords: Weaning foods, Rice, Soybean, Proximate, complementary food.

1.0 Introduction

Weaning foods also known as infant foods or complementary foods are nutrient dense foods or liquids other than breast milk which are given to young children during the period of complementary feeding usually between 6 to 24 months after birth (Folorunso *et al.,* 2018; Ijarotimi *et al.,* 2022). They are mostly produced from plant products which include cereals, roots and tubers, legumes and several others. It can be made by using one or a combination of more than one plant product. It comes in different forms (such as porridge and pap) depending on the location, culture and the staple foods that are available (Bolarinwa *et al.,* 2016; Ujioghene *et al.,* 2021). According to Ojinnaka *et al.* (2013), most of the weaning foods made in Nigeria especially pap, are cereal based. They are usually produced with maize, millet or sorghum, however, the use of rice which is also a cereal in production of weaning food is not very common in Nigeria.

Rice (*Oryza sativa* L.) is an essential global food. As a staple food for more than half of the world's population, rice has been relied on as one of the major sources of calorie (Ronie and Hasmadi*.,* 2022). Rice is grown initially to be consumed as a boiled rice grain but the utilization of rice flour as an ingredient in food preparation is becoming very common (Chusak and Adisakwattana, 2020). Rice grain is a major source of carbohydrates, protein, and other essential nutrients for billions of people globally, especially in developing countries (Saleh *et al*., 2019). Also, rice contains a small amount of fat and is a good source of thiamine, riboflavin, niacin and dietary fibre (Cherie and Dagnaw, 2019). Rice has not been considered a reasonable source of minerals; however, appreciable levels of calcium, magnesium and phosphorus are present along with some traces of iron, copper, zinc and manganese (Zhang *et al*., 2014). High levels of bioactive compounds such as phenolic acids, flavonoids, tocopherol, aminobutyric acid (GABA) and tocotrienol have been reported in rice (Gong *et al*., 2017; Pang *et al*., 2018). Nonetheless, rice

has various types with diverse qualities. According to Custodio *et al.* (2019), the perception of rice quality varies among regions, countries, and urbanization levels. Although rice is cultivated in Nigeria, the country still depends on foreign brands to meet the demand (Babatunde, 2022). Locally milled or processed rice in Nigeria is commonly brownish in colour and unpolished because of the partial milling activities. They are also associated with colour variation, having a mixture of different varieties in a pack and containing stones, as reported by (Osaretin *et al.*, 2017).

Soybean *(Glycine max)* is one of the most valuable crops in the world belonging to the family leguminosae (Otegbayo *et al.,* 2018). The seeds contain about 40% protein with a beneficial amino acid composition and about 20% fat, half of which is unsaturated fatty acids that lower blood cholesterol levels (Staniak *et al.,* 2021). Soybean is rich in iron, calcium, some B vitamins and antioxidants (Ochelle *et al.,* 2019). They are therefore a valuable raw material for the food (oil) and feed (extracted meal) industries. Soybean covers about 29% of the world supply of consumer vegetable oil. In many countries, soybeans are used as a meat substitute, because soy protein contains a set of amino acids in proportions similar to the reference protein (chicken egg). Soybean is also used in the pharmaceutical and chemical industries in formulation of health-promoting products (Ghani *et al.,* 2016, Otegbayo *et al.,* 2018; Staniak *et al.,* 2021). Its use in formulation of complementary food has been reported by many researchers (Ojinnaka *et al.,* 2013; Folorunso *et al.,* 2018).

2.0 Materials and Methods

2.1 Source of Raw Material

Two kilograms each of local rice grains and soybean seeds, sugar and packaging materials were purchased from Eke Oko Main Market in Orumba North Local Government Area of Anambra State All the raw materials were packaged in a clean bag and taken to the Food Processing Laboratory of Department of Food Technology, Federal Polytechnic Oko, Anambra State, Nigeria; for further processing.

2.2 Sample Preparation

2.2.1 Processing of Fermented Rice Flour

Fermented rice flour was produced following the methods described for fermented maize in the study of Folorunso *et al.* (2018) with slight modification. Two kilograms of local rice grains were cleaned by hand picking to remove dirt, stones and unwanted materials. It was steeped in clean water for 48 h in a plastic container with covers. The water was decanted after 48 h and the rice washed 3 times in water to reduce fermenting odour after which it was wet-milled using an attrition mill. The milled slurry was sieved using muslin cloth, which separates the pomace from the filtrate. The filtrate was allowed to settle after which the clear filtrate was decanted while the residue was bagged to further remove any remaining water. The residue which is the pap was dried for 48 hours in a cabinet drier at 50°C. The dry fermented rice powder was packaged in an airtight container prior to further use.

2.2.2 Processing of Soybean Flour

The method of Ojinnaka *et al.* (2013) was used in the production of soybean flour with slight modification by toasting the soybean before milling. The soybean seeds were sorted and unwanted materials were removed. The clean seeds were washed in water and soaked overnight and the water drained. The soybean was cooked in water twice its volume for 30 min. The cooked soybean seeds were dehulled, dried, winnowed, toasted, milled and sieved to obtain soybean flour.

2.2.3 Formulation of Weaning Food Blends

Weaning food was formulated by blending fermented local rice and soybean powders in the ratios, M44= 50:50, M11= 60:40, M22= 70:30, M33= 80:20, M55= 100:0. The local rice and soybean were properly mixed and packaged in airtight plastic containers until needed for analysis.

2.3 Determination of the Proximate Composition of the Weaning Foods

The proximate composition of the weaning food samples was determined using standard methods of AOAC (2012).

2.3.1 Sensory Evaluation

This sensory evaluation was performed using the method of Iwe (2014). A panel of 10 students (male and female) of Federal Polytechnic, Oko, Anambra State was used for the sensory evaluation of the complementary food. The different blends of the product were evaluated by panelists after they were reconstituted with hot water for colour, taste, mouthfeel, consistency, flavour and overall acceptability. The scoring was based on a 9-Point Hedonic Scale ranging from 1 (extremely dislike) to 9 (extremely like) and 5 (neither like nor dislike). The samples were presented in identical containers coded with 3digit random figures with each sample having a different figure. The samples were presented all at once and water was given to each panelist for rinsing of mouth.

2.3.2 Statistical Analysis

All measurements were carried out in triplicates. The data generated were analyzed using statistical program SPSS (version 25.0) and significant difference were compared by Analysis of Variance test (ANOVA) following Duncan's multiple range tests at the significance level of 5%.

3.0 Results and Discussion

3.1 Results

Table 2: Proximate composition (%) of weaning food produced from blends of local rice and soybeans flours

Samples	Moisture	Protein	Ash	Fibre	Fat	Carbohydrate
M11	$10.70^{e}\pm0.11$	$3.96^{d}\pm0.01$	$16.00^{d}\pm0.00$	$2.88^{a}\pm0.06$	$16.50^{b}\pm0.04$	$49.96^{a}\pm0.02$
M22	$13.71^{b}\pm0.01$	$3.96^{d}\pm0.00$	$21.00^{b}\pm0.00$	$2.45^{b}\pm0.01$	$13.50^{c}\pm0.02$	$45.38^{c}\pm0.04$
M33	$12.80^{c}\pm0.02$	$5.94^{c}\pm0.02$	$21.00^{b}\pm0.00$	$2.29^{c}\pm0.12$	$11.50^{d}\pm0.11$	$46.47^{b}\pm0.01$
M44	$11.50^{d}\pm0.10$	$6.90^{a}\pm0.01$	$17.00^{c}\pm0.01$	$1.89^{d}\pm0.07$	$17.00^{a}\pm0.00$	$45.71^{c}\pm0.11$
M55	$14.80^{a}\pm0.03$	$6.17^{b}\pm0.14$	$22.00^{a}\pm0.00$	$2.52^{a}\pm0.11$	$11.00^{e}\pm0.01$	$43.51^{d}\pm0.01$

*Values are means ± standard deviations of triplicate determinations. Means with the same superscript in the same column are not significantly different at $p< 0.05$.

Table 3: Sensory qualities of weaning foods from blends of local rice and soybean flours

Sample	Colour	Taste	Consistency	Flavour	Mouthfeel	Overall Acceptability
M11	$7.50^{a}\pm1.08$	$7.30^{ab}\pm0.95$	$7.30^{a}\pm0.82$	$7.50^{ab}\pm1.27$	$7.40^{ab}\pm1.26$	$7.40^{ab}\pm0.84$
M22	$6.60^{a}\pm1.26$	$6.60^{bc}\pm1.43$	$6.90^{ab}\pm0.99$	$6.30^{b}\pm1.16$	$6.50^{b}\pm1.43$	$6.58^{b}\pm0.91$
M33	$7.40^{a}\pm1.07$	$7.50^{ab}\pm1.08$	$7.70^{a}\pm1.25$	$7.00^{ab}\pm1.15$	$7.50^{ab}\pm0.85$	$7.32^{ab}\pm0.87$
M44	$7.90^{a}\pm0.88$	$8.10^{a}\pm0.74$	$7.80^{a}\pm0.92$	$8.00^{a}\pm0.82$	$7.90^{a}\pm1.20$	$7.94^{a}\pm0.74$
M55	$7.10^{a}\pm2.08$	$6.20^{b}\pm1.40$	$6.50^{b}\pm0.97$	$6.60^{b}\pm1.65$	$6.40^{b}\pm1.90$	$6.56^{b}\pm1.21$

*Values are means ± standard deviation of ten observations. Means on the same column with different superscripts are significantly different ($p<0.05$).

3.2 Discussion

3.2.1 Proximate Composition of from Blends of Local Rice and Soybean Flours

Table 2 showed the results of the proximate composition of the weaning foods produced from local rice and soybean flour blends. The percentage moisture composition of the samples ranged from 10.70 – 14.80%. Sample M55 (Rice 100%: Soybean 0%) recorded the highest moisture content while sample M11 (Rice 60: Soybean 40%) recorded the lowest moisture content. There was significant difference ($p < 0.05$) in the moisture contents of the samples. This is an indication that inclusion of soybean flour in the formulation significantly reduced their moisture content although no definite trend was observed. The percentage moisture obtained in this study is higher compared to 6.30 – 9.01% reported by Adebayo-Oyetoro *et al.* (2012) and similar to 1.49 – 3.80% reported by Uche *et al.* (2020) for weaning foods produced from different plant materials. The variations in the results could be as results of different raw materials used as well as their varied processing methods. According to Adebayo-Oyetoro *et al.* (2012), weaning food should have a maximum moisture content of 10% in order to be shelf stable. The values obtained in the present study were slightly higher than this probably because of the processing and drying methods adopted. This suggests that the weaning foods may not be stored for an extended period of time, which could have a negative impact on quality (Adebayo-Oyetoro *et al.*, 2017).

The protein content of the formulated weaning foods ranged from 3.96 to 6.90% with sample M44 (Rice 50%: Soybean 50%) having the highest value and samples M11 and M22 having the lowest value. There was no significant difference ($p > 0.05$) in the protein content of samples M11 (Rice 60: Soybean 40%) and M22 (Rice 70: Soybean 30%) but they differed significantly ($p < 0.05$) from those of the other samples. There were little observable effects of inclusion of both soybean flour on the protein content of the weaning food. This observation is contrary to the findings of Okoye and Ene (2018) as well as the findings of Adegbusi *et al.* (2022) who noted that incorporation of legume flour and crayfish in complementary food drastically improved the protein content of the products. The incorporation of soybean flour which is a leguminous seed with 37.59% protein (Toomer *et al.,* 2023) was expected to improve the protein content of the complementary foods, however, the reason for the low protein content obtained in study could not be explain but may probably be due to variations in the species of the raw materials as well as influence of processing methods used.

There was no significant difference ($p > 0.05$) in the ash content of samples M22 (Rice 70%: Soybean 30%) and M33 (Rice 80%: Soybean 20%) which recorded a value of 21.00%. However, the ash content of the other samples varied significantly ($p < 0.05$) and their values were 16.00%, 17.00% and 22.00% for samples M11 (Rice 60: Soybean 40%), M44 (Rice 50%: Soybean 50%) and M55 (Rice 100%: Soybean 0%) respectively. It was observed that inclusion of soybean flour in the formulation decreased the ash content of the samples. Ash content in food materials is a valuable indicator of the presence of inorganic elements within the food, primarily in the form of minerals. Therefore, comprehending and measuring ash content is crucial for assessing various food products' mineral content and nutritional value, enabling consumers and food manufacturers to make informed decisions and formulate well-balanced diets (Jenfa *et al.,* 2024). The high ash content obtained in this study suggests that the formulated weaning foods could be very rich in different mineral elements needed for proper growth and development of infants. The values for ash obtained in the present study were higher than 0.56 – 2.00% and 1.74 – 4.59% reported by Barber *et al.* (2017) and Ijeomah *et al.* (2023) respectively for complementary foods formulated from different materials. The varied results may be attributed to the differences in the composition of raw materials used.

The crude fibre content of the weaning food samples ranged from 1.89 - 2.88%. Sample M11 (Rice 60: Soybean 40%) recorded the highest crude fibre content (2.88%) and is significantly different ($p < 0.05$) from the other samples. The fibre content obtained in this study were lower compared to 6.59 – 19.77% reported by Adegbusi *et al.* (2022) for weaning food produced from blends of maize, soybean and cowpea flours. Variation in the composition raw materials used as well as processing methods adopted could be the reason for contradicting results obtained. Crude fibre content is a measurement of the overall natural fibre content within a food material (Jenfa *et al.,* 2024). The presence of high fibre in food products is essential owing to its ability to facilitate bowel movement (peristalsis) bulk addition to food and prevention of many

gastrointestinal diseases in man (Sharma *et al.,* 2011). The fibre content of the five formulations is desirable because the fibre content of the complementary blends was less than 3%, which would be suitable in the cereals of growing infants (Folorunso *et al.,* 2018). Increased fibre content of the complementary food blends has several health benefits, as it aids digestion in the colon and reduces constipation often associated with products from refined grain flours (Shah *et al.,* 2016).

There was significant difference ($p < 0.05$) in the crude fat content of the samples which ranged from 11.00% in sample M55 (Rice 100%: Soybean 0%) and 17.00% in sample M44 (Rice 50%: Soybean 50%). High fat content was recorded for sample M44 (Rice 50%: Soybean 50%) due to the high proportion of soybeans in the blend. Soybean is an oil seed, which has been reported to be a leading source of edible oils and fats (Toomer *et al.,* 2023). Fat is a rich source of energy and is essential as carriers of fat-soluble vitamins; A, D, E and K. However, high levels of fat in food products should be ≤25%, since a higher value could lead to rancidity in foods and development of unpleasant compounds (Folorunso *et al.,* 2018).

Carbohydrate content of the weaning foods ranged from 43.51% in sample M55 (Rice 100%: Soybean 0%) to 49.96% in sample M11 (Rice 60: Soybean 40%). There was significant difference ($p < 0.05$) in the carbohydrate content of the samples. The values obtained in this study fell within the range (41.71 – 77.30%) reported by Folorunso *et al.* (2018) for maize based complementary food enriched with soybean flour. Okoye and Ene (2018) however, reported higher carbohydrate content ranging from 65.34 – 78.08%. The variations could be due to differences in the raw materials used.

3.2.2 Sensory Qualities of Weaning Foods from Blends of Local Rice and Soybean Flours

The sensory qualities of the weaning foods produced from local rice and soybean flour are presented in Table 3. The mean score for the colour of the formulated complementary foods ranged from 6.60 – 7.90 with sample M44 (Rice 50%: Soybean 50%) having the highest score while sample M22 (Rice 70: Soybean 30%) had the least score. There were no significant differences ($p > 0.05$) amongst the samples in terms of colour. This indicated that the blending ratios did not affect the colour of the product. This is in agreement with the findings of Folorunso *et al.* (2018) who made similar observation for weaning foods produced from blends of maize and soybean.

The mean scores for the taste of the formulated weaning foods ranged from 6.20 in sample M55 (Rice 100%: Soybean 0%) to 8.10 in sample M44 (Rice 50%: Soybean 50%). There was no significant difference ($p > 0.05$) in the taste of the samples. The results in Table 4.3 showed that inclusion of up to 50% of soybean and tiger nut in the local based weaning food significantly increased its acceptability in terms of taste.

The mean scores for consistency ranged from 6.50 in sample M55 (Rice 100%: Soybean 0%) to 7.80 in sample M44 (Rice 50%: Soybean 50%). Consistency is the quality attribute used to determine how viscous a complementary food is after it is prepared with hot water (Sogo-Temi *et al.,* 2023). There was significant difference ($p < 0.05$) in the consistency of the formulated weaning foods. This implies that the blending ratios of the raw materials affected the consistency of the product.

Flavour is an integral part of taste and general acceptance of drinks before it is put in the mouth. It is therefore an important parameter when testing acceptability of complementary foods blends (Folorunso *et al.,* 2018). Results of sensory evaluation indicated that the flavour of the formulated weaning foods varied significantly ($p < 0.05$). Their mean scores ranged from 6.30 in sample M22 (Rice 70%: Soybean 30%) to 8.00 in sample M44 (Rice 50%: Soybean 50%). Inclusion of soybean flour improved the flavour of the product.

The mouthfeel is very important in a complementary food as it will determine the amount of food an infant would consume since they can only swallow a smooth gruel not a coarse one (Ojinnaka *et al.,* 2013). The mouthfeel of sample M44 (Rice 50%: Soybean 50%) was the most accepted with a score of 7.90 while that of sample M55 (Rice 100%: Soybean 0%) was the least accepted. There was significant difference ($p < 0.05$) in the mouthfeel of the samples.

The overall acceptability scores of the samples in their ascending order are 6.56, 6.58, 7.32, 7.40 and 7.94 for samples M55(Rice 100%: Soybean 0%), M22 (Rice 70%: Soybean 30%), M33 (Rice 80%: Soybean 20%), M11 (Rice 60%: Soybean 40%) and M44 (Rice 50%: Soybean 50%) respectively. There was significant difference ($p < 0.05$) in the overall acceptability scores of the samples. It can be deduced from Table 3 that all the samples were rated above average indicating that they were all accepted. However, the sample produced from blends 50% local rice flour and 50% of soybean flour was the most accepted in all the attributes evaluated.

4.0 Conclusion and Recommendations

The study proves that local rice and soybean can be used to produce weaning foods of improved nutritional and sensory qualities. The weaning foods were rich in ash, fat and carbohydrate content making the samples a good source of minerals and energy needed for the growth and development of infants. However, the sample produced from blends of 50% local rice flour and 50% soybean flour gave the highest protein content and it was the most accepted in all the sensory attributes evaluated. Mothers can be advised to prepare these kinds of weaning foods hygienically for their weaning babies. However, studies on the mineral and vitamin composition of the weaning foods should further be investigated

References

Adebayo-Oyetoro, A. O., Ogundipe, O. O., Lofinmakin, F. K., Akinwande, F. F., Aina, D. O. and Adeyeye, S. A. (2017). Production and acceptability of chinchin snack made from wheat and tigernut (*Cyperus esculentus*) flour. *Cogent Food and Agriculture*, *3*(1): 182–185.

Adebayo-Oyetoro, A. O.; Olatidoye, O. P.; Ogundipe, O. O.; Akande, E. A. and Isaiah, C. G. (2012). Production and quality evaluation of complementary food formulated from fermented sorghum, walnut and ginger. *Jiurnal of Applied Bioscience,* 54: 3901-3910.

Adegbusi, H. S., Ismail, A., Esa, N. M. and Daud, Z. A. M. (2022). Evaluation of nutritional quality of complementary foods formulated from blends of Nigerian yellow maize (*Zea mays*), soybean (*Glycine max*) and crayfish (*Procambarus clarkii*). *J Sci Food Agric*; 102: 6961–6973

AOAC (2012). Official Methods of Analysis of Association of Official Analytical Chemists: Official Methods of Analysis of AOAC INTERNATIONAL. 19th Ed. AOAC INTERNATIONAL, Gaitherburg. MD, USA, Official Method 2008.01

Folorunso, A. A., Ayetigbo, G. F. and Afolabi, W. A. O. (2018). Evaluation of Nutritional and Sensory Quality of Complementary Food from Selected Spices, Soy and Maize Blends. *European Journal of Nutrition and Food Safety;* 8(4): 291-299.

Ijeomah, O. C., Ukpong, E. S. and Azubuike, C. U. (2023). Chemical Composition of Fonio (*Digitaria-Exilis*)/Ricebean (*Vigna Umbellata*) Based Complementary Food Fortified with Carrot and Crayfish. *International Journal of Agriculture and Biological Sciences*, 28, 47-53

Iwe, M. O. (2014). Current Trends in Sensory Evaluation of Foods. Revised Edition. Rojoint Communication Services Ltd. Uwani Enugu, Nigeria.Pp. 144-145.

Jenfa, M. D., Adelusi, O. A., Aderinoye, A., Coker, O. J., Martins, I. E., and Obadina, O. A. (2024). Physicochemical compositions, nutritional and functional properties, and color qualities of sorghum–orange-fleshed sweet potato composite flour. *Food Science and Nutrition*, *12*, 2364–2378.

Ojinnaka, M. C., Ebinyasi, C. S., Ihemeje, A. and Okorie, S. U. (2013). Nutritional Evaluation of Complementary Food Gruels Formulated from Blends of Soybean Flour and Ginger Modified Cocoyam Starch. A*dvance Journal of Food Science and Technology;* 5(10): 1325-1330.

Okoye, J. I. and Egbujie, A. E. (2018). Nutritional and Sensory Properties of Maize-Based Complementary Foods Fortified with Soybean and Sweet Potato Flours. *Discourse Journal of Agriculture and Food Sciences,* 6(3): 17-24.

Sharma S, Kaur S, Dar BN and Singh B. (2011). Storage stability and quality assessment of processed cereal brans. *Journal of Food Science and Technology*; 51(3):583-588.

Sogo-Temi, C. M., 1Idowu, O. A. and Lateef, A. M. (2023). Nutritional Quality Assessment of Complementary Food from Plantain, Velvet Bean and Cray Fish. *International Journal of Scientific Research and Management,* 11(10), 143-148.

Toomer, O. T., Oviedo, E. O., Ali, M., Patino, D., Joseph, M., Frinsko, M., Vu, T., Maharjan, P., Fallen, B. and Mian, R. (2023). Current Agronomic Practices, Harvest and Post-Harvest Processing of Soybeans (*Glycine max*)-A Review. *Agronomy*, 13, 427.

Uche, O. C. (2020). Physicochemical Characteristics, Anti-nutritional/ Phytochemical Properties of Germinated/Malted Complementary Foods Based on Maize and Pigeon Pea Flour in Eastern Nigeria. Ann Food Process Preserv 4(1): 1026-1030.

Storage Stability of Extruded Foods: A Mini-Review

*Nwadi, O.M.M. and Okonkwo, T.M.

Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria.

*Corresponding author's email: oluchukwu.nwadi@unn.edu.ng

ABSTRACT

The aim of this review was to investigate the storage stability of foods. One major problem faced by food processors is to ensure the stability of foods during storage before it gets to the consumer, often regarded as the ultimate arbiter of food quality through the purchase or non-purchase of the product by the consumer. Storage stability is tested so as to investigate the changes in the quality of a product as time progresses with respect to certain influence such as inherent (intrinsic) or environmental (extrinsic) factors. Packaging material affects storage stability, a good measure is the use of antioxidants or removing oxygen from food stuff during packaging so as to improve storage stability, thereby increasing shelf-life. In order to maintain the crispness and extend shelf-life of extruded snacks, a low moisture content (1.8 - 2.4 %) is desirable, an acceptable limit of 10 % moisture is good for a better stability during storage which is not favourable for microorganisms to thrive. Also, low water activity levels (0.85) reduce potential microbial hazards of these products. The stability of foods during storage is an important parameter in food processing and needs to be properly considered by addressing factors that may influence the foods during storage. The type and nature of a food product determines the factors that may likely affect its storage stability. The maintenance of the storage stability of food is a necessary step in retaining the quality of food thereby preserving the integrity of the food

Keywords: Packaging material, moisture content, extrusion

Introduction

One major challenge faced by food processors is to ensure the stability of foods during storage. The time between food processing and consumption of the product by the consumer is crucial because the food must be wholesome and at the same time retain the desirable characteristics. Storage stability of food means the keeping quality or shelf-life of food over time under specific storage conditions. The shelf-life of a food may be regarded as the period of time the food is safe and suitable for consumption which means the consumer has no reason to consider it unacceptable (Awulachew, 2021). The microbiological quality, physical and chemical properties are usually monitored to ascertain the stability of the food during storage. The term food quality has different meanings to different professionals in the food industry, to chemists, it is synonymous with stability, to the nutritionist, it means nutritional value, while to microbiologists, safety, however, due to consumer perception and acceptability of the food products, the consumer as the end user is regarded as the ultimate arbiter of food quality (Taub and Singh, 1997). There is always a link between food quality and storage stability.

In a review, Boukid *et al.* (2018) reported that enzyme inactivation prolonged storage stability after microwave radiation was used to inactivate lipase in wheat germ by some authors. Sawhney *et al.* (2011) and Correia *et al.* (2017) reported that water activity determines deterioration in food systems and suggested modification in water activity for better storage stability.

The factors affecting storage stability may be inherent (intrinsic: water activity, available oxygen, nutrients, biochemical products (type and amount of enzymes present), moisture content, biological structures, natural microflora and surviving microbial counts, pH (total acidity and type of acid), preservative (such as

sugar and salt), antimicrobial components, nutrient content, oxidation-reduction potential) or environmental (extrinsic: cultural practices in production, time-temperature profile during processing, temperature and relative humidity control during storage and distribution, exposure to light ((UV and IR) during processing, storage and distribution), microbial environment, environment in packaging (composition of atmosphere within packaging), heat treatment (subsequent heat treatment, e.g reheating or cooking before consumption), mechanical handling in distribution, consumer handling) (Singh, 2012; Nemes *et al.*, 2020). The sensory quality of a food product could be assessed through taste and smell. Storage stability of foods may be improved by proper storage conditions and food processing techniques, suitable packaging materials and the use of safe food additives. All the above factors culminate into having a stable product, hence, the need to review the storage stability of foods.

Effect of packaging material on storage stability of foods

Wani and Kumar (2016) reported that packaging material also affects storage stability, the extrudates stored in low density polyethylene pouches may likely store longer than those stored in laminated pouches. A good measure is the use of antioxidants in packaging materials so as to improve storage stability, thereby increasing shelf-life. Storage stability may also be improved by removing oxygen from food stuff during packaging (Bhatia, 2017**;** Brennan, 2006)**.** Ogunmuyiwa *et al.* (2017) reported that the storage stability of wheat flour may be improved by removal of the bran during milling. In table eggs, the thickness of the shell membranes affects the storage stability. Imai *et al.* (1986) reported that shell quail eggs had a superior storage stability compared with chicken egg as a result of the thicker shell membrane of the quail egg. Ottaway (2010) reported that inadequate measures during processing and storage may also significantly affect the vitamin content of processed foods negatively. Some factors that affect vitamin stability include oxygen, light, moisture, heat and pH. Mu *et al.* (2019) reported that during the packaging of carotenoids-rich products such as sweet potato snacks, care must be taken because the carotenoids may be easily degraded by the presence of oxygen in the headspace, transmission of light through the package, permeability of oxygen through the package or even the dissolved oxygen in the product, faults in the herm of the seal of the packaging material, the storage conditions (such as time and temperature). All these factors may also go a long way in affecting the storage stability of the packaged sweet potato snack. The type and nature of a food product determines the factors that may likely affect its storage stability, for example peanut is rich in lipids, therefore, lipid oxidation will be the major cause of shortened shelf-life of peanut and consequent development of off-flavours. Gong *et al.* (2018) reported that some factors which affect the lipid oxidation of roasted peanuts include packaging conditions, vitamin E and storage temperature. Gong *et al.* (2018) also added that peanut butter stability is influenced by some fatty acids such as oleic and linoleic acids and concluded that peanuts with high oleic acid are better for peanut butter manufacture. Ngamwonglumlert and Devahastin (2018) reported that microstructure and composition of dried products affect its storage stability, adding that the more porous a product, the higher the surface exposure, thereby the product is more likely to take up oxygen, moisture and more exposed to light. When the dried product has an amorphous structural arrangement, it is also more likely to easily take up moisture and oxygen. One with crystalline structural arrangement will likely be more stable during storage (Ngamwonglumlert and Devahastin, 2018). The above factors need to be considered in choosing an appropriate packaging material.

Storage stability of extruded food products

During storage of extruded foods, some factors (storage conditions of the product and its initial moisture content) may cause rancidity (Kocherla *et al.*, 2012). Some of these storage conditions may be temperature and relative humidity (Ananingsih *et al.*, 2013). Lee and Lee (2008) suggested that shelf-life may be extended by keeping the moisture content of foods at a level which is not favourable for microorganisms to thrive. Lee and Lee (2008) stated that equilibrium relative humidity is an important parameter in improving the storage stability of foods. Kocherla *et al.* (2012) evaluated the storage stability of extruded snacks by analyzing moisture content of the products stored in different types of packaging material MPET (Metalized Polyethylene Terephthalate) and HDPE (High Density Polyethylene) and reported that MPET had better moisture barrier properties with respect to the moisture content of the extrudates after three months of storage (2.1 - 3.8 and 2.1 - 3.3 % for HDPE and MPET respectively).

Effect of moisture content on storage stability of foods

Kocherla *et al.* (2012) reported that in order to maintain the crispness of extruded snacks, a low moisture content (1.8 - 2.4 %) was desirable. David *et al.* (2015) reported an acceptable limit of 10 % moisture for flour to have a better stability during storage. This is in agreement with the report of Awolu (2018), that for shelf stability purposes, the moisture content should be equal to or below 10 %. Extrusion is basically a low moisture cooking process. As the moisture content increases, the tendency of product expansion decreases (Cheftel *et al.*, 1992). However, there are exceptions for proteins. Singh *et al.* (2007) reported that low temperature and high moisture during extrusion cooking, is most favorable for production of protein products. When extrusion is done at a high moisture content at a very low temperature and very short residence time, there is a higher retention of amino acids.

Kocherla *et al.* (2012) also reported that packaging materials possessing good barrier properties (especially against moisture) or modified atmospheric packaging was important to retain the texture and improve the keeping quality of extruded snacks. Oxidation does not occur during extrusion but flavour deterioration during storage is a serious concern (Fellows, 2017).

Effect of water activity on the storage stability of foods

Low water activity level of extruded products such as within 0.682 - 0.703 may be attributed to low moisture content (Nwadi and Okonkwo, 2021). The water activity of other dry foods such as confectionery foods ranges from 0.20 to 0.80, this makes microbial spoilage difficult (Buerman *et al.*, 2019). The low water activity of products supports the findings on moisture content that the products are dry. Very dry food products are expected to be microbiologically and chemically stable during handling and storage. This is because water requirement for microbiological activities and chemical reactions are expressed in terms of water activity. In the food industry, microbial growth is usually controlled by some parameters (pH, water activity and temperature) but moulds are more versatile than bacteria hence still survive these conditions (Copetti *et al.*, 2025). Foods with a water activity of less than 0.85 are referred to as low water activity foods (Liu *et al.*, 2023). With the low water activity levels, the potential microbial hazards (spoilage and food poisoning) of these products are low because the lowest water activity limit for fungi is put at about 0.85, for growth of most bacteria is put at about 0.94 while the only organisms that can grow below a water activity of 0.85 are yeast and mould (WHO/FAO, 1999). However, if storage abuse occurs and the products absorb moisture, fungi will be more apt to grow on the surface because the surface of the products will be the first to start absorbing water and oxygen is also plentiful at the surface of the products. Products with low water activity are also expected to be resistant to, physicochemical deteriorative reactions because, at these water activity levels, the solid components are more concentrated and viscous, thereby causing resistance to diffusion/mobility of reactants and consequently reducing rate of physicochemical deteriorative changes. Most bacteria and fungi are not capable of growing at a water activity of below 0.85 except for xerophilic fungi which are capable of causing visible spoilage at a water activity of below 0.85 (Buerman *et al.*, 2019).

Conclusion

The maintenance of the storage stability of food is a necessary step in retaining the quality of food thereby preserving the integrity of the food, which will necessitate acceptability by the consumer who is often regarded as the ultimate arbiter of food quality through the purchase or non-purchase of the product.

References

Ananingsih, V.K., Sharma, A., and Zhou, W. (2013). Green tea catechins during food processing and storage: A review on stability and detection. Food Research International 50(2): 469-479.

Awolu, O.O. (2018). Rheological Evaluation of Cocoyam-Bambara Groundnut-Xanthan Gum Composite Flour Obtained from the Optimization of Its Chemical Composition and Functional Properties. Rheology 2(1): 2-9.

Awulachew, M.T. (2021). Understanding to the shelf-life and product stability of foods. Journal of Food Technology and Preservation 5(8): 1-5.

Bhatia, S. C. (2017). Food biotechnology. In Food Biotechnology. CRC Press. https://doi.org/10.1201/9781315156491

Boukid, F., Folloni, S., Ranieri, R., and Vittadini, E. (2018). A compendium of wheat germ: Separation, stabilization and food applications. Trends in Food Science and Technology 78: 120-133.

Brennan, J.G. (2006). Food Processing Handbook. In Food Processing Handbook (1st edition). Wiley-VCH. https://doi.org/10.1002/3527607579

Buerman, E.C., Worobo, R.W. and Padilla-Zakour, O.I. (2019). Thermal Resistance of Xerophilic Fungi in Low-Water-Activity (0.70 to 0.80) Confectionery Model Foods. Journal of Food Protection 82(3): 390-394.

Cheftel, J.C., Kitagawa, M., and Queguiner, C. (1992). New Protein Texturization Processes by Extrusion Cooking at High Moisture Levels. Food Reviews International 8(2): 235-275.

Copetti, M.V., Bernadi, A.O. and Garcia, M.V. (2025). Chapter Ten - Food spoilage fungi: Main agents, sources and strategies for control. In A.S. Sant□ ana (Ed.), Food-Borne and Microorganisms: Spoilage and Pathogens and their Control (Vol. 113, pp. 475-518). Academic Press. https://doi.org/10.1016/bs.afnr.2024.09.011.

Correia, R., Grace, M.H., Esposito, D., and Lila, M.A. (2017). Wild blueberry polyphenol-protein food ingredients produced by three drying methods: Comparative physico-chemical properties, phytochemical content, and stability during storage. Food Chemistry 235: 76-85.

David, O., Arthur, E., Kwadwo, S.O., Badu, E., and Sakyi, P. (2015). Proximate composition and some functional properties of soft wheat flour. International Journal of Innovative Research in Science, Engineering and Technology 4(2): 753-758.

Fellows, P.J. (2017). Extrusion cooking. In Food Processing Technology (pp. 753-780). Elsevier Inc. https://doi.org/10.1016/B978-0-08-100522-4.00017-1

Gong, A. na, Shi, A. min, Liu, H. zhi, Yu, H. wei, Liu, L., Lin, W. jing, and Wang, Q. (2018). Relationship of chemical properties of different peanut varieties to peanut butter storage stability. Journal of Integrative Agriculture 17(5): 1003-1010.

Imai, C., Mowlah, A., and Saito, J. (1986). Storage Stability of Japanese Quail (Coturnix coturnix japonica) Eggs at Room Temperature. Poultry Science 65(3): 474-480.

Kocherla, P., Aparna, K., and Lakshmi, D.N. (2012). Development and evaluation of RTE (Ready to Eat) extruded snack using egg albumin powder and cheese powder. Agricultural Engineering International: CIGR Journal 14(4): 179-187.

Lee, J.H., and Lee, M.J. (2008). Effect of drying method on the moisture sorption isotherms for Inonotus obliquus mushroom. LWT - Food Science and Technology 41(8): 1478-1484.

Liu, Y., Sun, Y., Wang, Y., Zhao, Y., Duan, M., Wang, H., Dai, R., Liu, Y., Li, X. and Jia, F. (2023). Inactivation mechanisms of atmospheric pressure plasma jet on Bacillus cereus spores and its application on low-water activity foods. Food Research International 169: 112867.

Mu, T.-H., Sun, H.-N., and Ma, M.-M. (2019). Sweet potato snack foods. In Sweet Potato: Chemistry, Processing and Nutrition. Elsevier Inc. https://doi.org/10.1016/b978-0-12-813637-9.00011-9.

Nemes, S.A., Szabo, K. and Vodnar, D.C. (2020). Applicability of Agro-Industrial By-Products in Intelligent Food Packaging. MDPI Coatings 10(6): 1-25.

Ngamwonglumlert, L., and Devahastin, S. (2018). Microstructure and its relationship with quality and storage stability of dried foods. In S. Devahastin (Ed.), Food Microstructure and Its Relationship with Quality and Stability (pp. 139-159). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-08-100764-8.00008-3

Nwadi, O.M.M., and Okonkwo, T.M. (2021). Production, evaluation of quality characteristics and storage stability of extruded snacks from blends of whole wheat flour and chicken egg. https://doi.org/10.13140/RG.2.2.23390.36163

Ogunmuyiwa, O.H., Adebowale, A.A., Sobukola, O.P., Onabanjo, O. O., Obadina, A. O., Adegunwa, M. O., Kajihausa, O.E., Sanni, L.O., and Keith, T. (2017). Production and quality evaluation of extruded snack from blends of bambara groundnut flour, cassava starch, and corn bran flour. Journal of Food Processing and Preservation 41(5): 1-7.

Ottaway, P.B. (2010). Stability of vitamins during food processing and storage. In L.H. Skibsted, J. Risbo, A and M.L. Andersen (Eds.), Chemical Deterioration and Physical Instability of Food and Beverages (pp. 539-560). Woodhead Publishing. https://doi.org/https://doi.org/10.1533/9781845699260.3.539

Sawhney, I.K., Sarkar, B.C., and Patil, G.R. (2011). Moisture sorption characteristics of dried acid casein from buffalo skim milk. LWT - Food Science and Technology 44(2): 502-510.

Singh, R.P. (2012). Shelf Life of Foods (Including Food Losses) Copyright R. Paul Singh, Distinguished Professor of Food Engineering Department of Biological and Agricultural Engineering Department of Food Science and Technology University of California. pp. 1-8. https://iufost.org/iufostftp/Module1_Chapter1_Shelf_Life_of_Foods.pdf

Singh, S., Wakeling, L., and Gamlath, S. (2007). Retention of essential amino acids during extrusion of protein and reducing sugars. Journal of Agricultural and Food Chemistry 55(21): 8779-8786.

Taub, I.A., and Singh, R.P. (1997). Food Storage Stability. In Food Storage Stability. CRC Press. https://doi.org/10.1201/9781420048988

Wani, S.A., and Kumar, P. (2016). Moisture sorption isotherms and evaluation of quality changes in extruded snacks during storage. LWT - Food Science and Technology 74: 448-455.

WHO/FAO. (1999). Report of the thirtieth session of the CODEX committee on food hygiene (Issue July). https://www.fao.org/4/ac334e/ac334e02.htm

Development of probiotic yoghurt analogue using tiger nut and malted sorghum milk blends

*Uwandu, A.C[1] and Okoli, E.C [2]

[1] Department of Human Nutrition and Dietetics, Alex Ekwueme Federal University Ndufu-Alike Ikwo, Ebonyi State, Nigeria. [2] Department of Food Science and Technology, Ebonyi State University, Abakaliki, Nigeria.

*Corresponding Author Email: amarachisom2@gmail.com

ABSTRACT

This study investigated the proximate composition, physico-chemical properties and the sensory quality of probiotic yoghurt analogues made from blends of tiger nut milk (TNM) and malted sorghum milk (MSM) in the ratio of 0:100, 75:25, 50:50, 25:75 and 100:0 of tiger nut milk and malted sorghum milk respectively. A commercial brand whole milk (CBWM) was used as control. The proximate composition, physico-chemical properties and sensory evaluation were determined using standard methods. The moisture, ash, fat, protein, carbohydrate and caloric content ranged from 76.50 - 87.00%, 0.75 - 1.09%, 2.00 - 12.50%, 3.30 - 10.20%, 3.93 - 7.55% and 68.88 -152.14kcal/100g respectively. The pH, total tritratable acidity (TTA), total soluble solids (TSS), total solids (TS), and viscosity ranged from 4.00 - 4.50, 0.96 - 1.14%, 5.25 - 6.50 ^{0}Brix, 13.00 - 23.50% and 8.00 - 8.60 Pa/sec respectively. Sensory evaluation for appearance, flavour, sourness, consistency and general acceptability ranged from 5.00 - 7.70, 4.40 - 6.35, 5.15 - 6.15, 3.90 - 7.40 and 4.75 - 7.35 respectively and no significant differences existed among the sample blends in respect to the sensory attributes except for general acceptability. Among the sample blends, sample 75TNM:25MSM had good proximate, physicochemical and sensory quality suggesting the potentials of using the blends for production of a yoghurt analogue.

Keywords: yoghurt, milk, tiger nut, malting, sorghum.

1.0 Introduction

The increasing demand from consumers for dairy products with functional properties is a key factor driving value sales growth in developed markets. This has led to the promotion of added-value products such as probiotic and other functional yoghurts, reduced fat and enriched milk products and fermented dairy drinks as well as organic cheese (Esene, 2023). Yoghurt is the most popular type of fermented milk product globally that helps lactose-intolerant individuals and also contains probiotics beneficial for gut health (Anagboso *et al*., 2024).

Plant-based analogues of animal-derived foods certainly have marked a new trend in food production (Ishaq *et al*., 2022). Currently, the production, distribution, sales and consumption of plant-based analogues are on the increase due to consumers' awareness. This has led researchers to explore several strategies to develop alternative milk, cheese, meat and egg products from various plant-based sources (Daszkiewicz *et al.* 2024).

In Nigeria, attention has not been paid to the use of our locally available tiger nut (*Cyperus esculentus*) though Tiger-nuts has been recognized for its health benefits as they are high in crude lipid, fibre, protein, natural sugars and carbohydrate content. It is also rich in minerals such as phosphorous and potassium as well as antioxidants like vitamins E and C with a fairly good essential amino acids composition. According to Nwaoguikpe, (2010), the lysine content was found to be 4.16mg and 4.78mg for wet and dry samples of tiger nut.

Sorghum (*Sorghum bicolor*) is considered to be one of the most important cereal grains primarily used for human consumption. Zorica *et al.* (2022) reported that glutamic acid and proline are typically the most abundant amino acids in cereals. Malting is the control germination of seed, during the process of which hydrolytic enzymes and soluble materials (sugars, amino acids etc) are developed within the grain and the tissue structure modified in such a way that the grain becomes friable and easily crushed (Okoli, 2003). According to Feyera (2021) malting improve the nutritional value of sorghum. Malted sorghum has been extensively incorporated in beverage production, breakfast cereals, infant foods, sugar colorings, and coffee substitutes (Mohamed *et al.*, 2025).

Thus, tiger-nut with its inherent nutritional and therapeutic properties could serve as a good alternative to cow milk in the production of probiotic yoghurt analogue. In addition, it is expected that the lysine content of tiger-nut will complement the lysine content of sorghum thereby providing a product of improved protein quality with reduced cost.

2.0 Materials and Methods

2.1 Source of raw materials

Yellow variety of fresh tiger nuts, white variety of sorghum and a commercial brand whole milk powder were purchased from a local market in Abakaliki metropolis, Ebonyi State while, the probiotic starter culture was bought from a local supermarket in Enugu, Enugu State, Nigeria.

2.2 Sample preparations

The method of Belewu and Abodurin (2007) was used with some modifications to prepare the tiger nut milk and malted sorghum milk. Malting was as described by Okoli (2003). The procedure of Belewu *et al.* (2005) was used for yoghurt preparation.

2.3 Sample analysis

Proximate composition of the yoghurt samples was determined according to A.O.A.C (1990). Caloric values were determined using the description by Onyenuga (1968). Viscosity, pH, total titratable acidity (TTA) of the yoghurt samples were determined using the methods by Morris (1999). The total soluble solids (TSS) as well as total solids (TS) were determined by (AOAC, 1995) method.

2.4 Sensory evaluation

Twenty-member consumer panelists were used to evaluate the various sensory parameters (sourness, appearance, flavour, consistency, and general acceptability) and the scores were based on a 9 points Hedonic scale described by Ihekoronye and Ngoddy (1985); where 9 represents like extremely, 1 dislike extremely, and 5, neither like nor dislike.

2.5 Statistical analysis

Sensory ratings collected were analyzed using analysis of variance of a completely randomized design (CRD) model and its means which were different were separated using the Duncan's multiple range test. Data for chemical compositions were subjected to analysis of variance (ANOVA). Least significant difference (LSD) test was used to separate means. Significance was accepted at $p < 0.05$.

3.0 Results and discussion

Result of the proximate composition and sensory properties is presented in Table 1. There were significant differences ($p<0.05$) between the moisture content of samples from 76.50% to 87.00%. However, blends of tiger nut milk and malted sorghum milk samples were not statistically significant ($p>0.05$). The ash content increased from 0.750 - 1.090% with increase in the proportion of tiger nut milk in the blends. However, this increase was not statistically significant ($p>0.05$). This observation may be indicative of the presence of appreciable mineral elements in tiger nut, as well as malted sorghum. Fat content ranged from 2% to 12.5% as the quantity of tiger nut milk in the product increased. This could be due to the high fat content of tiger nut compared with malted sorghum. This was also consistent with the findings reported by Belewu *et al.* (2010) who found similar high fat levels in tiger nut products. The protein content increased

significantly ($p<0.05$) as the percentage malted sorghum milk increased and impacted a slight malt flavour to the yoghurt analogues. It ranged from 3.30% to10.20%. Thus, suggesting that the increase in protein content was contributed by malted sorghum portion. This result agrees with the results of Owuamanam *et al. (*2010) for quality characteristics of wheat:malted and weat:unmalted sorghum composite bread whereby the composite with malted sorghum had high protein content than that of the composite with unmalted sorghum. Significant differences ($p<0.05$) were observed in the caloric value of the samples as it ranged from 68.88kcal/100g to 152.14kcal/100g. The high caloric values of tiger nut and malted sorghum make them a valuable source of calorie energy for man especially in the tropics.

The pH of the yoghurt samples showed no significant difference ($p>0.05$). They fell within the reported range of 4.00 to 4.50 for the production of yoghurt (Imele and Atemnkeng, 2001). However, at 100% whole cow milk yoghurt (control) the total titratable acidity (TTA) was observed to drop. The TTA ranging from 0.960% to 1.144% were observed to have significant differences ($p<0.05$). The total titratable acidity of the yoghurt samples was within acceptable limits for yoghurt (Alakali *et al.,* 2008). No significant difference ($p>0.05$) in the viscosities of the yoghurt test samples with the values ranging from 8.00 Pa/sec to 8.60 Pa/sec, however, a general decrease in viscosity with total solids were observed in the analogues. This gives an indication of the effect of total solids on viscosity. This was observed in agreement with reported work of Nwiyi *et al*., (2009) who found similar trend with total solids and viscosity. The total soluble solids 5.25 - 6.50 ^{0}Brix were significantly affected ($p <0.05$).

Table 1: Proximate composition and physico-chemical properties of probiotic yoghurt produced from a commercial brand whole milk, tiger nut milk and malted sorghum milk blends

	100% CBWM yoghurt	100% TNM yoghurt	100% MSM	75:25 TNM:MSM yoghurt	50:50 TNM:MSM yoghurt	25:75 TNM:MSM
Moisture (%)	87.00^{a}	76.50^{c}	79.50^{bc}	80.50^{bc}	82.00^{b}	80.00^{bc}
Ash (%)	0.78^{a}	1.09^{a}	0.750^{a}	1.09^{a}	1.09^{a}	1.07^{b}
Fat (%)	4.00^{cd}	12.50^{a}	2.00^{e}	9.18^{b}	7.00^{c}	5.50^{c}
Protein (%)	3.30^{e}	3.88^{e}	10.20^{a}	5.20^{d}	6.00^{c}	7.66^{b}
CHO (%)	4.92^{a}	6.03^{a}	7.55^{a}	4.03^{a}	3.93^{a}	5.77^{a}
Cal. (Kcal/100g)	68.88^{e}	152.14^{a}	89.00^{d}	119.55^{b}	102.72^{c}	103.22^{c}
pH	4.00^{a}	4.23^{a}	4.50^{a}	4.32^{a}	4.38^{a}	4.44^{a}
TTA (%)	0.96^{c}	1.14^{a}	0.99^{bc}	1.25^{ab}	1.09^{abc}	1.08^{abc}
TSS (^{0}Brix)	6.50^{a}	6.00^{ab}	5.00^{c}	5.50^{bc}	5.25^{c}	5.40^{c}
TS (%)	13.00^{c}	23.50^{a}	20.50^{ab}	19.50^{b}	18.00^{b}	20.00^{ab}
Viscosity	8.60^{a}	8.57^{ab}	8.55^{ab}	8.52^{ab}	8.00^{b}	8.53^{ab}

Superscript followed by the same letter is not significantly different at $p>0.05$.

Sensory evaluation results in Table 2 showed that the most acceptable for blends is 75% tiger nut milk and 25% malted sorghum milk blend and this was statistically different from the control (commercial brand whole milk). All yoghurt samples containing blends of tiger nut milk and malted sorghum milk were not significantly different ($p>0.05$) from each other. Yoghurt from 100% tiger nut milk, was most desirable in appearance, soreness and consistency in the analogues.

Table 2: Sensory properties of probiotic yoghurt produced from a commercial brand whole milk, tiger nut milk and malted sorghum milk blends

	100% CBWM yoghurt	100% TNM yoghurt	100% MSM yoghurt	75:25 TNM:MSM yoghurt	50:50 TNM:MSM yoghurt	25:75 TNM:MSM yoghurt
Appearance	7.70^{a}	6.65^{b}	5.30^{c}	5.70^{c}	5.00^{c}	5.30^{c}
Flavour	6.35^{a}	4.85^{b}	5.05^{b}	5.35^{b}	4.40^{b}	4.70^{b}
Sourness	6.55^{a}	5.15^{b}	5.20^{b}	5.80^{ab}	5.40^{b}	5.20^{b}
Consistency	7.40^{a}	5.30^{b}	4.90^{bc}	4.70^{bc}	3.90^{c}	4.50^{bc}
Gen.	7.35^{a}	4.95^{b}	5.00^{b}	5.35^{b}	4.75^{b}	4.75^{b}

Superscript followed by the same letter is not significantly different at $p>0.05$.

4.0 Conclusion

This investigation revealed the potential of blending tiger nut milk and malted sorghum milk in the production of probiotic yoghurt analogue to enhance the sensory and nutritional qualities of yoghurt. Malted sorghum was found to impact a slight malt flavour to the yoghurt when used and it helped to increase the protein content of the yoghurt. Tiger nut milk:malted sorghum milk-based yoghurts were also rich in most of the nutrient contents. This, indicates the possibility of blending tiger nut milk and malted sorghum milk in the production of cheaper and improved protein quality yoghurt.

References

Alakali, J.S, Okonkwo T. M., and Iordye E. M. (2008). Effect of stabilizers on the physico-chemical and sensory attributes of thermized yoghurt. *African Journal of Biotechnology,* 7 (2): 158-163.

Anagboso, O. M., Ohaebuka, J. C., Mbah, I. E., Osuala, J. O., Daokoru-Olukole, G., C., Onu, N. E., Agedah, C. E., Nwankwo, A. G., Okafor, O., F., Silas-Olu, D. and Okonko, O. I. (2024). Microbial contamination and antibiotic resistance in selected yoghurt brands in Elele, Rivers State, Nigeria. *Covenant Journal of Physical and Life Sciences,* 12(2):1-7.

Association of official Analytical Chemists (AOAC), *1990 Official Methods of Analysis*, 15th ed. Association of Official Analytical Chemists Inc. Arlington, Virginia. USA.

Association of Official Analytical chemists (AOAC), 1995 Official methods of Analysis, *20th ed.* Association of official Analytical chemists lnc. Arlington, Virginia. USA.

Belewu, M.A., and Abodurin O.A. (2007). Preparation of kuunu from unexpected rich food source, tigernut (Cyperus esculentus). *Pake Journal of Nutrition,* 7:109-111.

Belewu, M.A., Belewu K.Y., and Bamidele R.A. (2010). Cyper-coconut yoghurt: Preparation, compositional and organoleptic qualities. *Partisan Journal of food science and Technology,* 1(1): 010-072.

Belewu, M.A., Belewu K.Y., and Olatunji S.A. (2005). Soy-coconut yoghurt preparation, composition and organoleptic qualities. *BioScience Resources Bulletin* 21 (2): 129-137.

Daszkiewicz, T., Michalak, M. and Smiecinska, K. (2024). A comparison of the quality of plain yoghurt and its analog made from coconut flesh extract. *Journal of Dairy School.* 107(6): 3389-3399.

Esene, F. E. (2023). Consumers' preference and willingness to pay for value-added dairy products in Kentucky- considering price, provenance and environmental product attributes. Theses and Dissertations Agricultural Economics. 106. https://knowledge.ucky.edu/agecon_etds/106. Accessed March, 24, 2025

Feyera, M. (2021). Overview of melting and fermentation role in sorghum flour, primarily for antinutrient reduction. *Journal of Human Nutrition Food Science,* 9(1): 1138.

Ihekoonye, A., and Ngoddy P.O. (1985). Integrated food science and technology for the tropics. Macmillan Publishers Ltd.

Imele, H., and Atemnkeng A. (2007). Preliminary study of coconut in yoghurt production. *African Journal of Food Technology, 6:1-12.*

Ishaq, A., Iran, S., Sameen, A. and Khalid, N. (2022). Plant-based meat analogs: A review with reference to formulation and gastrointestinal fate. *Current Resources Food Science*, 5: 973-983.

Mohamed, M. S. A., Zenib, M. Z., Muhammed, A. A., Mar Muhammad, G. and Ahmed, N. A. (2025). Development and quality assessment of cereals made from malted sorghum, bambara nut, pumpkin seed and mature unripe banana flour blend. *African Journal of Biological Science*, 7(2) 1pg 73-98.

Morris, J. B. (1999). The chemical analysis of foods and food products. 3rd ed. Indian: CBS published and distributors.

Nwaoguikpe, R. N. (2010). The phytochemical, proximate and amino acid composition of the extracts of two varieties of tiger nut and their effects on sickle cell hemoglobin polymerization. *Journal of Medicine and Medical Sciences*, 1(11):543-549.

Nwiyi, I. U. Ejiga, O and Alakali J. S. (2009). Effect of milk blends and temperature on the quality of thermized yoghurt. *Electronic Journal of Environmental, Agricultural and Food Chemistry.* 8. 676-684.

Okoli, E.C. (2003). In: Ogu, E.O. (2006). Fundamentals of brewing science and technology. Nigeria: John Baz Publishers.

Owuamanam, C.I., Iwouno J.O and Ntagu T. (2010). Quality characteristics of wheat; malted and unmalted sorghum (sorghum bicolor) composite Bread. *Nigerian Food Journal*, 28(2).

Oyenuga, V.A. (1968). Nigeria's foods and feeding stuff. Their chemistry and nutritive value. Ibadan University Press.

Zorica, M. T., Lato, L. P., Nedeljka, J., S., Jasmina, M. L., Ivana, S. C. and Ruzica, M. T. (2022). Diversity of amino acids composition in cereals. *Journal of Food and Feed Research,* 49(1), 11- 22.

Cornsilk: A By-Product with Potential Utilization in Food Industries

Okorafor-Nwosu, A[1]. Anigbogu, C.B.[2] Anukwuorji, E.O[1]. and *Kolawole, O.O.[1]

[1]Projects Development Institute (PRODA), Enugu State, Nigeria. [2]Department of Food Science and Technology, Nnamdi Azikiwe Univesity, Awka, Anambra State, Nigeria.

*Corresponding author's email: kolawoleoladimejiolubusayo7@gmail.com.

ABSTRACT

Corn silk, a major agricultural by-product of maize (*Zea mays L.),* has long been regarded as waste despite it rich reservoir of bioactive compounds. It is rich in several nutrients and bioactive compounds such as flavonoids, phenolic acids, alkaloids, saponins that possess various health benefits. Corn silk is known to have anti-diabetic, anti-cancerous, diuretic, anti-inflammatory and anti-microbial properties. Massive production of corn leads to the bulk production of corn silk as well. However, this nutritionally packed compound is usually regarded as waste. The utilization of corn silk in the production of various products is increasing day by day. Valorization of corn silk is not only helping in managing agricultural waste but is also adding up the nutritional and functional value of the food products This paper reviews the nutritional composition, functional properties, and emerging food industry applications of corn silk, particularly its role as a natural additive and nutraceutical ingredient. With increasing global interest in sustainable food systems and functional foods, corn silk offers significant potential for product development, waste valorization, and health-promoting innovations. Challenges in processing, regulatory acceptance, and standardization are also discussed, along with future research directions.

Keywords: Corn silk, bioactive compounds, nutraceutical, additive, health-promoting.

Introduction

Maize (*Zeal Mays L.)* is one of the most widely cultivated cereal crops globally, generating significant volumes of by-products such as husk, cob, and corn silk. Corn silk (*Stigma maydis)* is the long, thread- like style and stigma of the female maize flower, usually discarded during processing. However, increasing research interest has identified its rich phytochemical content and biological activity, supporting its potential applications in the food industry (Saeed *et al.* 2023). Corn silk (CS) is usually known for its antioxidant capacity that can prevent the oxidation process and it is being widely studied about its health-related benefit (Rahman and Rosli, 2014). It has several bioactive compounds such as steroids, alkaloids, anthocyanin, saponins, carotenoids, and phenolic compounds which have cooperative effects on physical health (Limmativapirat *et al.*, 2020). Some bioactive compounds possess pharmacological activities because of their antioxidant and free radical scavenging capacity (Zilic *et al.*, 2016). Many countries have been using corn silk for the treatment of numerous health diseases such as prostrate disorders, kidney stones, obesity, urinary infections and bedwetting, corn silk has also proven to be successful in treating conditions like diarrhea and stomach upsets, which are ascribed to be caused by the infection from *Staphylococcus aureus Salmonella spp* (Emmanuel *et al.*, 2016).

Corn silk contains flavonoids that are also responsible for their antimicrobial property because they dislocate the cell membrane in a way that denature bacterial proteins (Abiram *et al.*, 2021). The presence of water-soluble pigment anthocyanin in colored corn not only exhibits higher antioxidant activity but also is responsible for anti-inflammatory and anticarcinogenic effects (Saikaew *et al.*, 2018). The presence of phenolic compounds, alkaloids, polyphenols, saponins, and steroids in the silk possess an antiseptic and antimicrobial nature against some particular sets of micro-organisms. Its antioxidant activities could inhibit persistent high-risk human papillomavirus (HR-HPV) infection which plays a key role in the growth of

cervical cancer (Li *et al.*, 2020). Many studies claim that the corn silk extract is beneficial in decreasing hyperglycemia and its flavonoid extract significantly reduces the serum LDL-C, triglyceride and total cholesterol levels. The ethanolic extract of corn silk has proven to possess hypotensive effects and also act as a diuretic. Besides this, corn silk can increase the levels of antioxidant enzymes and inhibit lipid peroxidation (Wang *et al.*, 2017). However, corn silk is usually discarded as waste during the processing of maize but it can be used for the formulation of various products. This will not only increase the income of farmers but can also add nutritional density and diversity to the diet of people (Singh *et al.*, 2022). For example, it can be commercially used as a major ingredient for the production of value-added products like corn silk tea, snacks, noodles, cosmetics and medicines (Sarepoua *et al.*, 2015). This paper explores the utilization of corn silk as a functional ingredient in food systems, promoting sustainability and health-enhancing innovations.

Nutritional composition

Corn silk has numerous biochemical nutrient compounds like proteins, carbohydrate, vitamins, mineral salts, alkaloids, tannins, volatile chemicals, steroids and flavonoids. It is also rich in B complex vitamins. (Bhuvaneshwari and Sivakami, 2015). However, the nutritional composition of the silk varies with the genotype and it is found that corn silks at the silking stage are far a better source of phenolic compounds than those at the mature stage (Zilic *et al.* 2016). Several studies have been conducted to determine the nutritional composition, mineral contents, flavonoid, polyphenolic content and antioxidant activity of corn silk. It was found that the number of flavonoids, anthocyanins and phenolic compounds were comparatively good in association with their organic activities (Limmatvapirat *et al.*, 2020). Mostly, the samples used for the nutritional analysis were first dried. Drying reduces the weight and moisture content of the sample and also it is one of the most cost-effective methods of food preservation. Drying of corn silk is purposely done because at high temperature the determination of natural antioxidants from plant material is quite effective (Bhuvaneshwari and Sivakami, 2015). Several studies used different methods for sample preparation. According to Singh *et al.* (2022), the collected sample was firstly blanched at 100^{o}C for 60secs followed by the tray drying at 50 ^{o}C for 4 h and according to Thaiwong (2020) the corn silk sample was directly dried at 40 ^{o}C, 50 ^{o}C and 60^{o}C in a hot air oven.

Nutrition analysis of corn silk powder conducted by Singh *et al.* (2022) revealed the amount of moisture content to be 7.89±0.49 g/100 g and carbohydrate content to be 56.16±0.66 g/100 including high levels of pectin, glucan, cellulose, hemicellulose, and lignin. The total fat content was about 0.55% and fibre was around 14.82±0.84 g/100g. The amount of macro minerals like calcium (1338 µg/g), potassium (1135.7µg/g) were quite optimum and that of micro minerals like manganese, iron, copper and zinc was found to be in the range of 11.1 µg/g, 41.7 µg/g, 11.9 µg/g and 83.7 µg/g respectively, whereas Rahman and Rosli, (2014) compared the nutritional content between the mature and immature silk and found that the moisture content in mature silk (84.42%) was lower than that of immature silks (89.31%) and the amount of carbohydrates of mature silk was slightly higher than immature silks (27.80%). The lipid (1.27%) and protein (12.96%) content of immature silks was higher than that of immature silks which corresponds to 0.66% and immature corn (48.50 g/100g was higher). Besides this, Rahman and Rosli, (2014) determined the mineral content using an atomic absorption spectrophotometer and found a varied range of calcium (1087 µg/g), copper (5.60 µg/g), iron (4.50 µg/g), sodium (266 µg/g), copper (5.60 µg/g) in both mature and immature corn silks. An average range of amount of nutrient present in the corn silk is shown in the table below.

Table 1: Nutritional composition of corn silk powder/100 g

Nutritional compound	Amount in corn silk powder	References
Moisture	4.7 %	
Fat	0.5-12%	
CHO	27-56%	
Protein	12-15%	
Fibre	14-51 g/100g	(Singh *et al. 2022)*
Calcium	1080-1338 µg/g	
Magnesium	1169-1219 µg/g	
Sodium	266-3654 µg/g	(Rahman and Rosil 2014)
Potassium	1135-35671 µg/g	
Copper	5-11 µg/g	(Bhuvaneshwari and Sivakami, 2015)
Iron	4-41 µg/g	
Manganese	11-35 µg/g	
Zinc	46.83 µg/g	

Bioactive Compounds of Corn silk

Corn silk contains a diverse range of nutrients and phytochemicals. Corn silk is a natural source of flavonoids (Maysin, luteolin), saponins, alkaloids, tannins, and volatile oils. These compounds exhibit antioxidant, anti-inflammatory, hypoglycemic, and antimicrobial activities (Zhang *et al.*, 2021). Corn silk flavonoids are known to scavenge reactive oxygen species (ROS), inhibit lipid peroxidation, and modulate pro-inflammatory cytokines, which make them ideal for functional foods (Lee *et al.*, 2019).

Functional Properties in Food Systems

Corn silk exhibits key functional properties desirable in food processing.

- Water-holding capacity: Enhances moisture retention in bakery products
- Oil-holding capacity: Useful in meat substitutes and emulsions
- Dietary fibre content: improves gut health and satiety in consumers (Abdel-Rahman *et al.* 2020).
- Natural colour and aroma: suitable for use in teas and beverages.

These properties facilitate its use as a stabilizer, flavor enhancer, and health promoting agent in various formulations.

General utilization of corn silk

Corn silk can be utilized in vast sectors of marketing industries whether it be food, fodder, pharmaceutical, cosmetics etc. owing to its highly versatile nutritional composition. Dermatologists tested corn silk extract on Melan-A cells and it decreased melanin production by 37.2% therefore, corn silk powder is being added to skin products and cosmetics which can help to purify the skin, minimize the size of pores and can act as a brightener and highlighter (Dardouk *et al.,* 2019). Besides this some studies have found that the corn silk ethyl acetate extract holds a higher SPF value than its methanol extract. The presence of phenolic

compounds and high antioxidant content in corn silk makes it suitable to be used as a natural sunscreen because of its photo-protective nature (Laeliocattleya, 2019). Silver nanoparticles biosynthesized in an aqueous medium of corn silk extract can prevent bacterial infection because they exhibit antibacterial activity against several bacterial strains. Also, the nanocomposites of corn silk extract promote high bone differentiation which can be used for bone tissue regeneration (Markvandi *et al.* 2020). Nanocomposites made from corn silk extract is used for the efficient degradation of chemically and biologically resistant dyes in a short time (Khodaei and Dehghan, 2019). Corn silk water extract has an inhibitive property against the corrosion of mild steel. It acts as an effective inhibitor due to the hetero atoms; N, O, and S present in its phytochemical composition (Okorosaye-Orubite and Ngobiri, 2017).

Further, the polysaccharide extracts of corn silk have been used for the development of medications for the treatment and prevention of cancers. Hence, the application of corn silk extract for the treatment of various diseases and disorders is increasing appreciably (Saheed *et al.* 2023). Corn silk powder when used in meatballs, improved its nutritional values due to the presence of higher ash and fibre content in it. It also increased the juiciness and shrinkage of meatballs but the cooking yield was decreased because of the loss in moisture and fat content during cooking processes. Corn silk is rich in fibre and has a higher bioavailability as compared to corn. Corn silk powder when used for making traditional Indian snack Laddu, not only improved the fibre and energy content but also, increased the nutritive value and added value to the product (Singh and Raghuvanshi, 2021).

Application of Corn silk in Food Industry

Functional Beverages: corn silk tea, popular in East Asian countries, is rich in polyphenols and minerals. It is consumed as a diuretic and antioxidant drink (Kim *et al.*, 2018).

Natural Additives: Extracts from corn silk are used to extend shelf-life by reducing oxidation in oils, meats, and dairy products (Rahman *et al.*, 2021).

Food Packaging and Films: Corn silk mucilage and polysaccharides have been explored for biodegradable film production, contributing to sustainable food packaging (Mohamed *et al.*, 2022).

Baked and Extruded Products: Incorporating corn silk powder into flour-based products such as bread, cookies, and noodles enhances dietary fibre and antioxidant content without compromising texture.

Processing and Extraction Techniques of corn silk

The extraction of bioactive compounds from corn silk offers many potential applications in the food, pharmaceutical, and cosmetic industries. Processing methods such as solvent extraction, supercritical fluid extraction, ultrasound-assisted extraction, microwave-assisted, and enzyme assisted each have their unique advantages depending on the target compounds and application prior to extraction, corn silk is typically dried and ground into a powder to facilitate the release of bioactive compound. Drying can be done using different methods, such as air drying, freeze drying, or oven drying. Grinding the silk helps increase the surface area, improving the efficiency of the subsequent extract process (Ali *et al.*, 2021)

Safety, Toxicity and Regulatory Considerations of Corn Silk

Corn silk has a long history of use in traditional medicine across various cultures, including Traditional Chinese Medicine and Native American herbal practices, where it is employed primarily for its diuretic and anti-inflammatory properties. This ethno-medicinal background supports its general safety when used in conventional doses (Jin *et al.*, 2011). Preclinical studies confirm this safety profile. Guven *et al.* (2005) demonstrated that aqueous corn silk extracts administered to rats caused no significant changes in hematological or biochemical indices, nor any history pathological damage to vital organs. Furthermore, no significant allergenic effects have been widely reported, although individuals allergic to corn pollen or other maize parts may exhibit hypersensitivity. Despite its safety, corn silk may interact with certain medications which may enhance hypoglycemic activity, posing risks to individuals on anti-diabetic therapy (Zhao *et al.*, 2012). Toxicological studies have shown that corn silk has a low toxicity profile. Wang *et al.* (2017) reported an oral LD_{50} value exceeding 5000 mg/kg body weight in mice, suggesting that the extract is practically

non-toxic. Sub-chronic and chronic toxicity assessments in animals have also yielded favourable result. Rats given up to 2000 mg/kg only showed toxic effects (Guven *et al*., 2005). Corn silk is regulated as a dietary supplement under the Dietary Supplement Health and Education Act (DSHEA) of 1994. It is included in the FDA'S GRAS (Generally Recognized As Safe) list when used in typical food amounts (FDA, 2020).

Challenges and Limitations of Corn Silk

Despite its long history of traditional use and promising pharmacological properties, the application of corn silk in food, pharmaceutical, and nutraceutical industries is limited by several key challenges and limitations such as: lack of standardization, limited clinical evidence, stability and shelf-life issues, regulatory and market barriers, agricultural waste utilization constraints and potential for drug interactions and adverse effects (Zhao *et al*., 2012).

Future Prospects and Research Needs of Corn Silk

Corn silk has been traditionally valued for its medicinal properties, but modern scientific exploration is still unlocking its full potential across multiple industries. As interest grows in sustainable and functional food ingredients, the future of corn silk looks promising, especially in the domains of food, pharmaceuticals, nutraceuticals, and cosmetics. The future prospects include: functional food ingredient, natural antioxidant source, pharmaceutical applications, cosmeceuticals and sustainable utilization in agriculture (Lee *et al*., 2022).

Conclusion

Corn silk offers nutritional and functional benefits in food applications and supports sustainable innovation in the food industry.

References

Abirami, S., Priyalakshmi, M., Soundariya, A., Samrot, A.V., Saigeetha, S. and Emilin R.R. (2021). Antimicrobial activity, anti-proliferative activity, amylase inhibitory activity and phytochemical analysis of ethanol extract of corn (*Zea mays L.)* silk. *Current Research in Green and Sustainable Chemistry,* 4:100089.

Abdel-Rahman, M.A., El-Sayed, M.A. and El-Morshedy, H.A. (2020). Evaluation of chemical and bioactive components of corn silk (*Zea mays L.)* from different genotypes. *Journal of Agricultural and Environmental Sciences,* 29(2): 210-222.

Ali, G.W., Abd Ellatif, M.A. and Abdel-Fattah, W.I. (2021). Extraction of natural cellulose and zein protein from corn silk: Physicochemical and biological characterization. *Research Journal of Food Science and Nutrition,* 12(4): 45-59.

Bhuvaneshwari, K. and Sivakami, S. (2015). Analysis of nutrients and phytochemicals content in corn silk (*Zea mays). International Journal of Science and Research;* c2015.p.79-81.

Dardouk, F., Arandi, H. and Makharzeh, M. (2019). Extraction of Corn silk and its applications in healing and cosmetics.

Emmanuel, S.A., Olajide, O., Abubakar, S., Akiode, S.O. and Etuk-Udo, G. (2016). Chemical evaluation, free radical scavenging activities and antimicrobial evaluation of the methanolic extracts of corn silk *(Zea mays). Journal of advances in Medical and Pharmaceutical Sciences,* 9(4): 1-8.

FDA, (2020). GRAS Notices. U.S. Food and Drug Administration. Retrieved from https://www.fda.gov/.

Guven, A., Kucukboyaci, N., Kupeli, O. and Akkol, E. (2005). Evaluation of diuretic activity of corn silk extracts in rats. *Pharmaceutical Biology,* 43(8): 613-616.

Jin, M., Zhao, K. and Huang, Q. (2011). Antioxidant and hepatoprotective effects of corn silk flavonoids. *Food Chemistry,* 129(2): 385-392.

Khodaei, M.M. and Dehghan, M. (2019). A green and cost-effective approach for the production of gold nanoparticles using corn silk extract: A recoverable catalyst for Suzuki Miyaura reaction and adsorbent for removing of dye pollutants. *Polyhedron*, 162: 219-231.

Kim, H., Lim, Y. and Park, S. (2018). Corn silk water extract has anti-diabetic effects in strepto-zotocin-induced diabetic rats. *Nutrition Research and Practice,* 5(2):109-115.

Laeliocattleya, R.A. (2019). The potential of methanol and ethyl acetate extracts of corn silk (*Zea mays L.)* as sunscreen. In AIP Conference Proceedings (vol. 2099, No. 1, p.020012). AIP Publishing LLC: c2019 April.

Lee, K.J., Zhao, J.L. and Wang, K.J. (2019). Corn silk (*Zea may L.)*: A source of natural antioxidants with α-amylase, α-glycosidase, advanced glycation, and diabetic nephropathy inhibitory activities. *Biomedicine and Pharmacotherapy,* 110:510-517.

Lee, S.M., Jung, H.J. and Yoon, H.G. (2022). Functional evaluation of corn silk tea and potential health benefits. *Journal of Medicinal Food,* 25(2): 120-126.

Li, Y., Hy, Z., Wang, X., Wu, M., Zho, H. and Zhang, Y. (2020). Characterization of a polysaccharide with antioxidant and anti-cervical cancer potentials from the corn silk cultivated in Jilin province. *International Journal of Biological Macromolecules,* 155:1105-1113.

Limmatvapirat, C., Nateesathittarn, C., Dechasathian, K., Moohummad, T., Chinajitphan, P., Limmatvapirat S. (2020). Phytochemical analysis of baby corn silk extracts. *Journal of Ayurveda and Integrative Medicine.* 2020; 11(3):344-351.

Makvandi, P., Ali, G.W., Della-Sala, F., Abdel-Fattah W.I. and Borzacchiello, A. (2020). Hyaluronic acid/corn silk extract based injectable Nano composites: A biomimetic antibacterial scaffold for bone tissue regeneration. *Materials Science and Engineering*, 107:110195.

Mohamed, A., Abdin, M. and El-sayed, M. (2022). Characterization, rheological properties, and immunomodulatory efficiency of corn silk polysaccharides. *International Journal of Food Science,* Article ID 15832.

Okorosaye-Orubite, K. and Ngobiri, N.C. (2017). Corn silk as corrosion inhibitor for mild steel in 0.1 M HCI medium. IOSR *Journal of Applied Chemistry,* 10(3):51-60.

Rahman, N.A. and Rosli W.I. (2014). Nutritional compositions and antioxidative capacity of the silk obtained from immature and mature corn. *Journal of King Saud University Science,* 26(2): 119-127.

Saeed, A.A., Matar, A. and Ismail A.M. (2023). Chemical composition, physical properties, and sensory evaluation of wheat-based cookies enriched with different proportions of corn silk. *Italian Journal of Food Science,* 35(4): 1-12.

Saikaew, K., Lertrat, K., Ketthaisong, D., Meenune, M. and Tangwongchai, R. (2018). Influence of variety and maturity on bioactive compounds and antioxidant activity of purple waxy corn (*Zea mays L.* var. ceratina). *International Food Research Journal,* 25(5): 1985-1995.

Sarepoua, E., Tangwongchai, R., Suriharn, B. and Lertrat, K. (2015). Influence of variety and harvest maturity on phytochemical content in corn silk. *Food Chemistry.* 2015; 169:424-429.

Singh, A. and Raghuvanshi, R.S. (2019). Development and evaluation of Value-Added fibre rich Laddoo supplementary and Alternative Medicine; c2019.

Singh, J., Inbaraj, B.S., Kaur, S., Rasane, P. and Nanda, V. (2022). Phytochemical Analysis and Characterization of Corn Silk (*Zea mays,* G5417). *Agronomy*, 12(4):777.

Thaiwong N. (2020). Drying temperature of corn silk tea: physical properties, total phenolic content, antioxidant activity and flavonoid content. *Food and Applied Bioscience Journal*, 8(3):38-48.

Wang, Y., Xiang, L., Wang, C., Tang, C. and He, X. (2018). Anti-diabetic and antioxidant effects and phytochemicals of corn silk flavonoids. *Molecular,* 16(11): 9912-9924.

Wang, B., Xiao, T., Ruan, J. and Liu, W. (2017). Beneficial effects of corn silk on metabolic syndrome. *Current Pharmaceutical Design*, 23(34): 5097-5103.

Zhao, K., Jin, M. and Wang, Y. (2012). Hypoglycemic effect of corn silk in diabetic mice. *Nutrition and Metabolism,* 9:64.

Zhang, L., Yang, Y. and Wang, Z. (2021). Extraction optimization of polysaccharides from corn silk and their antioxidant activities in vitro and in vivo. *Frontiers in Pharmacology, 12:738150.*

Zhao, Y., Zhang, M. and Chen, H. (2022). Enzyme assisted extraction of functional bioactive compounds from agricultural waste. *Journal of Food Processing and Preservation,* 48(2):e17043.

Zilic, S., Jankovic, M., Basic, Z., Vancetovic, J. and Maksimovic V. (2016). Antioxidant activity, phenolic profile, chlorophyll and mineral matter content of corn silk (*Zea mays* L.): Comparison with medicinal herbs. *Journal of Cereal Science*, 69:363-370.

Innovative Processing of Yoghurt: Physicochemical Properties of Greek Yoghurt Derived from Blends of Cow Milk and Rice Milk

Elochukwu, C. U.

Department of Food Technology, Federal Polytechnic Oko, Anambra State

Correspondence: chielochukwu@yahoo.com

ABSTRACT

This study investigated the potential of rice milk as a substitute for cow milk in the production of Greek-style yoghurt, with a focus on evaluating their physicochemical properties. Rice milk was obtained by sorting, washing, soaking (6 h), wet-milling, filtering, and pasteurizing rice grains. The pasteurized rice milk was then blended with cow milk in ratios of 100:0 (GY1), 90:10 (GY2), 80:20 (GY3), and 70:30 (GY4) and used in yoghurt production. Standard analytical methods were employed to determine the physicochemical properties of the samples. Results revealed that significant differences ($p < 0.05$) existed between the control and the cow–rice milk yoghurt samples. The pH, titratable acidity, total soluble solids, water holding capacity, viscosity, and syneresis ranged from 3.90–4.20, 0.15–0.26%, 18.00–21.50 °Brix, 60.21–64.82%, 4.10–4.74 P.aS, and 13.50–12.63%, respectively. Proximate composition values ranged from 74.67–76.40% for moisture, 2.86–2.91% for ash, 3.57–4.12% for fat, 1.12–1.36% for fibre, 5.75–5.93% for protein, and 9.60–11.74% for carbohydrate. The findings indicated that Greek-style yoghurts with acceptable physicochemical qualities can be produced by replacing cow milk with up to 30% rice milk. This offers a promising approach to reducing the high cost of yoghurt production while maintaining quality

Keywords: Yoghurt, rice, proximate, physicochemical, substitution

1.0 Introduction

Yoghurt, a widely consumed fermented dairy product, is produced through the lactic acid fermentation of milk by *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. According to Nelios *et al.* (2023), Greek yoghurt is produced from cow's milk, and its standard production process involves bacterial fermentation (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) and whey straining from regular yoghurt to create a thicker and creamier product with high total solids and a characteristic strong tangy flavour. Traditionally produced from cow's milk, yoghurt is recognized as a highly nutritious food, rich in proteins, vitamins, and minerals, and offers various health benefits including improved digestion, immune support, and cholesterol reduction (Onyimba *et al.*, 2022). However, the growing prevalence of lactose intolerance, milk allergies, vegan dietary preferences, and the rising cost of dairy milk have necessitated the search for plant-based milk alternatives for yoghurt production (Ajogun *et al.*, 2023). Plant-based milks such as those derived from soy, coconut, tiger nut, and millet have been investigated as alternatives to animal milk in yoghurt production, offering comparable sensory and nutritional qualities (Anumba *et al.*, 2023). Among these, rice milk, derived from *Oryza sativa L.*, is increasingly recognized for its hypoallergenic, gluten-free, and cholesterol-free properties, along with its richness in essential minerals and antioxidants (Suman *et al.*, 2023). Despite its nutritional and functional advantages, the utilization of rice milk in yoghurt production remains underexplored, particularly in Nigeria, where rice is abundantly available and dairy milk is expensive and largely imported (Wannasupchue, 2023). In order to solve this problem, there is the need for cost-effective, locally sourced, and nutritionally adequate milk substitutes. This study investigated the potential of rice milk as a partial replacement for cow milk in the production of Greek yoghurt. The research aimed to evaluate the physicochemical properties of yoghurt formulated from various blends of cow and rice milk.

2.0 Materials and Methods

2.1 Source of Raw Material:

Powdered cow milk (Dano milk) (1 kg), rice grains (Coscharis rice, 1 kg), sugar (Dangote sugar), packaging materials were purchased in *Eke Ekwuluobia* Market in *Aguata* Local Government Area while starter culture was purchased from Ochanja Market in Onitsha North Local Government Area both in Anambra State. All the raw materials were packaged in a clean polyethylene bag and taken to Food Processing Laboratory of Department of Food Technology, Federal Polytechnic Oko, Anambra State for further processing.

2.2 Production of Rice Milk:

The method described by da Silva *et al.* (2023) was adopted in production of rice milk with slight modification. The rice grains were sorted to remove extraneous materials, washed and soaked in distilled water (1:4, w/v) for 6 h. After hydration, the water was discarded and the rice was blended with distilled water (1:3, w/v), with the aid of an electric blender for 3 min. The obtained slurry was subjected to filtration. The rice milk extracted was pasteurized at a temperature of 65°C for 15 min after which it was packaged in a sterile container prior to further use.

2.3 Production of Milk Solution:

The method described by Okoye and Obi, (2016) was adopted in preparation of milk solution with slight modification. Whole milk powder (1 Kg) was dissolved in three litres (3 L) of potable water in a sterile plastic bowl. The dissolved milk solution was transferred into a sterile pot and was pasteurized immediately at a temperature of 65 °C for 15 min with continuous stirring to avoid formation of lumps.

2.4 Formulation of Milk Blends:

Cow milk solution and rice milk were blended in the ratios of 90:10, 80:20 and 70:30 respectively. Whole cow milk solution was used as the control sample.

2.5 Production of Greek Yoghurt:

Yoghurt was produced following the method described in the study of Uduwerella *et al.* (2018) with some modification. A volume of 2.5 L each of the milk formulations was heated to 65°C for 15 mins and then cooled to 42 - 45°C. The different milk samples were poured separately into plastic bowls in equal volumes. Each of the milk samples were inoculated with 3 g of the starter culture (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) at the temperature of 43°C and mixed thoroughly. The bowls containing the milk samples were covered and incubated at 43°C for 8 h for fermentation and curdling of the milk samples to take place. At the end of the incubation period, the resulting yoghurts from different milk formulations were stirred and strained under refrigeration temperature (4°C) for 15 min with the aid of muslin cloth. Thereafter, the samples were thoroughly homogenized and separately packaged in well labeled and cleaned plastic containers until needed for analysis.

2.6 Physical and Chemical Analyses

Proximate composition (moisture, ash, fibre, fat, protein, carbohydrate) and physical properties were carried out using standard methods (AOAC, 2023). All analyses were performed in triplicate. Data were analyzed using SPSS version 25.0 with significance determined by two-way ANOVA.

3.0 Results and Discussion

The results of the physicochemical properties of Greek yoghurt derived from blends of cow Milk and rice Milk is revealed in Table 1, The pH values ranged from 3.90 (GY1) to 4.20 (GY2–GY4). The control sample had a significantly lower pH than the blends. These values, though lower than those reported by Kim *et al.* (2023), fall within acceptable limits (Mbae *et al.*, 2023). Low pH improves calcium bioavailability and inhibits spoilage organisms (Ibrahim *et al.*, 2020). Total soluble solids (TSS) increased with rice milk addition, ranging from 18.00 °Brix (GY1) to 21.50 °Brix (GY3 and GY4). Total titratable acidity (TTA) ranged from 0.10% (GY2) to 0.26% (GY3). The blends showed significant variation ($p < 0.05$). Water holding capacity (WHC) increased significantly ($p < 0.05$) from 60.21% (GY1) to 64.82% (GY4). This

increase was due to starch in rice milk, which binds water and increases viscosity (Ibrahim and Khalifa, 2015). The values exceeded those reported by Nelios *et al.* (2023). Viscosity also increased with rice milk inclusion, ranging from 4.10 P.aS (GY1) to 4.74 P.aS (GY4). The thickening effect was attributed to starch (amylose and amylopectin) and carbohydrate stabilizers in rice milk (Atwaa *et al.*, 2019). Syneresis index ranged from 12.63% (GY4) to 13.50% (GY1), with significant reduction in the blended samples ($p < 0.05$).

Table 1: Physicochemical Properties of Greek Yoghurt derived from blends of Cow Milk and Rice Milk

Parameter	GY1	GY2	GY3	GY4
pH	$3.90^{b}\pm0.00$	$4.20^{a}\pm0.10$	$4.20^{a}\pm0.00$	$4.20^{a}\pm0.00$
TSS (°Brix)	$18.00^{c}\pm0.00$	$21.40^{b}\pm0.01$	$21.50^{a}\pm0.00$	$21.50^{a}\pm0.00$
TTA (%)	$0.15^{c}\pm0.00$	$0.10^{d}\pm0.10$	$0.26^{a}\pm0.01$	$0.22^{b}\pm0.00$
WHC (%)	$60.21^{c}\pm0.26$	$60.33^{c}\pm0.06$	$64.17^{b}\pm0.21$	$64.82^{a}\pm0.03$
Viscosity (P.aS)	$4.10^{b}\pm0.00$	$4.71^{a}\pm0.02$	$4.69^{a}\pm0.05$	$4.74^{a}\pm0.02$
Syneresis (%)	$13.50^{a}\pm0.00$	$12.80^{b}\pm0.20$	$12.63^{b}\pm0.03$	$12.63^{b}\pm0.02$
Moisture (%)	$75.61^{b}\pm0.55$	$76.40^{a}\pm0.40$	$76.25^{ab}\pm0.15$	$74.67^{c}\pm0.15$
Ash (%)	$2.89^{a}\pm0.10$	$2.90^{a}\pm0.05$	$2.91^{a}\pm0.04$	$2.86^{a}\pm0.01$
Fat (%)	$4.11^{a}\pm0.04$	$4.12^{a}\pm0.03$	$4.00^{b}\pm0.00$	$3.57^{c}\pm0.05$
Crude Fibre (%)	$1.04^{c}\pm0.04$	$1.12^{b}\pm0.01$	$1.36^{a}\pm0.04$	$1.41^{a}\pm0.03$
Protein (%)	$5.93^{a}\pm0.06$	$5.86^{b}\pm0.02$	$5.82^{b}\pm0.02$	$5.75^{c}\pm0.02$
Carbohydrate (%)	$10.42^{b}\pm0.54$	$9.60^{c}\pm0.40$	$9.65^{c}\pm0.22$	$11.74^{a}\pm0.18$

*Values are means ± standard deviations of triplicate determinations. Means with the same superscript (a–d) indicate significant differences ($p < 0.05$) across rows. **GY1=** 100:0 Cow-Rice Milk Greek Yoghurt (control), **GY2=** 90:10 Cow-Rice Milk Greek Yoghurt, **GY3=** 80:20 Cow-Rice Milk Greek Yoghurt, **GY4=** 70:30 Cow-Rice Milk Greek Yoghurt. TSS= Total soluble solids, TTA= Total titratable acidity, WHC= Water holding capacity.

The presence of rice starch likely improved gel structure, minimizing water separation (Ketaren *et al.*, 2024). The proximate composition of Greek yoghurt produced from cow-rice milk blends is summarized in Table 1. Moisture content ranged from 74.67% (GY1) to 76.40% (GY2), with significant variation ($p < 0.05$). These values were higher than those reported by Kim *et al.* (2023) and Jiménez *et al.* (2022), but comparable to those by da Silva *et al.* (2023). The differences could stem from formulation and processing methods. Moisture content affects shelf life, as high moisture increases spoilage risk (Kumar and Mishra, 2014). The Ash content ranged from 2.86 to 2.91%, with no significant differences ($p > 0.05$), suggesting rice milk inclusion did not affect mineral content. These values were lower than those in bovine colostrum-enriched Greek yoghurt (Silva *et al.*, 2021) but higher than Meletharayil *et al.* (2016). A significant decrease ($p < 0.05$) in fat content was observed with higher rice milk substitution, likely due to rice's lower fat content. Fat levels were lower than those in studies by Silva *et al.* (2021) but higher than those by Meletharayil *et al.* (2016). The crude fibre increased significantly ($p < 0.05$) with more rice milk, from 1.04% (GY1) to 1.41%

(GY4), aligning with trends reported by Ityotagher and Julius (2020). The fibre enhancement was attributed to plant-based ingredients like rice milk, though the values were lower than the 3.00 to 3.05% reported by da Silva *et al.* (2022). Protein content showed a significant decline ($p < 0.05$) from 5.93% (GY1) to 5.75% (GY4), due to the low protein content of rice (Atwaa *et al.*, 2019). These values were below those reported by Silva *et al.* (2021) but higher than Karastamatis *et al.* (2022). Carbohydrate content ranged from 9.60% (GY2) to 11.74% (GY4). GY4 had significantly higher carbohydrate levels, likely due to the carbohydrate-rich rice milk. These values were lower than the 18.21% reported by Jiménez *et al.* (2022), who observed that Greek yoghurt have higher carbohydrate content than the plain yoghurt.

4.0 Conclusion

This study has shown that it is very feasible to produce Greek yoghurt by substituting cow milk rice milk. It was observed from the study that incorporation of rice milk in the yoghurt formulation significantly influenced the physicochemical properties of Greek yoghurt. The results showed slight increase in the pH, total soluble solids, total titratable acidity, water holding capacity and viscosity of the Greek yoghurt with increasing substitution of cow milk with rice milk. However, the syneresis indexes were reduced with the increasing level of substitution. The increased water holding capacity and viscosity which was attributed to the presence of starch in rice milk gave the yoghurt a good consistency and texture and also reduced occurrence of syneresis. The results of the nutritional analysis showed that inclusion of rice milk in the formulation slightly increased the moisture and crude fibre content. The ash content of the products was not affected significantly while the protein and fat content decreased slightly with increasing substitution of cow milk with rice milk. All the samples had low carbohydrate content although they differed significantly from one another

References

Ajogun, C. O., Achinewhu, S. C., Kiin-Kabari, D. B. and Akusu, O. M. (2023). Physicochemical Characteristics and Sensory Properties of Coconut Milk Based Yoghurt. *Research Journal of Food Science and Quality Control* 9(3): 92-104.

Anumba N., Eke-Ejiofor, J., Ishiwu, C. and Wabali, V. (2023). Physicochemical Properties and Sensory Evaluation of a Plant-Based Yoghurt Produced from Blends of Tiger Nut, Coconut and Dates. *World Journal of Food Science and Technology* 7(3): 48-56.

AOAC, (2023). Official methods of Analysis. 22th edition. Association of official Analytical chemists. Washington, D.C., U.S.A.

Atwaa, E. H., Elmaadawy, A. A. and Awaad, E. A. (2019). Production of Fruit Flavored Probiotic Rice Milk Beverage. *Journal of Food and Dairy Science, Mansoura University* 10(2): 453-458.

da Silva, L. R., Velasco, J. I. and Fakhouri, F. M. (2023). Use of rice on the development of plant-based milk with antioxidant properties: From raw material to residue. LWT - *Food Science and Technology* 173: 114271.

Ibrahim, A. N., Igwe, C. E., Asogwa, I. S., Agbaka, J. I. and Ajibo, Q. C. (2020). Influence of *Ocimum gratissimum* (Scent Leaf) on the Organoleptic Acceptability and Shelf Stability of Yoghurt. *Asian Food Science Journal* 16(1), 28–44

Ibrahim, A. H. and Khalifa, S. A. (2015). Improve sensory quality and textural properties of fermented camel's milk by fortified with dietary fibre. *Journal American Science* 11(3): 42-54

Ityotagher, A. P., and Julius, A. (2020). Physiochemical composition, sensory properties and keeping quality of functional yoghurt produced from milk-soy flour blends. *Journal of Nutritional Health Food Engineering,* 10(1):5–12.

Jiménez, M. E., García, L. M. H, Mérida, L. G. R., Alcano, M. and Richards, N. S. P. (2022). Greek vs traditional yogurts: Sensory and physicochemical comparison. *Revista Chilena de Nutrición* 49(2): 167-172.

Karastamatis, S.; Zoidou, E.; Moatsou, G. and Moschopoulou, E. (2022). Effect of Modified Manufacturing Conditions on the Composition of Greek Strained Yogurt and the Quantity and Composition of Generated Acid Whey. *Foods*, 11: 3953.

Ketaren, N. B., Hasanah, U. and Agustien, A. (2024). Physical quality of goat milk yogurt with the addition of pineapple and purple sweet potato. *IOP Conf. Series: Earth and Environmental Science*, 1302: 1-10.

Kumar, P. and Mishra, H. N. (2014). Effect of stabilizer addition on physicochemical, sensory and textural properties of soy fortified set yoghurt. *Journal of Food Chemistry 87:501 – 507.*

Mbae, J., Koskei, R. and Mugendi, B. (2023). Effect of Addition of Coffee Extract on Physicochemical and Sensory Properties of Yoghurt. *European Journal of Agriculture and Food Sciences* 5(1): 27-33.

Meletharayil, G. H., Metzger, L. E. and Patel, H. A. (2016). Influence of hydrodynamic cavitation on the rheological properties and microstructure of formulated Greek-style yogurts. *Journal of Diary Science* 99: 8537–8548.

Nelios, G.; Nikolaou, A.; Papazilakis, P. and Kourkoutas, Y. (2023). Developing New High-Protein-Content Traditional-Type Greek Yoghurts Based on Jersey Cow Milk. *Dairy* 4: 235–248.

Okoye, J. I., and Obi, C. D., (2016). Effect of Sweet Potato Starch Addition on the Proximate Composition, Energy Content and Sensory Properties of Stirred Yoghurts. *International Journal of Science and Research (IJSR)* 5(5): 929-931.

Onyimba, I. A., Chomini, M. S., Job, M. O., Njoku, A. I., Onoja, J. A., Isaac, D. C., Isaac, I. C., and Ngene, A. C. (2022). Evaluation of the Suitability of Tigernut Milk and Tigernut-Cow Composite Milks for Yoghurt Production. *European Journal of Biology and Biotechnology 3*(2): 38–44.

Silva, E. G., Anaya, K., Bezerra, M., Macêdo, C. S., Urbano, S. A., Borba, L. H., Barbosa, I., Ramalho, H. M., Cipolat-Gotet, C., Galdino, A. B., Oliveira. J. P. And Rangel, A. H. (2021). Physicochemical and sensory evaluation of greek style yoghurt with bovine colostrums. *Food Science Technology Campinas*, 1: 1 – 7.

Suman, S., Harshita, S., Susheel, G., Lalita, S., Archana, M. and Suryapal, S. (2023). The Magical Chemistry and Nutritional Importance of Rice Seeds: A Review. *Intechopen* 1: 1-9.

Uduwerella, G.; Chandrapala, J. and Vasiljevic, T. (2018). Minimizing generation of acid whey during Greek yoghurt manufacturing. *Journal of Dairy Research* 84: 346–354.

Wannasupchue, W. (2023). Chemical properties and sensory evaluation of sweetened condensed rice (*Oryza sativa* L.) milk. *Food Research* 7(4): 352 – 359

Proximate Analysis of Cooked and Raw Jackfruit Seed Flour

Eneasato O.S

Department of Food Science and Technology Federal Polytechnic Oko, Anambra State.

Correspondence: susaneneasato75@gmail.com

ABSTRACT

This study evaluated the proximate composition of cooked and raw jackfruit seed flour. The analysis covered the parameters, moisture, protein, fat, fibre, ash, and carbohydrate. The results revealed that moisture content ranged from 12.33%(cooked) to 13.00%(raw). Protein Levels were significantly higher in raw seeds (30.20%) compared to cooked seeds (21.38%). Fat content was relatively similar between the two forms: raw seeds (24.60%) and cooked seeds 24.00%. The fibre content also showed higher levels in raw seeds (12.63%) than in cooked seeds (11.81%). The ash content was slightly elevated in raw (3.37%) compared to the cooked seeds (3.11%). Conversely, carbohydrate content was higher in cooked seeds (27.37%) than in raw seeds (16.20%). These findings indicate that cooking significantly alters the nutritional profile of Jackfruit seeds, particularly affecting protein, fibre, and carbohydrate levels. This research highlights the importance of processing methods on the nutritional value of plant-based food sources, suggesting potential dietary applications for Jackfruit seed flour.

Keywords: Proximate, Jackfruit, composition, cooked, raw

1.0 Introduction

Since ancient times, seeds have played a vital role in human nutrition and wellness. These little yet powerful kernels are packed in vitamins and minerals that the body requires to function at its best. Chia (*Salviahispanica L*), Hemp (*Cannabis Sativa L.*), Pumpkin (*Curcubita Spp*), Sunflower (*Helianthus Anna's L.*) and Safflower (*Carthamus tinctorious L*) are some of the most popular seeds due to their health promoting compound (Alasalvar *et al*, 2021). These seeds are high in fibre and minerals like iron, calcium, magnesium, zinc, and phosphorus. They also act as energy boosters and storehouses of healthy fats like monounsaturated fatty acids, and polyunsaturated fatty acids, and are loaded with polyphenol like phenolic acids and Flavonoid, vitamin B antioxidants like vitamin E, selenium, and carotenoid along with proteins, essential amino acids, bioactive peptides, and phytoestrogen Hassan *et al*.,2011. Numerous researchers have shown that fruit seeds are rich in nutrients (dietary fibre, vitamins, and minerals), phytochemicals, antioxidants, food ingredients like pectin, natural colors, antifungal compounds and antimicrobial compounds etc. (Hassan *et al.,* 2011, Maniyan *et al*., 2015; Opara *et al.,* 2009). Jackfruit is a dicotyledonous compound fruit of the jack tree (*Artocarpus heterophyllus* L.) which belongs to the family Moroceae which grows in many of the tropical countries of Southeast Asia. The Jackfruit seeds are approximately 2-3 cm long and 1-1.5 cm in diameter with a light brown color and rounded shape (Prakash *et al*., 2009). Approximately, 10-15%of the total weight of a Jackfruit consists of seeds. These seeds are enveloped by the fruit's flesh and are situated within a white aril. This aril surrounds a delicate brown seed coat, which in turn encases the fleshy white cotyledon. The seeds are edible after being cooked or fried or roasted. Additionally, their flour is utilized for the preparation of different food products like cake, bread, cookies, biscuits, noodles, etc. These seeds are abundant in carbohydrates and proteins Babu *et al* (2017). The seeds are packed with nutrients, including carbohydrates, fat, potassium, and minerals such as Mn and Mg, which are also present in the Jackfruit seed powder. Considering the rich nutritional and health values of Jackfruit seeds, there is need for quality assessment to ascertain their economic value and improve their utilization.

2.0 Materials and Methods

The Jackfruits (3kg) were purchased from the market from *Eke Market* Ekwulobia Aguata L.G.A of Anambra State.

2.1 Preparation of cooked Jackfruit seed flour

The seeds were extracted from the Jackfruits. 2.5 kg of Jackfruit seeds which were free from dirt and other foreign particles such as stones, sticks and leaves were weighed, cleaned and 2kg of the seed were boiled in water for 30min. Thereafter, the seeds were washed manually then dried in a cabinet dryer at 65°C for 6hrs. The dried seeds were milled (Model SK-30-SS Attrition mill from China) and sieved with 300 mesh sieved to obtain a finer Jackfruit seed flour. Flour obtained was finally packed in air tight polyethylene containers.

2.2 Preparation of raw jackfruit seed flour.

The remaining ½ kg of Jackfruit seeds which were free from dirt and other foreign particles such as stones, sticks and leaves were washed in tap water. The seeds were then dried in cabinet dryer (65^{o}C, 6hrs). The dried seeds were milled (Model SK-30-SS Attrition mill from China) and sieved with 300 mesh sieved to obtain a finer Jackfruit seed flour. Flour obtained was finally packed in air tight plastic container.

2.3 Determination of Proximate composition

The proximate composition of the Jackfruit flour was determined using the AOAC (2010)

2.3.1 Determination of moisture

The moisture content was determined by hot oven method. 5g of crucible sample was weighed and placed in a hot air oven at 100^{o}C for about 6h and reweighed. The procedure was repeated till a constant weight was achieved. The crucible with the sample were allowed to cool and were put in a desiccator for about 30minutes. The crucible was weighed again and then the moisture content was calculated using the following formula

$$\text{Moisture (\%)} = \frac{\textit{weight of sample (g)-weight of dried sample (g)}\times 100}{\textit{weight of sample(g)}}$$

2.3.2 Determination of crude ash

To determine the Ash content, empty and clean crucible was placed in a muffle furnace to around 600^{o}C for 1h. Immediately it was cooled, the crucible was weighed. 2g of sample was placed in the crucible and the sample was charred using a burner. After Charring, the crucible was placed again in muffle furnace for 4h at 550^{o}C. The occurrence of grey and white matter showed oxidation of organic matter. The machine was turned off. The Ash content was determined after cooling as follows:

$$\text{Ash (\%)} = \frac{\textit{weight of Ash sample (g)}\times 100}{\textit{weight of sample (g)}}$$

2.3.3 Determination of crude fat/lipid

Crude Fat was determined using Whatsman Filter paper along with ethanol and N-hexane as a solvent. 2g of dried sample was weighed and put in extraction flask then closed with a cotton plug. The sample was introduced into a beaker containing ethanol and N-hexane and was heated using heating mantle. Crude fat was determined using the formula below:

$$\text{Crude fat (\%)} = \frac{\textit{weight of petroleum ether extract} \times 100}{\textit{weight of original sample (g).}}$$

2.3.4 Determination of crude fibre.

Oven dried fat free sample of about 2g was used to determine crude fibre in a glass beaker for 30min in 200ml of boiling H_2SO_4 (1.25%). The sample was digested, filtered and washed three times to make it acid-free. The filtered sample was digested again for 30min in 200ml of boiling distilled 1.25% NaOH. The sample was filtered and washed three times to make it alkali. The filter sample was dried in a hot oven at 105°C. The crucible was put in a muffle furnace for fibre content. The percentage fibre was determined using the following formula:

$$\text{Crude Fibre (\%)} = \frac{\textit{Oven dried weight - weight of incineration in furnace} \times 100}{\textit{Weight of original sample (g)}}$$

2.3.5 Determination of crude protein

Kjehdal apparatus was used in determining the Nitrogen percentage. A samp2g of concentrated H_2SO_4 was taken. Digested mixture (5g of potassium sulphate, copper sulphate, ferric sulphate with 100:10.5 parts) was taken. The sample was added in it and digested until it turned green after 6h. The sample was filtered and made up the volume up to 250ml in a volumetric flask. About 10ml solution was distilled with 40% boric acid. After distillation, it was titrated with 0.1mole NH_2SO_4 to attain a light pink colour as an end point. The following formula was used to obtain crude protein.

$$\text{Nitrogen (\%)} = \frac{\textit{Volume of 0.1N}NH_2SO_4\textit{ used (ml)} \times \textit{Volume of distillation (m)} \times 0.0014 \times 100}{\textit{Weight sample in g} \times \textit{Volume of distilled Solution (ml).}}$$

2.3.6 Determination of carbohydrate

Total carbohydrate was determined by subtracting the amount of ash, protein and fat from the total dry matter. That is, Percentage of Carbohydrates = 100 - (moisture + protein + Crude fat + Crude fibre + Ash).

3.0 Results and Discussions Results.

Table 1 shows the proximate composition values of the Jackfruit seed flour. The moisture content (12.33%) of the boiled Jackfruit seed flour was lower than the value obtained for raw sample (13.00%). Boiling could have induced hydrophilic-hydrophobic interaction within the jackfruit seed which led to reduction in the amount of moisture escaping from the seed during dehydration. The values obtained from the study is higher than the range of moisture (4.83% to 10.41%) reporter for selected plant seeds flours by Buitrago *et al* (2015) but lower than the report by Azeez *et al*, (2015) for Jackfruit clones of J29(24.08%), J31(14.26%) and J33(14.26%),.Conversely, the moisture value reported in this study was higher than the amount of 6.09% found by Ocloo *et al* (2010) in Jackfruit seed. Lower moisture content increased the shelf stability and the quality of flour. The differences in moisture content might have resulted from the different methods of the processing. Moisture content provides the quantity of water in the seed flour as well as its total solid content (Ocloo *et al*, 2014).

The crude protein content of the Jackfruit seed flour investigated was lower (21.38%) in the boiled sample while a higher value (30.20%) was obtained for raw sample. Cooking of the seed may have degraded the protein composition of the seed. This value was higher than the protein values observed in the *Artocarpus odoratissimus* (8.78%), *A. altilis* (8.12%) and *A. integer* seed flour (Tukura and Obliva, 2015; Masri *et al*.,2017). Furthermore, the protein content reported for the Jackfruit seed flour was also higher than the value reported for Jackfruit clones such as J29 (7.62%), J31(8.46%) and J33(8.24%) seed flour (Azeez *et al*.., 2015). Much lower values of 12.25 - 16.80% and 13.50% protein was also reported by Eke-Ejiofor *et al* (2014) and Ocloo *et al* (2010) respectively, for selected plant seeds.

The fat content obtained was 24.00% for boiled sample and 24.60% for the raw sample. Some fats may have leached into the boiling water, hence the slightly higher fat value of raw sample than the boiled sample. The lipid content was much higher than the published value (0.47%) reported by Adebowole (2015). The values were also higher than reported by Andualem and Gessesse (2014) for Brebra seed flour. The result was also higher than 0.4% fat reported by Sreeletha *et al* (2017) and relatively high when compared to other *Artocarpus* species seed flour such as Tarap (15.60%) and breadfruit (9.0%) seed flour (Akubor *et al*., 2000; Masri *et al*., 2017). The relatively high fat value suggests that the flour will be prone to lipid-related forms of detoriation (Okpala and Gibson,2013).

The crude fibre value 11.81% was obtained for cooked Jackfruit seed while a higher value of (12.63%) was obtained for the raw Jackfruit seed flour. Soluble fibres may have been washed away in the boiling water hence the lower fibre content of the boiled sample. The values obtained from the seed sample were higher than the range 1.10% to 1.4% reported by Andualem and Gessesse (2014) for Brebra (*Millrttia Ferruginea*) seed flour.

From table 1 the ash content for cooked jackfruit was observed to be 3.11%, while that of raw jackfruit was 3.37%. The drying of the seeds might have improved the ash content as higher value of ash was reported for Mucuna seed flour (14.44%) on dry weight basis (Adebowale 2005), while a slightly higher value (0.84%) was reported by Andualem and Gessesse (2014) for Brebra (*Millettia ferruginia*) seed flour. The ash content is the residual of inorganic materials remaining after the organic matter has been removed by heating (Ocloo *et al*., 2010).

The carbohydrate value was 27.37% for cooked jackfruit while that of raw jackfruit was 16.20%. The value was higher compared to the value (16.20%) reported by Andualem and Gessesse (2014) for Brebra (*Millettia Ferruginea).* Again, the carbohydrate content values presented in this study were also higher than those of mucuna seed flour (14.20%) by Adebowale (2005). The carbohydrate value was also higher when compared to other *Artocarpus* species such as breadfruit (58.9%) and Tarap (49.65%) seed flour (Akubor *et al*.,2000; Masri *et al*.,2017)

Table 1

Results of the proximate composition of jackfruit seed powder

Parameters	Cooked Jackfruit seed	Raw Jackfruit seed
Moisture	12.33+0.19	13.00+0.13
Protein	21.38+1.17	30.20+0.15
Fat	24.00+0.32	24.60+0.21
Fibre	11.81+0.01	12.63+0.61
Ash	3.11+0.01	3.37+0.11
Carbohydrate	27.37+0.01	16.20+0.13

4.0 Conclusion and Recommendations

The study revealed that Jackfruit seed is a good source of nutrient-rich flour considering it's the analysed proximate compositions. It revealed that cooking slightly reduced the protein, fat, and moisture content of the Jackfruit but increased the ash and carbohydrate contents. Various factors, such as temperature, cooking time and cooking method can influence the extent of nutrient loss during the boiling process. It is important

to consider the impact of nutrient loss on the overall nutritional value of boiled Jackfruit and to take steps to mitigate these losses to maintain its nutrient content.

Based on the conclusion that boiling Jackfruit seed can result in the loss of essential nutrients, it is therefore recommended to minimize the cooking time when boiling Jackfruit seed. This can help to preserve heat-sensitive nutrients.

References

Adebowale, Y.A, Adeyi, I.A and Oshodi, A.A (2005). Functional and Physicochemical properties of flours of six *mucuna* species. *African Journal of Biotechnology*. 4 (12).

Alasalvar, C., Chang, S. K. C., Shahidi, F., and Hwang, H. I. (2021). "Nutritional and health benefits of specialty seeds: An overview." *Critical Reviews in Food Science and Nutrition*, 61(7); 1197-1211.

Andualem, Berhanu and Gessesse, Amare. (2014). Proximate composition, mineral content and antinutritional factors of Brebra (Millettia ferruginea) seed flour as well as physicochemical characterization of its seed oil. *SpringerPlus*. 3. 298. 10.1186/2193-1801-3-298.

Akubor P.I, Isolokwu P.C, Ugbanne O., Onimawo I, (2002) Promimate composition and functional properties of African breadfruit kernel and wheat flavor. *Food processing international* 33 (8): 707-712

Azeez, S.O., Lasekan, 0., Jinap, S. and Sulaiman, R. (2015). Physico-chemical properties, amino acid profile and antinutritional factors in seeds of three Malaysian grown jackfruit cultivars. *Journal of Food, Agriculture and Environment*, 13(2), 58-62.

Babu, N.G, Kumar S and Sundar S (2017) Extraction and Comparison of properties of Jackfruit seed oil and sunflower seed oil *International Journal of Scientific and Engineering Research* 8(11): 635-639

Buitrago M., Paquette A., Thiffault N., Belanger N., Messier C. (2015). Early performance of planted hybrid larch: effects of mechanical site preparation and planting depth. *New Forests* 46(3): 319-337.

Eke-Ejiofor, J., Beleya, E.A. and Onyenorah, N.I. (2014). The effect of processing methods on the functional and compositional properties of jackfruit seed flour. *International Journal of Nutrition and Food Sciences*, 3(3), 166-173.

Hassan, F.A., A. Ismail, A.A. Hamid, A. Azlan, and S.H. Al-sheraji. 2011. Characterization of fibre-rich powder and antioxidant capacity of Mangifera pajang K. fruit peels. *Food Chemistry*. 126(1):283-288.

Madruga, M.S., de Albuquerque, F.S., Silva, I.R., doAmaral, D.S., Magnani, M. and Queiroga Neto, V. (2014). Chemical, morphological and functional properties of Brazilian jackfruit (Artocarpus heterophyllus L.) seed starch. *Food Chemistry*, 143:440-445.

Maniyan, A., R. John, and A. Mathew. 2015. Evaluation of fruit peels for some selected nutritional and anti-nutritional factors. Emergent Life Science Research, 1(2), 12-19.

Ocloo, F.C.K., Okyere, A.A. and Asare, I.K. (2014). Physicochemical, functional and pasting properties of flour produced from gamma irradiated tiger nut (Cyperus esculentus L.). *Radiation Physics and Chemistry*, 103, 9-15.

Opara, L.U., Al-Ani, and Y.S. Al-Shuaibi. 2009. Physico-chemical properties, vitamin C content and antimicrobial properties of pomegranate fruit (Punica granatum L.). *Food Bioprocess Technology*. 2(3):315-321.

Prakash, 0., Kumar, R., Mishra, A., and Gupta, R. (2009). Artocarpus heterophyllus (Jackfruit): An overview. *Pharmacognosy Reviews*, 3, 353-358.

Sreeletha, A.S., Lini, J.J., Dhanyalekshmi, C.S., Sabu, K.R. and Pratap, C.R. (2017). Phytochemical, Proximate, Antimicrobial, Antioxidant and FTIR Analyses of Seeds of Artocarpus heterophyllus Lam. *Advances in Biotechnology and Microbiology,* 5(1), 555-653.

Formulation and Evaluation of Nutrients Values and Sensory Properties of Complementary Diet from Millet (*Pennisetumglaucum*), Soybeans (*Glycine max)*, Groundnut (*Arachishypogaea*) and Date palm (*Phoenix dactylifera L.*) for children (6-24 months)

*Sa'eedu, A.M.[1], Haruna, H.[2], Osagede, E.A.[2], Daniel C.S.[2], Anda, S.A.D.[3], Sulaiman, L.A[5], Ishaq, R.A[5], Ejembe, P.A[3], Agboola, F.O[4], and Sale, A.[1].

[1]Nutrition and Dietetics Department, College of Medical Sciences, University of Maiduguri, Nigeria. [2]Nutrition and Dietetics Department, College of Agriculture, Science and Technology Lafia, Nasarawa State. [3]Home and Rural Economics Department, College of Agriculture, Science and Technology Lafia, Nasarawa State. [4]Nutrition and Dietetics Department, Shehu Idris College of Health, Science and Technology Makarfi, Kaduna State. [5]Nutrition and Dietetics Department, Nasarawa State College of Health, Science and Technology, Keffi.

*Corresponding author's email: auwalsaeedu@gmail.com

ABSTRACT

This study investigated the nutrient values and sensory properties of a complementary food blend produced from millet, soybeans, groundnut, and dates. Evaluation of the nutritional values of the formulated complementary food blend for texture, taste, appearance, and general acceptability were assessed by 15 judges using a 6-point scale. The formulated food blend had an energy value of 418.02kcal, with a composition of 57.98% carbohydrate, 17.50% crude protein, 12.90% crude fat, and 5.70% moisture. The food's texture, taste, and appearance were acceptable to panelists, with mean scores of 5.13, 5.40, and 5.00, respectively. The study concluded that complementary foods with improved nutritional values and acceptable sensory qualities can be produced by adding nutrient-dense crops like dates.

Key words: Complementary food, nutrients-dense, sensory qualities, diet, and nutritional values

1.0 Introduction

Breast milk is the best food for infants and supports them with all necessary nutrients for babies' normal mental and physical growth. However, breastmilk alone is no longer sufficient to meet the nutritional needs of the growing babies after 6 months of their age (Hampson *et al*., 2019). So, children need additional foods to support their growing nutritional demands besides mother's milk, begin from 6 months and continue to 24 months of age or beyond (WHO, 2019). Complementary foods are foods other than breast milk given to children during the second part of the first year of life for both nutritional and developmental reasons to enable transition from breastfeeding to family foods. It needs to be balanced and nutritionally well-adjusted for the babies (Cichero, 2016; Koletzko *et al*., 2019). Undernutrition can be particularly caused by consuming inadequate energy, vitamins, and minerals (WHO, 2021). Children from low-income households have limited access to nutritious food and healthcare resources that increase their risk of malnutrition (Frison *et al.,* 2017). Children from marginalized communities, including ethnic minorities often time experience discrimination, social inequalities, and lack of resources contributing to the higher rates of malnutrition among them (Frison *et al.,* 2017). The high cost of enriched nutritious proprietary complementary foods is always beyond the reach of the Nigerian average family; hence many depend on inadequately processed traditional foods consisting mainly of foods not supplemented cereal porridge made from maize (*Zeamays*), guinea corn (*Sorghum bicolour*) and millet (*Pennisetumglaucum*) popularly called *pap* or *ogi* in Nigeria. Thus, this study was therefore undertaken to formulate and evaluate the nutrients values and sensory properties of complementary diet from millet (*pennisetumglaucum*), soybeans (*glycine max)*, groundnut (*arachishypogaea*) and date palm (*phoenix dactylifera l.*) for children between ages 6-24 months.

2.0 Materials and Methods

2.1 Sources of Materials

Pearl millet (*Pennisetumglaucum*), Soybeans (*Glycine max*), Groundnut (*maiborgo*) (*Arachis hypogaea*) and date (*Dan Shuwarin*) (*Phoenix dactylifera L.*) were purchased from Lafia modern market, Nasarawa state.

2.1.1 Processing of the ingredients into flour and formulation of the complementary food blend

The millet was sorted, washed, sun-dried and roasted; the soybeans was sorted, soaked for 12 hours, de-hulled, washed, sun-dried and roasted; groundnut was sorted, roasted and winnowed while date fruits were sorted, sliced to remove seeds, washed and sun-dried. After which all the ingredients were then mixed together at the ratio 6:3:1:1 and milled into fine flour.

2.2 Chemical Composition of complementary food flour

Moisture content, crude fat, total ash, crude fibre, crude protein of the complementary food flour was determined using the AOAC (2010) methods and total carbohydrate was calculated by difference while energy was calculated using the Atwater Conversion factors in Kcal.

2.2.1 Sensory Evaluation of the complementary food

Fifteen (15) untrained taste panelists examined the sensory attributes of the formulated samples. About 100 ml of the complementary food poured into a transparent glass bowl and presented to them rate the samples on perceived intensities of standard sensory attributes (Taste, Texture, Appearance and General Acceptability) using a 6-point score with 6 as excellent, 5 as very good, 4 as good, 3 as undecided, 2 as fair, and 1 as poor and 1. Drinking water was served in glass for panelists, and they properly rinsed their mouths before and after tasting each sample.

2.2.2 Statistical analysis

Experiments were conducted in triplicates. The means and standard deviations (SD) were calculated taking all the readings into consideration. Statistical analysis was performed using SPSS (Statistical Package for Social Sciences, version 21.0). One sample t-test at the level of significance ($p < 0.05$) was performed to ascertain the significance of the means.

3.0 Results and Discussion

Moisture, proteins, fats and carbohydrates were the major components of millet, soybean, groundnut and date formulated complementary food flour (Table 1). Fortification with roasted soybeans has been shown to improve nutritional composition of 'ogi' as reported by Adeyemo and Onilude, (2019). Dates have a consortium of nutrients that are prolific with high carbohydrate content mainly in the form of sugars, a rich dietary fibre content, an abundance of vitamins and minerals, and, ultimately, high levels of both antioxidant activity and phenolic content. The sweet– savoury sensation derived from dates is attributed to the enormous abundance of natural sugars that are sucrose, glucose and fructose. There was balance carbohydrate (57.98%), protein (17.5%), fat (12.9%), fibre (4.9) and total ash (1.02%) content in the complementary food formulated in this study. The results were similar to the findings of Jahan *et al.* (2021) who reported that a good-quality complementary food has balanced protein and calorie contents, adequate vitamins and minerals, and low fibre with a soft texture.

The protein content (17.50%) may be as results of soybeans and groundnut added to the formulation. The result is similar with Saeeda *et al.* (2009) who reported 17.5% crude protein from wheat, pea, cabbage and groundnut blend; but lower than the protein content (27.70g in 100g), reported by Jahan *et al.* (2021) from a locally formulated complementary food made from wheat, mung beans and soybeans and that of Bassey *et al.* (2013), who reported a weaning food formulated from cowpea and local cereals in Nigeria had 25.31% protein composition. A previous study on complementary feeding in London reported that high protein intake at age 6–24 months is positively associated with the proper growth of the children (Jabri *et al.*, 2020). There was adequate composition of fat (12.90%) in the formulated complementary food under study. Fat composition is higher than that reported by Jahan *et al.* (2021) and Muhammed *et al.* (2021) from various

samples of locally made complementary foods in their studies. The complementary food blend favorably compares with the recommended dietary allowance (RDA) for infant's nutrition (Muhammed *et al*., 2021) and also with the ideal amount of fat in weaning food which should be up to 10% (Sajilata *et al*., 2002). Legumes are good sources of unsaturated fatty acids and as such this formulated complementary food is rich in unsaturated fatty acids compared to Polak *et al*., 2015. According to Laminu *et al.* (2014), food with high fat and moisture content is more liable to spoilage than one with the low fat and moisture content. The carbohydrate composition reported in this study is similar to that reported by Jahan *et al.* (2021) in 100g sample of all formulations (52.80 – 61.20%) but a lower carbohydrate content than the content of six commercial complementary foods (71.24 – 76.92%) studied by Jahan *et al.* (2020). The higher energy value (418.02kcal/100g) is similar to that reported by Jahan *et al.* (2020) (416.65 Kcal). It's noted in many studies that children at complementary feeding age need more energy to cope up with their daily requirements. The first year of life is important for the growth of gut microflora. Low dietary fibre can inhibit infant growth; and has implications for child constipation and appendicitis (O'Keefe, 2019). The fibre content in this formulated sample was 4.90% slightly higher that 3.15% reported by Jahan *et al.* (2021). The total ash content in this study was 1.02% (table 1), which meets the recommended ash content by WHO/FAO (2004) for complementary food (<5 g/100 g).

The results from the mean sensory attributes (including texture, taste, overall acceptability and overall acceptance) scores of the complementary foods are presented in figure 1. Taste and overall acceptability were the most liked sensory attributes while appearance was the least liked sensory attribute. The result obtained for the overall acceptability of the complementary food is consistent with the previous report of Muhammed *et al* (2021) which revealed that the formulated complementary food blend had an overall acceptability when compared to the cereal only based food 'Akamu'. The improvement of the nutritional values of the complementary food in this study by the combination of roasted soybeans, groundnut and date palm has significantly improved the texture, taste and appearance of the babies' food. According to Muhimbula *et al*., (2011); Bintu *et al*., 2019), food processing techniques help in enhancing the palatability and storage ability of foods.

Table 1: Proximate Composition of complementary food powder

Parameters	**Composition per 100g**
Moisture (%)	5.70±0.01
Crude protein (%)	17.50±0.02
Crude fat (%)	12.90±0.03
Total ash (%)	1.02±0.01
Crude fibre (%)	4.90±0.02
Carbohydrate (%)	57.98±0.01
Caloric Value (Kcal/100g)	418.02±0.39

Values recorded as mean ± SD of triplicate determinations.

Figure 1: Overall acceptability of the formulated complementary food by the panelists on a 6-point scoring chart.

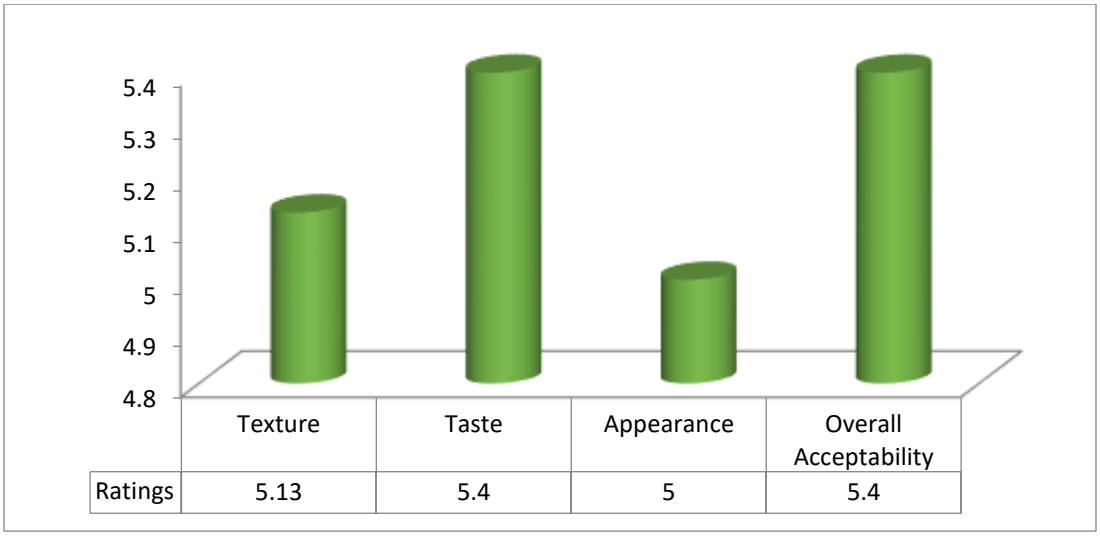


Figure 1: Column graph showing results of 6-point hedonic scale sensory evaluation of the formulated complementary food blend.

4.0 Conclusions and Recommendation

From this research, we conclude that complementary food with improved nutritional values and acceptable sensory attributes can be formulated from millets, soybeans, groundnuts and dates. This complementary food is a good source of proteins and energy, which can be potentially used to address the prevailing acute malnutrition among vulnerable groups especially in developing countries like Nigeria. The use of locally and affordable ingredients which have good nutritional composition and sensory attributes, is recommended to produce acceptable complementary of good sensory and nutritional quality.

Reference

A.O.A.C. (2010). Official Methods of Analysis of Association of Official Chemists.18th Ed., Washington, D.C., USA.

Adeyemo S. M. and Onilude A. A. (2018). Weaning food fortification and improvement of fermented cereal and legume by metabolic activities of probiotics Lactobacillus plantarum Article Number - C9A41FF58519. *African Journal of Food Science* 12(10): 254 - 262

Bassey, F.I., Mcwatters, K.H., Edem, C.A., Iwegbue, C.M.A., (2013). Formulation and nutritional evaluation of weaning food processed from cooking banana, supplemented with cowpea and peanut. *Food Science and Nutrition* 1 (5), 384–391.

Bintu BP, Falmata AS, Maryam BK, Raihatu MA, Chellube Z, Hauwa H and Modu S (2019). Microbial, pH, titratable Acidity, Functional and Sensory Properties of Complementary food blend Blends Formulated from Maize, Cowpea, Bambara nut and Groundnut. *Food Science and Nutrition* 3(2): 60 - 72

Cichero, J.A.Y., (2016). Introducing solid foods using baby-led weaning vs. spoon-feeding: a focus on oral development, nutrient intake and quality of research to bring balance to the debate. *Nutrition Bulletin* 41 (1), 72–77.

Frison S, Blanchet K, Ramesh A, *et al.* (2017). Evidence on public health interventions in humanitarian crisis. *The Lancet*. 2017;390(10109):2287-96.

Hampson, G., Roberts, S.L.E., Lucas, A., Parkin, D., (2019). An economicj analysis of human milk supplementation for very low birth weight babies in the USA. BMC Pediatr.

Jahan, S.A, Bisrat, F.B, Omar, F.C, Ferdaus, J.C, Sharmin, S.K.A, Farzana, T. (2021). Formulation of nutrient enriched germinated wheat and mung-bean based weaning food compare to locally available similar products in Bangladesh.

Koletzko, B., Bührer, C., Ensenauer, R., Jochum, F., Kalhoff, H., Lawrenz, B., Zimmer, K.P., (2019). Complementary foods in baby food pouches: position statement from the Nutrition Commission of the German Society for Pediatrics and Adolescent Medicine (DGKJ, eV). *Molecular and Cellular Pediatrics 6* (1), 1–5.

Laminu HH, Sheriff M, Bintu BP and Mohammed AA (2014). Evaluation of the protein Quality of composite meals produced from selected cereals and legumes of infants. *Scholarly J. Agr. Sci.* 4(11): 536 – 542

Mohammed, Z.K., Petrol, B.B., and Ahmad, U (2021). Formulation and nutritional evaluation of a complementary food blend made from fermented yellow maize (Improved variety), soybean and African cat fish meal. *Nig. J. Biotech.*38 (1) 98-108

Muhimbula, H.S., Issa-Zacharia, A., Kinabo, J., (2011). Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania. *African Jornal Food Science.* 5 (1), 26–31.

O'Keefe, S.J., (2019). The association between dietary Fibre de□ ciency and high-income lifestyle-associated diseases: burkitt's hypothesis revisited. *Lancet Gastroenterology and Hepatology* 4 (12), 984–996.

Polak, R., Phillips, E.M., Campbell, A., (2015). Legumes: health bene□ ts and culinary approaches to increase intake. *Journal of Clinical Diabetes* 17, 198–205.

Saeeda, R., Muhammad N. S., Amer M., Noumann S., Khalid N., and Muhammad A. (2009). Preparation and quality evaluation of nutritious instant baby food from indigenous sources. Pak. J Agri. Res. 22:50–55.

Sajilata, G., Singhal, R.S., Kulkarni, P.R., (2002). Weaning foods: a review of the Indian experience. *Food and Nutrition Bulletin 23* (2), 208–226.

WHO (2021). Obesity and Overweight. Geneva.

WHO/FAO. (2004). Human vitamin and mineral requirements. Report of a joint FAO/WHO consultation, Bangkok, Thailand. Rome: Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO).

World Health Organisation (2019). Appropriate complementary feeding. E-Library of evidence for nutrition actions (ELENA). Retrievd from. https://www.who.int/elena/titles/complementary_feeding/en/. Accessed January 25, 2025

Role of Artificial Intelligence in Foodservice Systems/Operation: A Review

*Nwigwe, I. C.[1] and Nwankwegu, R. O.[2]

[1]Department of Nutrition and Dietetics, David Umahi Federal University Teaching Hospital Uburu, Ebonyi State, Nigeria. [2]Department of Food Science and Technology, Ebonyi State University, Abakaliki, Nigeria.

*Corresponding author's email: nwigweikenna@gmail.com

ABSTRACT

Artificial intelligence (AI), being one of the latest technologies of interest has proven useful in different sectors of human endeavors. AI's prospects and utility are significant considering the continuous updates and improvement in the foodservice industry and food value chain. This paper explores the role AI plays in foodservice operations to address food handling operations and guarantee food safety. It further explores AI's incorporation in waste management, food regulations and data/record keeping. It ends with exploring the concerns to this technology and concludes by encouraging continuous human monitoring and machine learning updates, to maintain accuracy.

Keywords: Machine learning, foodservice, hospitality, food system

Introduction

Alan Turing, a British mathematician and philosopher, is often credited as the father of artificial intelligence (AI). The question, "Can machines think?" gave birth to the so-called "Turing machine" (Mijwel, 2015). Turing machine was a device capable of performing a programmed mathematical operation, so long as it was represented by an algorithm.

Russell and Norvig (2016) defined AI as a system that imitates cognitive functions generally associated with human attributes such as learning, speech and problem solving. Kaplan and Haenlein (2019) further defined AI as the ability of a system to correctly interpret external data, learn from it and achieve specific goals through adaptation.

AI terminology includes two main terms; machine learning (ML) and deep learning (DL). Machine learning is a subset of artificial intelligence that helps people build AI-driven applications which focuses on programming, automation, scaling, and the inclusion and storage of results. On the other hand, Deep learning is a subset of machine learning that uses vast volumes of data and complex algorithms to train a model. It uses artificial neural networks in the same way the human brain processes information. Deep learning imitates human thinking by combining multiple layers of algorithms to process data. As data moves through each layer, algorithms convert some of the data elements into a numeric format which makes processing data easier.

Recent advances in information and communication technology have had tremendous impact in AI, with the application currently utilized in several fields in government, education, medicine and engineering (Micheni *et al.,* 2024). The food industry has also recorded some successes with the use of emerging technologies facilitating global adoption (Jan *et al.,* 2022; Mariani *et al.,* 2023). For example, Orbisk, an AI-based waste management tool, has connected weight scales that reduces cooking waste by recording the quantity of food waste during disposal, categorizing sources of waste and proffering recommendations from a pre-programmed food waste coach (ACCOR, 2021). Taneja *et al.,* (2023) estimates that the global population will reach around 9.7 billion in 2050, thus leading to demographic changes, increase in world population, urbanization, and an increasingly ageing populace, thus the improving the demand for food

and altering the consumption patterns of people (Brini 2023). Against this, a precedent in potential food waste and pressure exerted on available resources in food systems will arise, leading to an increase in competition for limited resources, exacerbation of food insecurity, malnutrition in vulnerable populations, increase of climate change, and degradation of natural resources due to increased food demand (FAO, 2024).

Do-Rosario and Walton (2019) explains that the search for pleasure (e.g., as seen in restaurants) or food consumption as a necessity in institutional settings (e.g., as seen in hospitals, nursing homes, prison etc.) have necessitated more meals being consumed away from home. With the Internet of Things (IoT) enabling seamless access to extraordinary amount of data and information, Omigie *et al.,* (2023) asserts, the global AI and IoT market would reach an estimated over $26.79 billion at a growing rate of a compound annual growth rate (CAGR) of 29.6% and as such, AI-based solutions hold tremendous benefits in the foodservice industry; improving cost savings on employee training, quicker problem solving with fewer human errors and human interferences, with cost effective automated, accurate, and reliable decision-making processes (Ikram *et al., 2024)*. Due to numerous food safety crisis and occurrences, a well-documented traceability system has also become important for quality assurance in the food supply chain.

Importance and Application of AI In Foodservice Systems

Food safety and hygiene: Food safety management utilizes a traditional approach, which struggles to keep up with the evolving landscape of food safety risks as they are often reactive in nature (Kumar and Maheshwari, 2024). These conventional methods typically involve responding to incidents after they have occurred rather than preventing them beforehand. Globalization in food supply chain and its intricate nature has led the limitations of these reactive methods become more apparent, giving rise to the need for more robust and effective management systems (Abideven *et al.,* 2021). AI in food safety is seen in predictive analytics as ML algorithms can analyze historical data on foodborne illness outbreaks, supply chain logistics, weather patterns, and other relevant factors, to predict the occurrence of future outbreaks. This predictive capability allows for more targeted and timely interventions, which can significantly reduce the incidence of foodborne illnesses as AI algorithms can process data from temperature and humidity sensors to ensure that perishable goods are stored under optimal conditions; preventing spoilage and contamination.

Menu development and online ordering: Menus play a central role as the presentation and selection of food items in an attractive and well-thought-out manner, which contributes to the overall success of foodservice delivery (Al-Amro, 2025). With advancements in technology, the foodservice industry can benefit from modern tools such as online ordering, mobile applications for payment and ordering, and AI-powered electronic menus (e-menus). The use of AI in application development can utilize individual preferences, factors such as weather and time-of-day, to provide clear illustration and concept of food ingredients as well as offer customers thoughtful, personalized choices of food products.

Inventory management/Supply chain: For agri-food products that are raw materials for food production, there are intricate characteristics in the supply chain due to the perishability, seasonality, fluctuating nature, as well as increased consumer awareness of product quality and safety (Kamble *et al.,* 2018). AI in supply chain optimization epitomizes a transformational shift bent towards upholding efficiency, transparency and sustainability of agri-food industry (Taneja *et al.,* 2023). AI algorithms can be employed to analyze the data on product characteristics, environmental conditions, transport mechanism and other relevant factors, in order to elevate the packaging and shelf life of food products. Also, the foodservice industry can optimize logistics through predictive analytics and real-time monitoring, using big data analytics integrated with Artificial Intelligence. This will enable foodservice to anticipate demand fluctuations and optimize inventory management accordingly.

Workforce management and training: With support from AI and insights into data, strategic labor deployment, machinery use and inputs have led to improved productivity and efficiency, and creating a positive working environment (Ajlal, 2023). AI can transform the education/training of Foodservice personnel by automating the administrative responsibilities, providing prompt feedback, and customizing

teaching strategies to meet the students' individual needs. AI can aid assessment and grading systems, affording trainers the time to concentrate on designing curricula and delivering exceptional training modules. Using AI educational tools, the foodservice operators can be trained to acquire skills in problem-solving and online collaboration, enhancing learning quality.

Financial management and costing: AI, with its capabilities in data analysis, predictive modeling, and automation, can offer powerful tools for improving overall decision-making processes by enhancing cost prediction accuracy and optimizing resource allocation (Deeba *et al.*, 2023). In financial management and cost estimation, AI makes significant impact when it comes to automating routine and repetitive tasks. In changing conditions, such as supply chain disruptions or labor shortages, AI can continuously update cost estimates as project makes progress (Hutchings, 2024). This predictive analysis capabilities, which extends beyond mere cost estimation, can help foresee potential risks and challenges that might inflate costs in the future, allowing businesses to prepare and allocate resources more effectively.

Environmental regulation and waste management: Improper waste disposal poses many environmental and health risks, such as groundwater contamination, land degradation, increased cancer incidence, child mortality, and congenital disabilities (Fang *et al.*, 2023). Nwigwe *et al.* (2025) has disclosed that foodservice is responsible for 20.4% of food waste with the global estimates close to 2.6 trillion dollars. The incorporation of AI and robotics in the design and operation of waste treatment plants can revolutionize how food waste is managed, leading to increased operational efficiency and more sustainable waste management practices (Goutam Mukherjee *et al.*, 2021; Yigitcanlar and Cugurullo, 2020). AI technologies, particularly for sorting and treating solid waste, are increasingly critical in waste management. Waste management can be achieved using AI by designing ML algorithms that record, using sensors, the quantity of food waste, categorize the sources of waste and proffer recommendations in accordance with encoded sanitary laws.

Documentation/ record keeping: Applying AI to records keeping and archival management system would greatly provide excellent management control system and valuable documentation (Omigie *et al.*, 2023) as AI's predictive analytics capabilities can analyze historical data/record patterns, which provides insights into future records management requirements as well as help the foodservice industry identify trends and patterns in their recordkeeping that may have gone unnoticed. This proactive approach enables accurate allocation of resources and well-informed decision making because of its growing capacity in data management development. The design of a well-structured and customized AI system has capacity for easy multiple integration for effective data upload, which would lead to maintaining records integrity and creating appropriate metadata. Teamwork in records management can be achieved using AI-powered collaboration tools as these tools enable document sharing, version control, and real-time editing. Team members in foodservice operations can collaborate effortlessly, ensuring that records are consistently up to date and accurate by tracking changes and revisions in records and datasets thus preserving the integrity of records.

Ethical Concerns

As AI systems integrate further into our lives, questions about their ethical implications have risen. Issues like data privacy, algorithmic bias, and concentrated power have become central topics in AI ethics discussions, covering concerns from data misuse to potential threats to democratic principles.

Technical unemployment: Employing AI can also present certain challenges. Automation of processes may lead to job reductions, impacting the economy and employment within the industry (Zarifhonarvar, 2023). A lack of human interaction could result in decreased service quality if modalities for configuration and training of AI systems are neglected.

Privacy concerns: The Overreliance on AI and automation can pose risks to the security and privacy of customer data, leading to customer churn and damaging the business's reputation (Limna, 2022). Also, there are concerns that a company can deliberately introduce biases while training AI systems, targeting a particular group of customers or users. In today's interconnected world, vast amounts of data are collected by small number of companies. Accessing these aggregated data can provide insights, not only into a users'

daily activities and interactions but also into their clearly expressed or vaguely identified interests. Through these data, one can create a personality profile or general life pattern by obtaining extensive information about a person's activities and history. Given the potential for illegal access, such a threat endangers not only the privacy of online users but 'disconnected' users whose activity may trigger suspicious monitoring (Pravendra and Pushpendra, 2024).

Conclusion

This research has demonstrated that integrating artificial intelligence (AI) into foodservice operations holds significant potential for reducing foodborne illnesses and improving public health. The adoption of AI-powered food safety management systems can transform the foodservice industry by enhancing food safety, minimizing waste, and increasing consumer trust. Predictive AI models can effectively forecast potential risks, allowing for more proactive food safety practices. Additionally, AI technologies can automate real-time monitoring and analysis of food production, distribution, and storage conditions, providing an unprecedented level of oversight and control. It is noteworthy that AI systems are as efficient as the data they are trained on and as such, it is important to continuously monitor and update in real-time, these ML algorithms, to maintain accuracy.

References

Abideen, A.Z., Pyeman, J., Sundram, V.P.K. and Tseng, M.S. (2021). Leveraging Capabilities of Technology into a Circular Supply Chain to Build Circular Business Models: A State-of-the-Art Systematic Review. *Sustainability*. 13. 8997

ACCOR (2021). Universal Registration. https://group.accor.com/-/media/Corporate/Investors/Documents-de-reference/OPT_ACCOR_DEU_2021_MEL_US_300322.pdf. Accessed February 22, 2025.

Ajlal, H. (2023). AI in Agriculture: Transforming Farming Practices for a Sustainable Future. https://Agtech.Folio3.Com/Blogs/Ai-in-Agriculture/#:~:Text=With%20the%20integration%20of%20AI%2C%20precision%20agriculture%20has,Further%20helps%20in%20resource%20management%20through%20automated%20processes. Accessed January, 2025

Al-Amro A. M. K. (2025). The Role of AI-Powered E-Menus in Enhancing Customer Satisfaction and Promoting Restaurants in Jordan's Tourism Sector. *Pakistan Journal of life and social Science*. (2025), 23(1): 3563-3580.

Andeobu L, Wibowo S, Grandhi S (2022). Artifcial intelligence applications for sustainable solid waste management practices in Australia: a systematic review. *Science of Total Environment* 834:155389.

Brini, M. (2023). The Digital Transformation of Food Systems Artificial Intelligence and other digital opportunities in the modern Food Systems Artificial Intelligence and other digital opportunities in the modern Food Systems at the ETH World Food System Center in. https://www.researchgate.net/publication/373718966. Accessed January, 10 2025

Deeba K, O. Rama Devi, Mohammed Saleh Al Ansari, Bhargavi Peddi Reddy, Manohara H T, Yousef A. Baker El-Ebiary and Manikandan Rengarajan, "Optimizing Crop Yield Prediction in Precision Agriculture with Hyperspectral Imaging-Unmixing and Deep Learning" *International Journal of Advanced Computer Science and Applications* (IJACSA), 14(12), 2023.

Do-Rosario, V.A., Walton, K. (2019). Hospital Foodservice. In: Meiselman, H. (eds) Handbook of Eating and Drinking. Springer, Cham.

Ekellem, E. A. F. (2023). Operational Renaissance: Harnessing AI for Enhanced Business Efficacy. *ESS Open Archive*.

FAO. (2024). The State of Food Security and Nutrition in the World 2024. https://doi.org/10.4060/cd1254en. Accessed February 2, 2025

Fang B., Yu1 J., Chen Z., Osman A., Farghali M., Ihara I., Hamza E.H., Rooney D. W., Yap P (2023). Artifcial intelligence for waste management in smart cities: a review. *Environmental Chemistry Letters*. 21:1959–1989.

Goutam M. A., Ramesh W. U., Chakraborty R., Renu K., Vellingiri B., George A., Sundara R. C. R., Valsala G. A. (2021). A review on modern and smart technologies for efficient waste disposal and management. *Journal of Environmental Managagement,* 297:113347.

Hutchings (2024). "How artificial intelligence will shape the future of cost estimation". https://sdcexec.com/software-technology/ai-ar/article/22884532/galorath-inc-how-artificial-intelligence-will-shape-the-future-of-cost-estimation. Accessed: February 20, 2025.

Ikram, A., Mehmood, H., Arshad, M. T., Rasheed, A., Noreen, S., and Gnedeka, K. T. (2024). Applications of artificial intelligence (AI) in managing food quality and ensuring global food security. *CyTA - Journal of Food*, *22*(1).

Jan, Z., Ahamed, F., Mayer, W., Patel, N., Grossmann, G., Stumptner, M., and Kuusk, A. (2022). Artificial Intelligence for Industry 4.0: Systematic Review of Applications and Challenges.and opportunities." *Expert Systems with Applications*, 216(119456).

Omigie, C., Krubu, D. and Solomon, A. (2023). Exploring Artificial Intelligence for Records and Archival Management System (AI-Rams) For Nigerian Public Organizations.

Kamble S S, Gunasekaran A, and Gawankar S A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. Process Saf. Environ. Prot., 117(408–25).

Kaplan, A. M and Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. Bus. Horiz. 62, 15-25

Limna, P. (2022). Artificial Intelligence (AI) in the hospitality industry: A review article. International Journal of Computing Sciences Research. Advance online publication

Mariani, M. M., Machado, I., Magrelli, V., and Dwivedi, Y. K. (2023). Artificial intelligence in innovation research: A systematic review, conceptual framework, and future research directions. *Technovation,* 122, 102623.

Micheni, E., Machii, J. and Murumba, J. (2024). The Role of Artificial Intelligence in Education. *Open J for Information Technol.* 7. 43-54.

Mijwel, M. (2015). History of artificial intelligence. 1–6. https://doi.org/10.13140/RG.2.2.16418.15046. Accessed February, 2, 2025

Nwigwe, I.C., Umahi G.N. and Awoke, E.C (2025). The Role of Food Science in Hospital Foodservice systems: A Review. *African Journal of Health and Social Sciences*, *1*(3):103-107. https//www.afrjhss.com/index.php/afrjhss/article/view/61. Accessed March, 5, 2025

Pravendra D and Pushpendra B.S. (2024). The Impact of Artificial Intelligence on Various Sectors: Benefits, Challenges, and Future Prospect. https://doi.org/10.69968/ijisem.2024v3si2140-144. Accessed March, 5, 2025

Popkin, B. M. (2015). Nutrition Transition and the Global Diabetes Epidemic. *Current Diabetes Reports*, 15(9), 64.

Taneja, A., Nair, G., Joshi, M., Sharma, S., Sharma, S., Jambrak, A. R., Roselló-Soto, E., Barba, F. J., Castagnini, J. M., Leksawasdi, N., and Phimolsiripol, Y. (2023). Artificial Intelligence: Implications for the Agri-Food Sector. *Agronomy*, 13(5), 1397.

Russell, S. and Norvig, P (2016). Artificial Intelligence: A Modern Approach; Russell, S.J., Norvig, P., Eds.; Pearson Education Limited: Selangor, Malaysia.

Wilts H, Garcia BR, Garlito RG, Gómez LS, Prieto EG (2021) Artifcial intelligence in the sorting of municipal waste as an enabler of the circular economy. Resources 10:28.

Yigitcanlar T, Cugurullo F. (2020). The sustainability of srtifcial intelligence: an urbanistic viewpoint from the lens of smart and sustainable cities. *Sustainability,* 12:8548.

Zarifhonarvar, A. (2023). Economics of chatgpt: A labor market view on the occupational impact of artificial intelligence. *Journal of Electronic Business and Digital Economics*. DOI: https://doi.org/10.1108/JEBDE-10-2023-0021. Accessed March, 5, 2025

Phytochemical Composition and Antioxidant Properties of Bread Enriched with Groundnut Testa

*Uchegbu, N. N. and Amaefuna, B. C.
Department of Food Science and Technology, University of Nigeria, Nsukka
*Corresponding Author: Nneka.uchegbu@unn.edu.ng

ABSTRACT
The study aimed to determine the phytochemical composition of bread enriched with groundnut testa. Bread enriched with groundnut testa was formulated using standard method. Phytochemical composition, of the bread samples were carried out using standard methods. The phytochemical analysis of bread samples revealed significant ($p > 0.05$) differences in the levels of phenolics, flavonoids, alkaloids, tannins, saponins, and terpenoids across the samples.

Keywords: Phytochemical, Bread, Groundnut testa, Phenolics, Flavonoids

1.0 Introduction

Nowadays, consumer behavior is changing due to raised health concerns associated with food quality. In addition, healthy eating habits towards more nutritious foods are encouraged. Consuming foods rich in antioxidants or other bioactive compounds that can promote human health is highly recommended (Schefer *et al.,* 2021). Bread is one of the most widely embraced food products consumed daily by most people in different countries (Kaim and Goluch, 2023). It is a vital source of easily consumed and digestible carbohydrates. More recently, common foods are increasingly being considered or modified to become functional foods. The formulation of bread with plant-based functional food ingredients can enhance its bioactive properties. For example, ingredients that increase polyphenol and carotenoid concentrations increase the antioxidant properties of the bread. For wholegrain breads that have oil added, shelf-life and texture of the bread are improved but potential for lipid oxidation is increased (Ranawana *et al.,* 2016). The addition of bioactive compounds from plant-based functional ingredients to these breads may inhibit lipid and protein oxidation and slow the growth of molds and slow bread spoilage. Plants product such as groundnut can be added to enhance the overall quality of bread. Groundnuts, also known as peanuts (*Arachis hypogaea*), are not only a rich source of proteins, fats, and vitamins but also contain various bioactive compounds, including antioxidants and phytochemicals. These compounds contribute to the health benefits associated with groundnut consumption. While often discarded during processing, the groundnut testa contains several bioactive compounds and offers various health benefits. The aim of this study was to determine the phytochemical composition of bread enriched with groundnut testa.

2.0 Materials and Methods

2.1 Collection of raw materials

Wheat flour, sugar, fat, milk, salt, and yeast were purchased from Ogige Market in Nsukka, Enugu state. The roasted groundnut testa was purchased from the peanut processing merchants within Nsukka.

2.2 Preparation of groundnut testa powder

The roasted groundnut testa was first sorted to remove unwanted materials. It was then washed with clean water and dried using hot air oven at a temperature of 60°C for 2 hours. The dried testa was then pulverized using an electric blender and then sieved to get a fine powder.

2.3 Formulation of flour blends and bread recipe

Table 1: Formulation of flour blends from wheat flour and groundnut testa

Bread samples	Wheat flour (%)	Groundnut testa (%)
CON	100	0
WGTA	97	3
WGTB	94	6
WGTC	91	9
WGTD	88	12

KEY: CON= Control, W= wheat flour, GT= groundnut testa

2.3 Production of bread

Five different bread samples were made using the 100 -g straight dough method which involves the addition and mixing of all ingredients at once to obtain the dough. The basic formula included 100 g of flour, 4g instant yeast, 2.5 g of salt, 12.5 g of sugar, 20 g of fat, 12.5 g of milk, 50 ml of water as needed, and different concentrations of groundnut testa powder which has been added at 3, 6, 9, and 12% concentration on a flour replacement basis. After mixing and kneading, the dough was allowed to rest or ferment for 1 hour at room temperature, then punched down, cut, weighed and molded into round balls and panned in a well-greased baking pan to proof for another 30 minutes at room temperature. After proofing, the dough was placed in a pre-heated oven to bake at a temperature of 180 °C for 45 minutes. After baking, the bread was removed from the oven, de-panned and allowed to cool for 15-20 minutes before weighing and packaging in a ziplock bag for further analysis.

2.4 Phytochemical analysis:

Phytochemical analysis of the samples was carried out for Total phenolic content, Total flavonoids, Alkaloid content, Saponin content, Tannin content, Terpenoid content (Lodhi *et al.,* 2017)

2.5 Statistical Analysis: Results were analyzed statically using Analysis of Variance (ANOVA) and means were separated by Least Significant Difference (LSD) procedure (Ihekoronye and Ngoddy, 1985).

3.0 Results and Discussion

3.1 Phytochemical composition of the enriched bread samples

The phytochemical analysis of bread samples (CON to WGTD) revealed significant differences ($p > 0.05$) in the levels of total phenolics, total flavonoids, alkaloids, tannins, saponins, and terpenoids across the samples (Table 5). CON= wheat flour (100%), WGTA= (wheat flour 97%, groundnut testa 3%), WGTB= (wheat flour 94%, groundnut testa 6%), WGTC= (wheat flour 91%, groundnut testa 9%), and WGTD= (wheat flour 88%, groundnut testa 12%). The results show a progressive increase in all phytochemical contents from sample CON to sample WGTD. Each parameter demonstrated a positive correlation with the phytochemical richness of the bread samples, with sample WGTD consistently exhibiting the highest values across all measured components. Overall, sample WGTD had the highest levels of all measured phytochemicals, while sample CON had the lowest.

Table 2: Phytochemical contents of bread enriched with groundnut testa

Bread Samples	Total phenolic (mg GAE/100g)	Total flavonoids (mg CAE/g)	Alkaloids (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g	Terpenoids (mg/g)
CON	82.77 ^{a}±0.30	60.84 ^{a}±0.31	4.32 ^{a}±0.00	0.52 ^{a}±0.00	0.41 ^{a}±0.01	1.81 ^{a}±0.01
WGTA	94.26 ^{b}±0.33	69.27 ^{b}±0.35	4.92 ^{b}±0.00	0.610 ^{b}±0.01	1.65 ^{b}±0.00	3.18 ^{b}±0.01
WGTB	107.33 ^{c}±0.38	78.88 ^{c}±0.40	5.61 ^{c}±0.01	0.67 ^{c}±0.02	2.84 ^{c}±0.01	4.88 ^{c}±0.00
WGTC	122.22 ^{d}±0.45	89.82 ^{d}±0.45	6.38 ^{d}±0.02	0.78 ^{d}±0.00	3.03 ^{d}±0.00	5.26 ^{d}±.01
WGTD	139.17 ^{e}±0.50	102.28 ^{e}±0.52	7.27 ^{e}±0.02	0.95 ^{e}±0.00	3.90 ^{e}±0.02	6.06 ^{e}±.02

Values are means ± standard deviation of 2 replicate determination. Means with the same superscripts in a column are not significantly ($p > 0.05$) different.

KEYS: CON = (wheat flour 100%) WGTA= (wheat flour 97%, groundnut testa 3%) WGTB= (wheat flour 94%, groundnut testa 6%) WGTC= (wheat flour 91%, groundnut testa 9%) sssWGTD= (wheat flour 88%, groundnut testa 12%).

3.2 Total phenolic content

There is significant difference ($p > 0.05$) among the samples. The total phenolic content ranged from 82.77±0.30 mg GAE/100g in sample CON to 139.17±0.50mg GAE/100g in sample WGTD. The observed increase in phenolic content across the samples aligns with previous studies that suggest enrichment of bread with functional ingredients, such as whole grains or plant extracts, significantly enhances the phenolic content (Nwachukwu *et al.,* 2019). Phenolic compounds are known for their antioxidant properties, which play a critical role in reducing oxidative stress and mitigating the risk of chronic diseases.

3.3 Total flavonoid content

Similarly, there is significant difference ($p > 0.05$) in the total flavonoid content among the samples Flavonoid levels ranged from 60.84±0.31 mg CAE/g in sample CON to 102.28±0.52 mg CAE/g in sample WGTD. Flavonoids contribute to the sensory attributes of bread, such as flavor and aroma, and offer health benefits through their anti-inflammatory and cardioprotective effects (Oladipo *et al.,* 2021). The progressive increase in flavonoid content may be attributed to the incorporation of flavonoid-rich ingredients.

3.4 Alkaloid content

The alkaloid content increased from 4.32±0.00 mg/100g in sample CON to 7.27±0.02 mg/100g in sample WGTD. The increase is not much across all the samples. Alkaloids are bioactive compounds known for their antimicrobial and analgesic properties. Enrichment with alkaloid-rich additives may enhance the functional properties of the bread, as noted in related research by Eze *et al.,* (2020).

3.5 Tannin content

Tannin content varied from the lowest (0.52±0.00 mg/100g) in sample CON to the highest (0.95±0.00 mg/100g) in sample WGTD. Tannins are polyphenolic compounds that contribute to the antioxidant potential of food. While tannins may impart astringency, their moderate levels in the bread samples are within acceptable sensory thresholds (Ahmed and Uthman, 2018).

3.6 Saponin content

Saponin levels varied among the samples with the highest 3.90±0.02mg/100g observed in sample WGTD. Saponins are associated with cholesterol-lowering and immune-boosting effects. The progressive increase observed suggests the utilization of saponin-rich additives, enhancing the functional attributes of the bread (Okoroafor *et al*., 2021).

3.7 Terpenoid content

The terpenoid content ranged from 1.81±0.01 mg/g in sample CON to 6.06±0.02 mg/g in sample WGTD. Terpenoids contribute to the aroma and therapeutic potential of food products, and their increasing trend supports the hypothesis of functional ingredient incorporation (Adebayo *et al.,* 2020).

The progressive increase in phytochemical content from sample CON to sample WGTD suggests the incorporation of functional or bioactive ingredients during formulation. These findings highlight the potential of enhancing bread products with natural phytochemical-rich additives to improve their nutritional and health-promoting properties.

4.0 Conclusion

The enriched bread samples revealed significant ($p>0.05$) differences in their phytochemical composition. The sample WGTD with higher phytochemical, demonstrated enhanced nutritional and functional benefits which can contribute to improved health outcomes. Overall, the study highlights that optimizing groundnut testa as a functional ingredient can significantly enhance bread quality, consumer satisfaction and acceptability if optimized in the right proportion.

References

Adebayo, B., Johnson, O. and Alabi, A. (2020). Terpenoids in food products: Contributions to flavor and health benefits. *Food Chemistry*, 334: 127567.

Ahmed, S. and Uthman, S. (2018). Role of tannins in food and nutrition*:* A review. *Journal of Food Science and Technology*, 55(8): 2935 2942.

Eze, O., Onwuka, G. and Akubor, P. (2020). Alkaloid content and functional properties of enriched bakery products. *International Journal of Food Studies,* 9(3): 205 218.

Ihekoronye AI, Ngoddy PO (1985) Integrated Food Science and Technology for the tropics. Macmillian Publishers Ltd. London pp 178- 180, 305-306, 372-373.

Lodhi, S., Rai, G., Shukla, A. and Mourya, P. (2017). Hypoglycemic and hypolipidemic effect of ethanolic and aqueous extracts from Ziziphus oenophillia L Mill on alloxan-induced diabetic rats. *Beni-Seuf University Journal of Basic and Applied Sciences*, **6**:1-9.

Nwachukwu, E., Ugochukwu, A. and Ezeokeke, T. (2019). Enrichment of bread with phenolic-rich plant extracts. *Journal of Nutritional Biochemistry*, 64: 136 145.

Okoroafor, C., Umeh, C. and Chukwu, O. (2021). Saponin fortification in bread: Nutritional and health perspectives. *International Food Research Journal,* 28(4): 987 996.

Oladipo, A., Akinwale, T. and Oyinloye, T. (2021). Flavonoids in fortified bread: Impact on health and sensory attributes. *Journal of Functional Foods*, 77: 104350.

Ranawana, V., Campbell, F., Bestwick, C., Nicol, P., Milne, L., Duthie, G. and Raikos, V. (2016). Breads fortified with freeze-dried vegetables: quality and nutritional attributes. Part II: Breads not containing oil as an ingredient. *Foods*, **5:** 10.

Schefer, S., Oest, M. and Rohn, S. (2021). Interactions between phenolic acids, proteins, and carbohydrates Influence on dough and bread properties. *Foods*, **10**:2798

Effect of malting periods on the physicochemical and sensory properties of Milk Analogue from Mungbean grain

*Onwurafor, E.U.[1], Akamelu, S. M[1]. and Okafor, E.N[2].

Department of Food Science and Technology, University of Nigeria, Nsukka. [2].Federal Institute of Industrial Research Oshodi, Lagos

*Corresponding author email: eucharia.onwurafor@unn.edu.ng

ABSTRACT

The study evaluated the effect of malting periods on the physicochemical and sensory properties of milk analogues produced from mungbean grain. Mungbean grain was sorted, weighed into 5 different portions. Each portion was washed, steep in water for 6 hours, drained and germinated at room temperature at 24, 48, 72 and 96 hours while out-of-steep sample was not germinated. The out-of-steep and germinated grains were processed into milk analogues and pasteurized. The processed milk analogues were evaluated for physicochemical and sensory properties. Increasing the malting period significantly ($p<0.05$) lowers the pH of mungbean milk analogue and the values ranged from 4.00 and 4.60. The viscosity and titratable acidity of mungbean milk analogue varied from 5.10 to 6.70 and 0.58 to 0.69, respectively and increased significantly ($p<0.05$) as malting period increased. The sensory scores gradually increased significantly ($p<0.05$) as malting period increased for all the parameters. The milk analogue from 96 hours malted sample scored highest in appearance (7.15), colour (7.30), flavour (7.20), and overall acceptability (7.25) and was preferred by the panelists. Milk analogue produced from 96 hours malted mungbean grain was preferred in all sensory parameters and overall acceptability, hence for better sensory appeal, mungbean grain should be malted for 96 hours for production of milk analogue.

Keywords: Malting, mungbean, milk analogue, physicochemical properties, sensory properties

1.0 Introduction

Recently, many people have been switching from regular cow's milk to plant-based milk. This change is due to several reasons, such as ethical reasons involving animal welfare, and environmental sustainability (Sethi *et al.,* 2016; Vanga and Raghavan, 2018). Other reasons include high cost of dairy milk and health concerns (food allergies) like lactose intolerance and Vegan. While plant-based milk from soybeans and almonds is well-known, mung beans (*Vigna radiata*) are not as popular, even though they are nutritious and can be used to make milk analogue (Sethi *et al.,* 2016). Mungbean is renowned for its high nutritional value, making it a vital component of diets in many developing countries. It is an excellent source of protein, dietary fibre, vitamins (such as folate and B vitamins), and essential minerals (including iron, magnesium, and potassium). Additionally, mungbean is low in fat and contains bioactive compounds such as polyphenols and flavonoids, which have antioxidant and anti-inflammatory properties (Kumar *et al*., 2023). Malting has been reported to improve the nutrient content and reduced the antinutrients in legumes thus making the end products more nutritious. During malting process, the seed activates enzymes that break down stored nutrients, leading to significant biochemical changes that enhance nutritional value, digestibility, and bioactive compounds (Kumar *et al*., 2023). Malted flour has been used in various product development, however limited information on the consumption of milk analogue from malted legume exist (Koyro *et al.,* 2017). Since malting periods had effects on the composition of mungbean flour (Onwurafor *et al.,* 2020), there is possibilities that it can also affect milk alternative from mungbean malted for different durations. The study evaluated the effect of malting periods on the physicochemical and sensory properties of the mungbean milk analogue.

2.0 Materials and Methods

Mungbean grain (*Vigna radiata)* and muslin cloth were purchased from Ogige market in Nsukka, Enugu State. Analytical grade chemicals were also procured from a dealer, JOECHEM Ltd in Nsukka Market. Five lots of sorted mungbean grain (500 g each) were weighed into porous bags (25 cm × 45 cm) and steeped in water for 3 h, air rested for 90 min. and re-steeped in fresh tap water for 3 h (a modification of the two-step wet-steep method of Etok-Akpan and Palmer (1990). One lot of mungbean seeds was wet-dehulled. The second, third, fourth and fifth lots of 500 g of grain each was spread in a dark room to germinate for 24, 48, 72 and 96 h, respectively, during which they were, turned every 24 h. The samples were moistened by dipping the malting bags containing the germinating grains in water for 30 sec. One lot (bag) was picked at intervals of 24, 48, 72 and 96 h and wet dehulled, milled to slurry, mixed with 120 cl of fresh tap water and sieved with muslin cloth to obtain the liquid (milk). The mungbean milk analogue was pasteurized at 90 ^{o}C for 10 min. It was packaged hot in a sterilized bottle then cooled and packaged in bottles. The pH, titratable acidity and viscosity of the milk beverage sample were determined according to AOAC (2010). The mungbean milk analogue samples were evaluated for sensory properties as described by Karagül-Yuceer and Drake (2013). The sensory scores obtained were further subjected to a one-way Analysis of Variance (ANOVA), Duncan's new multiple range test was used for mean separation using the statistical product for service solution (SPSS) version 25.0 (Steel and Torrie, 1980) and the significance was accepted at $p<0.05$.

3.0 Results and Discussion

The results of malting periods on the physicochemical quality of milk analogue from mungbean grain are shown in Table 1. Increasing the malting period significantly ($p<0.05$) decreased the pH of mungbean milk analogue. Sample MM1 (out of steep) has the highest pH value (4.60) and the lowest pH (4.00) was recorded in sample MM5 (96h). The pH of the samples was significantly ($p<0.05$) affected by malting period. Malting has been shown to enhance the release of nutrients and reduce antinutritional factors, but it also tends to lower the pH due to increased acidity (Singh *et al*., 2021). This phenomenon was consistent with the findings in other legume-based products, where malting has been reported to reduce pH as a result of enzymatic activity and the accumulation of organic acids (Sharma *et al*., 2021).

The titratable acidity of milk analogue from mungbean grain malted for different durations ranged from 0.58 to 0.69%. The total titratable acidity of the milk analogue samples revealed a significant ($p<0.05$) increase in acidity as the malting period increases until 72 hours. The breakdown of complex molecules and the release of acidic substances during the malting process may be responsible for the increase in acidity. Enzymatic processes like proteolysis and amylolysis become more active with longer malting periods, producing acidic chemicals and raising the total titratable acidity (Vasiljevic *et al*., 2020).

Table 1: Physicochemical properties of milk analogue from mungbean grain malted at different periods

Sample	pH	TTA (%)	Viscosity (Cp)
MM1	$4.60^{c} \pm 0.00$	$0.58^{a} \pm 0.02$	$5.48^{ab} \pm 0.11$
MM2	$4.50^{b} \pm 0.00$	$0.59^{ab} \pm 0.00$	$5.10^{a} \pm 0.14$
MM3	$4.40^{b} \pm 0.00$	$0.61^{b} \pm 0.01$	$5.75^{b} \pm 0.07$
MM4	$4.20^{a} \pm 0.00$	$0.69^{c} \pm 0.01$	$6.70^{c} \pm 0.14$
MM5	$4.00^{a} \pm 0.00$	$0.69^{c} \pm 0.00$	$5.25^{ab} \pm 0.35$

Values are means of 2 replications ± standard deviation. Means with the same superscripts in a column are not significantly ($p> 0.05$) different. Key: MM1= out-of-steep mungbean; MM2= mungbean malted for 24 hours; MM3= mungbean malted for 48 hours; MM4= mungbean malted for 72 hours; MM5= mungbean malted for 96 hours

The viscosity of mungbean milk analogue ranged from 5.10 to 6.70Cp. The viscosity of the milk analogue decreased in grain malted for 24 hours and then increased significantly ($p<0.05$) as the malting period of the grain increased until 72 hours, it then decreased significantly($p<0.05$). This may be caused by the breakdown of complex molecules and the release of soluble chemicals during the malting process, which might result in a thicker, more viscous texture (Wang *et al.*, 2022). Viscosity levels may have stabilized as a result of the enzymatic activities reaching their peak, as indicated by the increase of viscosity values at 72 hours and decrease in 96 hours (Zhang *et al.*, 2022).

The results of the sensory scores of mungbean milk analogue malted at different periods were presented in Table 2. Milk analogue from 96 hours malted sample had highest score for appearance (7.15) indicating that it was the preferred sample among the five samples. Out of steep sample (**MM1)** scored the lowest in **appearance (**5.20). From the results (Table 2), the higher the malting periods, the more appealing the appearance becomes to the panelists. The protein and carbohydrate modifications probably contributed to a more enticing visual presentation. During the 48 – 72-hour malting window, Singh and Patel (2022) reported significant improvements in milk clarity and colour uniformity. Enzymatic activities during this period break down complex molecules, resulting in a smoother, more uniform appearance.

The sensory scores for colour of mungbean milk varied from 4.50 to 7.30. Similar to appearance, colour scores improved with malting duration. Samples MM3, MM4, and MM5 (48-96 hours) showed significantly higher scores. The highest score was recorded in milk analogue from mungbean grain malted for 96 hours and was preferred. Enzymatic activities during this period probably break down complex pigment molecules; generating lighter, more consistent coloration (Kumar *et al.*, 2021).

Table 2: Sensory scores of milk analogue from mungbean malted at different periods

Sample	Appearance	Colour	Flavour	Taste	Consistency	Mouthfeel	After Taste	Overall acceptability
MM 1	$5.20^{a}\pm2.40$	$4.50^{a}\pm1.79$	$3.86^{a}\pm1.46$	$4.15^{a}\pm1.87$	$5.20^{a}\pm2.07$	$5.05^{a}\pm2.06$	$4.05^{a}\pm2.00$	4.65 ± 1.70^{a}
MM 2	$5.50^{b}\pm2.09$	$4.70^{b}\pm2.08$	$4.15^{b}\pm2.08$	$4.20^{a}\pm2.19$	$5.60^{c}\pm1.85$	$5.05^{a}\pm2.04$	$4.15^{b}\pm2.16$	4.80 ± 2.12^{a}
MM 3	$6.55^{c}\pm1.70$	$6.55^{c}\pm1.28$	$4.30^{c}\pm1.66$	$4.65^{b}\pm1.98$	$6.05^{a}\pm1.79$	$5.35^{b}\pm1.93$	$4.40^{c}\pm1.39$	5.65 ± 1.63^{a}
MM 4	$7.10^{d}\pm1.29$	$6.90^{d}\pm1.29$	$6.95^{d}\pm1.61$	$5.75^{b}\pm1.80$	$6.85^{d}\pm1.93$	$5.35^{b}\pm2.10$	$4.45^{c}\pm2.10$	6.00 ± 2.18^{a}
MM 5	$7.15^{d}\pm2.13$	$7.30^{e}\pm1.56$	$7.20^{e}\pm1.77$	$6.45^{d}\pm1.85$	$7.15^{e}\pm2.25$	$7.20^{c}\pm2.33$	$4.45^{c}\pm2.24$	7.25 ± 2.20^{a}

Values are means of 20 replications ± standard deviation. Means with the same superscripts in a column are not significantly ($p> 0.05$) different. KEY: MM1= Out of steep mungbean; MM2= Mungbean malted for 24 hours; MM3= Mungbean malted for 48 hours; MM4= Mungbean malted for 72 hours; MM5= Mungbean malted for 96 hours.

Milk analogue from mung bean grain malted for 96 h scored highest in flavour 7.20), taste, after-taste (4.45), consistency (7.15) and mouthfeel (7.20) and the scores were significantly ($p<0.05$) high compared to other samples indicating that malting at 96 h improve these parameters. The milk analogue from the out of steep sample (MM1) had the lowest flavour score (3.86) among all samples which could be due to pronounced beany flvour which is characteristic of unsprouted beans. Singh *et al.* (2021) reported that complex molecules are broken down by enzymatic activity during malting, which lowers bitter chemicals and improves the flavour profile. The sensory scores for the thickness of the mungbean milk varied from 5.60 to 7.15. Significant ($p<0.05$) differences were observed in the consistency of milk analogue from mungbean grain malted at different periods. The scores gradually increased as malting period increased. Through

enzymatic changes, milk analogue from mungbean grain from 48 to 96 hours malt increases its thickness. According to Kumar *et al.* (2021), regulated malting improves thickness and texture by increasing colloidal stability.

4.0 Conclusion

The study has shown that milk alternative can be produced from mungbean grain malted at different periods. Malting of mungbean grain at different period affected the physicochemical and sensory properties of milk analogue differently. While pH decreased in milk with more malting periods, titratable acidity and viscosity increases. Milk analogue produced from 96 hours malted mungbean grain was preferred in all sensory parameters and overall acceptability, hence for better sensory appeal, mungbean grain should be malted for 96 hours for production of milk analogue.

References

AOAC. (2010). Official methods of analysis of AOAC International (18th ed.). Association of Official Analytical Chemists.

Etok-Akpan, U. O., and Palmer, G. H. (1990). A two-step wet-steep method for malting sorghum. Journal of the Institute of Brewing, 96(2):111-114.

Karagül-Yüceer, Y. and Drake, M. A. (2013). Sensory analysis of dairy foods. Journal of Sensory Studies, 28(2):94-109.

Kumar, N., Sharma, S. and Gupta, R. K. (2021). Influence of malting on bioactive compounds and microbial safety of legume-based milk substitutes. International Journal of Food Science and Technology, 56(7):3412–3421.

Kumar, S., Anderson, J. and Wilson, T. (2023). Advances in plant-based milk production technologies. Food Engineering Reviews, 15(2):123-135.

Koyro, H. W., Kumar, P. and McGhee, J. (2017). Plant-based milk alternatives: A review. Journal of Food Science and Technology, 54(4):1202-1212.

Onwurafor E.U., Uzodinma E.O., Uchegbu N.N., Ani J.C., Umunnakwe I.L. and Ziegler, G. (2020). Effect of Malting Periods on the Nutrient Composition, Antinutrient Content and Pasting Properties of Mungbean Flour. Journal of Tropical Agriculture, Food, Environment and Extension, 19 (1):18-24

Sharma, P. and Peterson, R. (2024). The International Dairy Federation's updated definition of milk. Journal of Dairy Science, 107(1):123-135.

Sethi, S., Tyagi, S. K. and Anurag, R. K. (2016). Plant-based milk alternatives: A review. Journal of Food Science and Technology, 53(2):925-935.

Singh, R., Sharma, N. and Gupta, M. (2021). Bioavailability of minerals in mungbean milk and the impact of germination. Journal of Functional Foods, 84:104534.

Singh, A. and Patel, K. (2022). Influence of germination on the physicochemical and sensory attributes of plant-based milk substitutes. International Journal of Dairy Technology, 75(4):782-794.

Steel, R. G. D. and Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach (2nd ed.). McGraw-Hill.

Vanga, S. K. and Raghavan, V. (2018). Drying and milling characteristics of soybean and mung bean. Journal of Food Engineering, 231:45-53.

Vasiljevic, T., Kaur, M. and Mishra, V. (2020). Influence of enzymatic hydrolysis on acidity and nutritional properties of dairy and plant-based alternatives. Trends in Food Science and Technology, 98: 142–153.

Wang, C., Liu, H., and Zhang, X. (2022). Changes in carbohydrate metabolism during mungbean sprouting: Implications for functional food development. Food Bioscience, 48:101-242.

Zhang, Y., Zhou, W., and Chen, H. (2022). Viscosity modification of plant-based milk analogues through controlled germination. Food Hydrocolloids, 13:107707

Design, Construction and Evaluation of 5-Liter Capacity Process for Refining of Soy Bean Oil

*Okoyeuzu, C. F[1]., Nwaogwugwu, J. N[1]., Nduka, O. C[1]., Nwankwo, C. S[2]. Okoronkwo, N. C[1]. and Eze, J. I[1].

[1]Department of Food Science and Technology, University of Nigeria, Nsukka. [2]Department of Food Science and Technology, Federal University of Agriculture, Makurdi, Nigeria

*Corresponding author's email; chigozie.okoyeuzu@unn.edu.ng

ABSTRACT

The design, construction and evaluation of 5-liter capacity process for refining of soya bean oil were studied. The equipment was designed and constructed, used to refine soybean oil with varied phosphoric acid ratios of 0.10%, 0.15%, 0.20% and lye excess factor of 0.10, 0.11, and 0.12 respectively. The products were analyzed for chemical properties using standard methods. The result of the study showed that with power consumption of 102W by the electric motor (591.6 W entire powers) and power delivered as 5.389W, the liquid was agitated at Reynold number of 3,425 to bring about the particles settling at a terminal velocity of 0.00349m/s. The results of the analyses showed that fat content ranged from 99.84 - 99.98%, fibre 0.01 - 0.04%, moisture 0.01 - 0.13%. There was no value detected for protein, carbohydrate, and ash. The peroxide value ranged from 1.44 - 1.87meq/kg and saponification value 187 - 192 mg KOH/g

Key words: design, construction, evaluation, refining, soy bean oil

1.0 Introduction

Oils and fats are described as the main nutritional components of human food and an important raw material of food processing (Anyang, 2020). More than 90 per cent of the world production from vegetable, animal and marine sources is used as food or as an ingredient in food products. They are rich sources of dietary energy and contain more than twice the calorific value of equivalent amount of sugar. Research has shown that their functional and textural characteristics contribute to the flavour and palatability of natural and prepared foods. It has also been confirmed that they contain certain fatty acids which play an important role in human nutrition and are also carriers of fat-soluble vitamins **(**Fssai, 2015).

It is also observed that during storage these oils and fats slowly deteriorate due to chemical reactions. This results in a loss of quality and value of the oil (Wolf *et al.*, 2013). The deterioration which is caused by the changes that occur in the food products affects the sensory properties (colour, taste, odour). This first of all diminishes their nutritional properties by contributing to the loss of the activity of biological precursors, vitamins A and E. It is already known that vitamin E functions as an antioxidant, so any change on the oil or fat which led to loss of vitamin E will equally increase health risk as a result of the emerging free radicals, which display carcinogenic properties. In the quest for a quality oil product, industries are evolving into processing plants that can refine the oils and fats into wholesome product. Another challenge facing the edible oil industry apart from the oil deterioration and quality is identification of the geographical region of the origin of oils, their purity or their adulteration (Justyna and Waldemar, 2011).

Soy bean oil has fat-soluble impurities, which has to be removed before the oil is fit for consumption. So, the refining of edible oil and fats is very important. Local soya bean oil refineries are scarcely found or yet to be established. The soy bean refining plant in Nigeria are foreign technologies; Desmit, Alfa Laval or Kumar Metal in the capacities of 30 metric tons and above. The smaller capacities of 1 – 10 metric tons are mainly the China technologies in the tune of 52,000 – 53,000 US dollars, which are costlier than a small-scale entrepreneur could afford. So, depending on these foreign plants alone with their corresponding cost

will not support the industrialization the Nigerian market craves for l*et al*one support the availability of quality oil at an affordable rate to the common man. Therefore, the aim of this study was to design, construct and evaluate a 5-liter capacity process for refining of soya bean oil. The specific objectives were to design and construct a 5-litre capacity process machine for refining soya bean oil and to determine the chemical compositions of the product

2.0 Materials and methods

2.1 Materials for Construction and Sources: Metal plate, 20 mm (2 cm) pipes were procured from Timber market, Kenyeta Enugu State. Electric Motor (0.5 kw at 1450 rpm), 20 mm (2 cm) valves, 240 v electric heating filament, temperature and pressure gauges were procured from Ariaria Market, Aba, Abia State. Electrical accessories and paint were obtained from Kenyeta Enugu State. Soy bean seed was obtained from New Market, Enugu. Phosphoric acid was obtained from Onitsha Main Market, Anambra State. Caustic soda was procured from *Ogbete* Market, Enugu State.

2.2 Oil Refining; the method of the design was batch chemical refining (Figure 1).

2.3 Design of the Hydration Vessel; the viscosity of the mixture agitated using a paddle fall within the range of 10^2 - 30 cp (Filipp, 2007), a type of radial flow impeller (John, 2012) (Figure 2).

2.4 Process Description

Water degumming: The crude soy bean oil was filled into the hydration vessel for the chemical refining process. It was agitated with hot water (65 °C) to remove hydratable gums. The caustic solution (lye) (3ml of 16°Be /1litre of oil) was added, agitated for 45 minutes and allowed to stand for one hour and drained. **Washing**: The process was done by the following procedure; **Silent washing:** This was done by showering water at 100 °C without agitation. Allowed to settle and drained. This was repeated three consecutive times, and then water washed achieved by raising the temperature to 80 °C, under agitation for 40 minutes, then water at 100 °C was added. It was allowed to stand for one hour and drained. This was repeated for second and third stages by raising the temperature to 90 and 95 ^{0}C, respectively. **Bleaching**: At a temperature of 90^{o}C the oil was bleached with a special type of bleaching earth bentonite at the ratio of 0.2% earth. **Filtration**: The washed oil was passed through filtration unit with pore size (150 micrometer) and then deodorized. The **deodorisation** process started with the working temperature of 120°C at a residence time of 15 minutes. The available water vacuum was supported with vacuum pump, while the oil was also placed on circulation within the 15 minutes and thereafter tested for free fatty acids and odour, cooled and ready for storage or consumption. The refined oil was evaluated for proximate composition, peroxide and saponification value using standard methods of AOAC (2010).

3.0 Results and Discussion

Proximate Composition of the Soy bean Oil Processed with different Ratio of Caustic Soda - Excess Factor and Phosphoric Acid

The result of proximate composition of soy bean oil is presented in Table 1. The fat content ranged from 99.84 - 99.99%. Samples A, C, and D showed no significant ($p > 0.05$) difference amongst them having values of 99.84, 99.85 and 99.87%, respectively, Samples E and H were statistically ($p > 0.05$) similar having values of 99.97 and 99.97%. All the other samples were significantly ($p < 0.05$) different when compared with the commercially available product XY with fat content of 99.99%. It was observed that the fat content makes approximately the only component of the oil. This is because the oil as a sample is already a class of food and the other classes maybe seen in traces, (Hammond, 2003). The differences in the fat content of the sample maybe as a result of poor drying or removal of moisture from the oil. This gives rise to the variation in the fat content of the samples.

There was a significant ($p < 0.05$) difference between the commercially available product which has a fibre content of 0% and the samples. This could be as a result of the filtration process and its efficiency. Some fibrous materials that may have escaped the filter press during extraction may have contributed to the various percentages of the fibre content as observed in the result. Samples A, B, C, D, E, F, G, and H

showed no significant ($p > 0.05$) difference in the values of the fibre content ranging from 0.01 - 0.03%. There was a significant ($p < 0.05$) difference between the commercial product and sample I with fibre content of 0.04%. There was no significant ($p > 0.05$) difference regards the moisture content of samples B, E, F, G, H, I and the commercial product where the moisture content ranged from 0.01- 0.05%. But samples A, C and D had significant ($p < 0.05$) differences compared to the commercial product. This may be due to the drying process which was done by heating the oil and application of water vacuum. The oil passed through the process of water washing. So, there was enough water that is needed to be removed which the process could not handle on those samples. Water washed oil was dried with a vacuum dryer until the moisture level of the oil falls below 0.1%. This result was in agreement with Gharby (2022). The result does not show any value for protein, ash and carbohydrate. This agreed with the report of Gilles (2017) having zero percent for protein, ash and carbohydrate. The reason was that the product is a pure class of food and should be free from other component of food. The result agreed with the report of Bundeslebensmittelschlussel (2019) that soybean oil consists of 100% fat, 0% protein, 0% carbs, 0% fibre and 0% water.

Peroxide values greater than 20meq/kg correspond to poor quality fats and oils. Soya bean oils 1 – 5meq/kg, 5 – 10meq/kg and above 10meq/kg correspond to low, medium and high levels of oxidation, respectively. Samples D and H with highest peroxide value of 1.87 and 1.77meq/kg were within acceptable range indicating that the operation in the fabricated equipment was able to reduce the peroxide value. Samples A, B, C, D, F, and H shows no significant ($p > 0.05$) differences with the control- (commercial product), while there were significant ($p < 0.05$) differences among samples E, G, I and the control sample. It was clear fact that the samples were expected to have the same saponification value and at least they fall within the range of value (187 – 192. (mg KOH/g oil) for saponification of soybean oil. The result shows that the designed process did not expose the products to contamination by unsaponifiable matters like grease, paraffin wax or engine oil which could cause abnormal change of saponification value as observed by Rechard (2008).

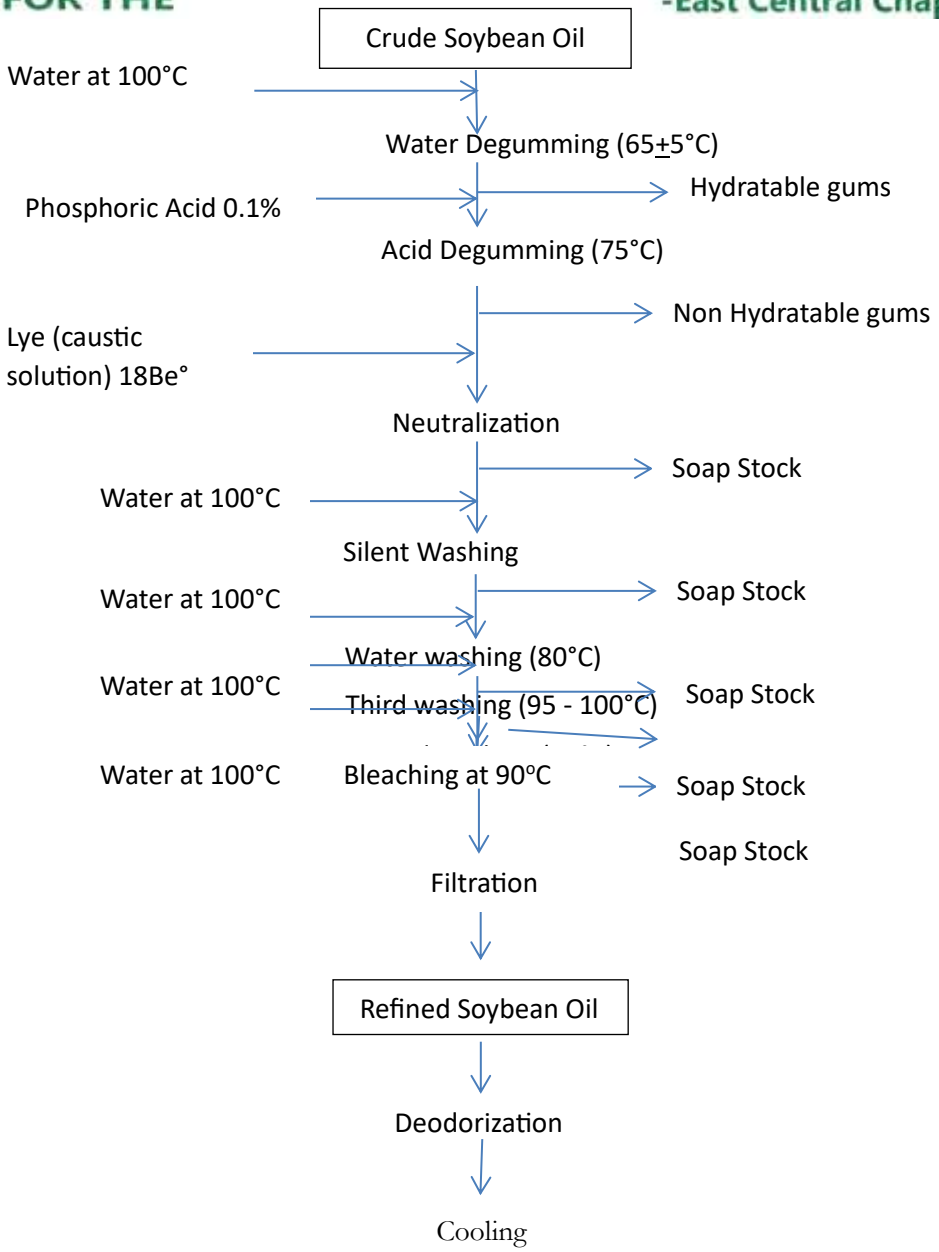


Figure 1: The production of soybean oil

Table 1: Proximate Composition, peroxide and saponification value of soy bean oil

Sample	Fat (%)	Protein (%)	Fibre (%)	CHO (%)	Ash (%)	Moisture (%)	Peroxide Value (10meq/kg)	Saponification (mg KOH/g oil)
A	$99.84^{a}\pm0.00$	ND	$0.03^{ab}\pm0.01$	ND	ND	$0.13^{b}\pm0.01$	$1.46^{b}\pm0.007$	$190^{ab}\pm1.41$
B	$99.94^{c}\pm0.01$	ND	$0.01^{ab}\pm0.01$	ND	ND	$0.05^{a}\pm0.03$	$1.68^{g}\pm0.007$	$189.5^{ab}\pm2.1$
C	$99.85^{a}\pm0.01$	ND	$0.02^{ab}\pm0.01$	ND	ND	$0.13^{b}\pm0.00$	$1.46^{c}\pm0.007$	$190.5^{ab}\pm0.7$
D	$99.87^{a}\pm0.01$	ND	$0.02^{ab}\pm0.01$	ND	ND	$0.11^{b}\pm0.00$	$1.87^{h}\pm0.007$	$189^{ab}\pm1.40$
E	$99.97^{cde}\pm0.01$	ND	$0.02^{ab}\pm0.01$	ND	ND	$0.01^{a}\pm0.00$	$1.65^{f}\pm0.007$	$187^{a}\pm0.70$
F	$99.98^{de}\pm0.01$	ND	$0.01^{ab}\pm0.01$	ND	ND	$0.01^{a}\pm0.00$	$1.58^{e}\pm0.007$	$189.5^{ab}\pm0.70$
G	$99.95^{cd}\pm0.01$	ND	$0.01^{ab}\pm0.01$	ND	ND	$0.04^{a}\pm0.00$	$1.66^{f}\pm0.007$	$192^{b}\pm1.40$
H	$99.97^{cde}\pm0.01$	ND	$0.01^{ab}\pm0.01$	ND	ND	$0.02^{a}\pm0.03$	$1.77^{h}\pm0.007$	$189.5^{ab}\pm2.10$
I	$99.91^{b}\pm0.01$	ND	$0.04^{b}\pm0.01$	ND	ND	$0.05^{a}\pm0.03$	$1.44^{a}\pm0.007$	$192^{a}\pm1.40$
XY	$99.99^{e}\pm0.01$	ND	$0.00^{a}\pm0.00$	ND	ND	$0.01^{a}\pm0.01$	$1.56^{d}\pm0.007$	$190.5^{ab}\pm0.70$

Values are presented in mean ± standard deviation of n = 3. Mean values on the same column with different superscripts are significantly ($p<0.05$) different. ND = Not Detected.

Key: A: 0.1% phosphoric and 0.1 caustic soda excess factor, B : 0.1% phosphoric acid and 0.11 caustic soda excess factor, C : 0.1% phosphoric acid and 0.12 caustic soda excess factor, D: 0.15% phosphoric acid and 0.11 caustic soda excess factor, E: 0.15% phosphoric acid and 0.12 caustic soda excess factor, F: 0.15% phosphoric acid and 0.10 caustic soda excess factor, G: 0.2% phosphoric acid and 0.12 caustic soda excess factor, H: 0.2% phosphoric acid and 0.10 caustic soda excess factor, I: 0.2% phosphoric acid and 0.11 caustic soda excess factor, XY: control (commercial oil)

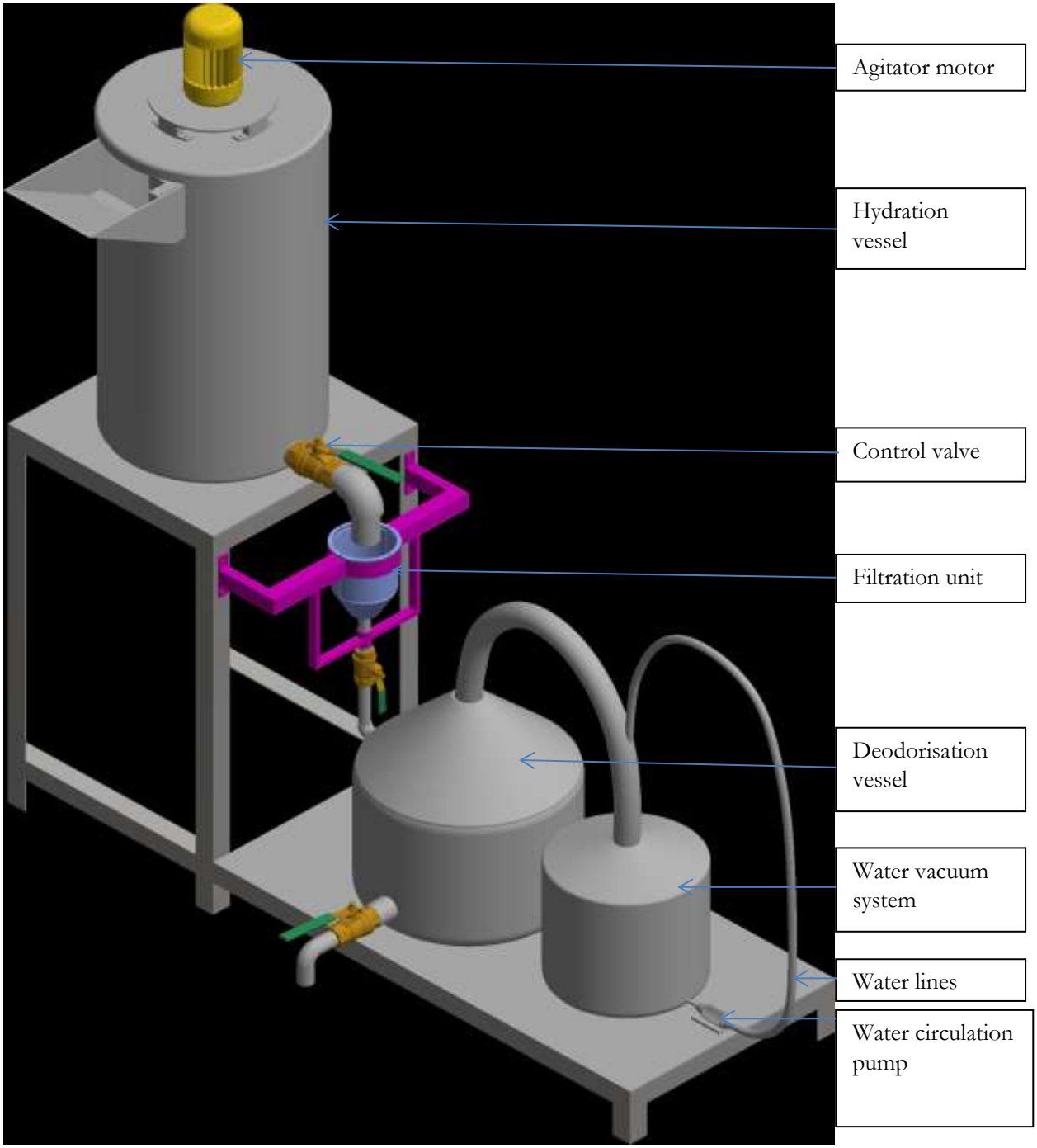


Figure 2: 3D diagram of the designed process for soya bean oil production

References

Anyang Best Complete Machine, (2015). Small cooking oil refinery plant. www.abcmach. com/oil-press Accessed December, 11, 2022.

FSSAI. (2015). Manual of methods of analysis of foods, oils and fats. Food Safety and Standards Authority of India ministry of health and family welfare Government of India, New Delhi, pages 19-25, 57.

Wolf, E. J., Harrington, K. M., Clark, S. L. and Miller, M. W. (2013). Sample Size Requirements for Structural Equation Models: An Evaluation of Power, Bias, and Solution Propriety. Educational and Psychological Measurement, 73(6): 913-934.

Justyna G. and Waldemar, W. (2011). Trends in Edible Vegetable Oils Analysis. Part A. Determination of Different Components of Edible Oils. Poland Journal Food, Nutrition Science, 61(1):33-43.

Filipp, K. J. and Petri, H. (2007). Agitation handbook**.** Master of Science Thesis, Industrial Engineering and Management Machine Design, Stockholm pages 28 - 30, https://www.coursehero.com/file/66511830/FULLTEXT01pdf/. Accessed 30th December 2022

John, F. P. (2020). Mechanical Agitator power Requirements for Liquid Batches. https://www.pdhonline.com/courses/k103/k103content.pdf. Accessed 20th September 2022.

AOAC (2010): AOAC. (2010). Official methods of analysis. AOAC International, 1 19th edition, Washington DC, USA.

Gharby, S. (2022). Refining Vegetable Oils: Chemical and Physical Refining. Scientific World Journal, 2022:1-10. https://doi.org/10.1155/2022/6627013 . Accessed January, 4, 2023

Gilles, T. (2017). Soybean oil Feedinamics. https://www.feedtables.com/content/soybean-oil. Accessed July, 17, 2022)

Bundeslebensmittelschlussel (2019). Soybean oil - Carbs, Glycemic Index, Fats, Minerals, Vitamins and much more. https://lowcarbcheck.com/foods/soybean-oil/ Accessed June, 24, 2022.

Richard D. O. (2008). Soybean Oil Purification, AOCS Press, pp. 377-408,

Physicochemical Characteristics of Fresh and Stored Juice from Zobo (*Hibiscus sabdariffa*), Date Palm (*Phoenix dactylifera L.*), Ginger (*Zingiber officinale*) and Cloves (*Syzygium aromaticum*).

*Orji, R. N[1], Chima, J. U.[1] and Ayodele, E. A.[1]

[1] Department of Food Science and Technology, Akanu Ibiam Federal Polytechnic Unwana, Afikpo, Ebonyi State,

Corresponding Author's email rachelorji123.ro@gmail.com,

ABSTRACT

This present work evaluated the Physicochemical characteristics of fresh and stored juice from the blends of zobo, date palm, ginger and cloves. Result indicated that the Total Soluble Solids (TSS) of the fresh juice samples ranged from 5.05-7.03 % for Total Titratable Acidity (TTA), ranged from 0.19 to0.22 % pH (2.55-2.74) and Vitamin C contents (20.03-35.61 mg/100g) while the TSS of stored juice was (4.67-6.84 %), TTA (0.22-0.42 %) pH (2.39-2.65) and Vitamin C contents (24.63-46.74 mg/100g). TSS increased appreciably in Sample D for both fresh and stored samples compared to the other samples. TTA and Vitamin C increased in all the stored samples compared to the fresh and there were significant changes in the pH of the fresh and stored samples. Zobo spiced with dates, ginger and cloves and stored for a period of seven days at ambient temperature showed improved vitamin C content and Total soluble solids. This showed the influence of spices used on the storage ability of the zobo juice.

Keywords: Physicochemical properties, Zobo juice, Dates, Ginger, Cloves.

1.0 Introduction

Zobo is a non-alcoholic beverage produced from Roselle calyx leaves of *Hibicus sabdariffa,* consumed commonly in tropical and subtropical regions of West Africa including Nigeria. The leaves, seeds, flowers and roots of *Hibiscus Sabdariffa* are consumed but the red calyces are the most useful (Salami and Afolayan, 2020). They contain several important therapeutic properties that reduce the risk of various diseases. There exists credible documentation on the culinary and medicinal properties of the leaf and calyx extracts of *Hibiscus sabdariffa* due to high level of polyphenolic compounds and antioxidants in it which confer notable health benefits *(*Adeoye *et al.,* 2019.)

Date palm (*Phoenix dactylifera L.*) is the oldest fruit crop that can serve as a natural sweetener. It is rich in medicinal bioactive and functional compounds including polyphenols, flavonoids, carotenoids, phytosterols, phytoestrogens, vitamins and minerals (Younas *et al.*, 2020). It is grown mostly in the north arid desert regions of South West Asia and North Africa.

Date fruit is not only a nutritional food containing sufficient amounts of vitamin A and B complexes, it is also readily preserved, stored, and transported over long distances thereby encouraging food security (Adeoye *et al.*2019).

Spices such as cloves have been reported to have antioxidant, anti-inflammatory, anti-microbial and other immune balancing properties (Otolowo *et al.*, 2022).

Ginger (*Zingiber offianale*) is a spicy, herbaceous perennial plant that belongs to the *zingiberacae* family, originating from South East Asia. It is documented to be medicinal, possessing antimicrobial and anti-inflammatory properties (Awes, 2023).

This work aimed at evaluating the physicochemical properties of fresh and stored (for seven days) juice from zobo, date palm, ginger and cloves.

2.0 Materials and Methods

2.1 Source of Raw Materials: The zobo leaves, dates, gingers and cloves were sourced from *Eke* Market in Afikpo, Ebonyi State.

2.2 Sample preparation

Zobo leaves were sorted and washed. Dates were washed, deseeded, diced and ground into slurry. Gingers were peeled, washed and grated while Cloves were washed and ground into powder. All the sample materials were boiled with a clean water (300 ml) to the temperature of 100^{o}C per formulation for 45 minutes. Each formulation was filtered with a muslin cloth to get a clear spiced zobo drink. Each of the juices were formulated in the following ratios as shown:

Sample A had Zobo with Dates:Ginger:Cloves:Sugar ratio of 50:40:10:0. Sample B had Zobo with Dates:Ginger:Cloves:Sugar ratio of 50:30:20:0. Sample C had Zobo with Dates:Ginger:Cloves:Sugar ratio of 50:20:30:0, Sample D had Zobo with Dates:Ginger:Cloves:Sugar ratio of 0:0:0:100. All samples were introduced with water with volume as 300 mL.

2.3 Evaluation for Total Soluble Solids:

The methods for evaluating Total Soluble Solids (TSS) measured in percentage brix was determined using a digital refractometer (ATAGO CLASSIC JAPAN HHR-2N). Total Titratable Acidity (TTA) was determined by titrating 10 mL of the juice sample against 0.1N NaOH to an end point of 8.1 and the values were given a citric acid percentage. pH was determined using a pH meter and Vitamin C contents were determined by titrimetric method as described by Onwuka (2018) and expressed in mg/100g.

3.0 Results and Discussion.

Table 1 showing the physicochemical properties of the fresh zobo juice blends.

Sample	Total Soluble Solids (%)	Total Titratable Acidity (%)	pH	Vitamin C (mg/100 g)
A	$5.33^{b}\pm0.02$	$0.22^{a}\pm0.03$	$2.74^{a}\pm0.01$	$35.61^{a}\pm0.01$
B	$5.07^{c}\pm0.02$	$0.21^{a}\pm0.01$	$2.66^{ab}\pm0.03$	$23.48^{c}\pm0.03$
C	$5.02^{c}\pm0.02$	$0.22^{a}\pm0.01$	$2.64^{b}\pm0.06$	$26.24^{b}\pm0.02$
D	$7.03^{a}\pm0.03$	$0.19^{a}\pm0.01$	$2.55^{c}\pm0.02$	$20.03^{d}\pm0.02$

Values are mean ± standard deviation of duplicate determinations. Means in the same column bearing different superscripts are significantly ($p<0.05$) different.

Table 2 showing the physicochemical properties of the stored zobo juice blends.

Sample	Total soluble solids (%)	Total titratable acidity (%)	pH	Vitamin C (mg/100 g)
A	$5.18^{b}\pm0.03$	$0.42^{a}\pm0.03$	$2.65^{a}\pm0.01$	$46.74^{a}\pm0.02$
B	$4.72^{c}\pm0.02$	$0.28^{bc}\pm0.01$	$2.61^{ab}\pm0.01$	$28.35^{c}\pm0.01$
C	$4.67^{c}\pm0.01$	$0.30^{b}\pm0.01$	$2.57^{b}\pm0.00$	$30.31^{b}\pm0.02$
D	$6.84^{a}\pm0.02$	$0.22^{c}\pm0.02$	$2.39^{c}\pm0.02$	$24.63^{d}\pm0.02$

Values are mean ± standard deviation of duplicate determinations. Means in the same column bearing different superscripts are significantly ($p<0.05$) different.

3.1 *Total Soluble Solids (TSS)*

The TSS of the fresh juice samples ranged from (5.05-7.03 %) with sample D being significantly ($p< 0.05$) different from other samples. Sample D was also significantly ($p< 0.05$) different in TSS in the stored sample. This could be attributed to the presence of sugar in sample D which contains high amount of soluble carbohydrates. TSS values recorded in this work for fresh zobo juice samples (5.05-7.03 %) and for stored Zobo juice samples (4.67-6.84%) were lower compared to what Bagwai *et al, (*2022), reported. They reported (8.80%) and (8.70%) respectively as the TTA values of Zobo beverage flavoured with ginger and cloves.

3.2 *Total Titratable Acid (TTA)*

The TTA of the fresh juice samples (0.19-0.22 %) were not significantly ($p< 0.05$) different from one another but they were among the stored samples. Sample A (0.42%) was significantly ($p< 0.05$) different from all the other samples. There was a significant increase in the TTA of the stored juice samples compared to the fresh ones. Bagwai *et al. (*2022), reported (34.50%) and (37.90%) as the TTA values of Zobo beverage flavoured with ginger and cloves respectively. This report is higher than the TTA (0.19-0.22%) or fresh samples and (0.22-0.42%) or stored samples seen in this work.

Total Titratable acidity is a measure of the amount of acid or acid present in a food sample. It shows the level of total acidification of a solution (Orji, 2022).

3.3 *pH*

The pH of the fresh samples ranged from (2.55-2.74) and that of the stored samples (2.39-2.65) and were significantly ($p< 0.05$) different from each other. The change in the pH of the fresh juice and the stored ones were not appreciable high as seen in the sample's TTA and Vitamin C contents. The range of pH values seen in this work (2.39-2.65) is lower compared to what Adesokan (2013) reported as the pH of zobo tea spiced with ginger and garlic. It recorded a range of (6.63-7.67). pH is a measure of how acidic or basic a food substance or solution is. Variations in pH values can impact flavour, consistency and shelf life in juices (Onwuka,2018).

Low pH as seen in this work shows the production of acidic juice and this indicates higher shelf stability as this pH will not allow the growth of spoilage microorganisms in the juice.

3.4 *Vitamin C*

The Vitamin C contents of the fresh juice samples ranged from (20.03-35.61mg/100g) Sample A (35.61 mg/100g) was significantly ($p< 0.05$) different from all the other samples as well as among the stored samples (46.74 5 mg/100g There was a sharp increase in the vitamin contents of the juice after seven days storage. This may be attributed to the dissolution of the zobo leaves, dates, cloves and ginger which contain

sufficient amounts of different vitamins especially water soluble and antioxidant vitamin C after seven days storage.

The range of the vitamin content seen in this work (20.03-35.61mg/100g) is higher compared to what: Nwankwo *et al.* (2022) recorded. It recorded (13.90-15.85mg/100g) as the vitamin content of Zobo tea spiced with cloves and ginger but this report was close to what Bagwai *et al.* (2022), reported (35.20mg/100g) and (23.10mg/100g) as the vitamin contents of zobo beverage flavoured with ginger and cloves respectively. Addition of spices such as ginger and garlic improve the vitamin C content of zobo beverage (Adesokan *et al.* 2013).

4.0 *Conclusion*

The use of Spices such as cloves, ginger and dates improved the antimicrobial and antioxidant properties such as vitamin C of zobo drink. These spices impart low pH to the drink which stabilised the shelf life of the drink. Zobo spiced with dates, ginger and cloves and stored for a period of seven days at ambient temperature showed improved vitamin C content and Total soluble solids. These attributes indicate improved health benefits as well as longer shelf life for the juice.

References

Adeoye, B. K., Oyewole, O. B., Idowu, M. A., Ademuyiwa, O. Obadina, A.O., Adaramola, F. B, Ani, I. F and Ngozi, E. O. (2019). Protection against Oxidative Damage Properties of *Hibiscus sabdariffa* Drink (Zobo) and added Natural Food additives. European Journal of Scientific Research.152(2),52-162.

Adesokan, A. I., Abiola, O.P., Adigun, M.O and Anifowose, O.A. (2013). Analysis of Quality Attributes of *Hibiscus sabdariffa* (zobo) drink blended with aqueous extract of ginger and garlic. *Academic Journals*. 7(7),174-177).

Awes, F .B., Fagbemi, T.N.I., Ifesan, B.O.T. and Badejo, A.A. (2023). Antioxidant properties of cold and hot water extracts of cocoa, Hibiscus flower extract, and ginger beverage blends. *Food Research International. 5(21,490-495.*

Bagwai, M.A. ,Bakar, A., Bagwai, B.A., Nat'alah, F.M and Khaleel,Z.I.(2022).Effect of ginger and clove extracts on the Nutritional quality of *Hibiscus sabdariffa* beverage(Zobo).*Bayero Journal of Pure and Applied Sciences*.13(10,467-470.

Nwankwo, C.S., Edozie, P.C., Okpomor, E.O., Mbachiantim, J.T., Okoyeuzu, C.F, Carew, I.E, Belay, D. and Abebe, T.(2022). Quality Evaluation of Zobo Tea flavoured with clove and ginger packed in tea bags. *African Journal of Agriculture and Food Science*. 5(1),1-10

Onwuka G. I (2018) food Analysis and instrumentation (theory and practice). Second edition Naphtali Printers, Lagos Nigeria. Pp. 299-314.

Orji, R.N. (2022) Proximate and Sensory Determination of Therapeutic Yoghurt produced from Tigernut and Coconut Milk flavoured with Pineapple juice. *Current Studies in Agricultural, Business Valuation, Education, Management, Science and Technology (AFRIBVAM).* 2(3):317-327.

Otolowo, T., Akinmoladun, O. F., Omosebi, O.M.,Anifowose T.M. and Olanrewaju,T.A. (2022). Evaluation of the chemical contents of Zobo (*Hibiscus sabdariffa*) flavoured with natural spices. *Mountain Top University Journal of Applied Science and Technology*.2(1),39-54.

Salami, S.O and Afolayan, A.J. (2020). Suitability of Roselle-*Hibiscus sabdariffa* L. as raw material for soft drink production. *Journal of Food Quality*. (604),1-9.

Younas, A., Naqvi, S.A., Khan, M.R., Shabbir, M.A. and Anwar, F. (2020). Functional Food and Nutra Pharmaceutical perspectives of date (*Phoenix dactylifera L.*) fruit. *Journal of Food Biochemistry*.44(9),13332-13335.

Functional and Sensory Evaluation of Weaning Food Produced from Malted Sorghum Enriched with Soybean, Unripe Plantain, Crayfish and Termites.

*Chidolue, P.U., Ojokoh, E., Egege, J.N.

Department of Food Science and Technology, Akanu Ibiam Federal Polytechnic, Unwana

*Corresponding author email: chidoluepaul1@gmail.com

ABSTRACT

This study aimed at determining the functional and sensory properties of weaning food produced from malted sorghum enriched with soybean, unripe plantain, crayfish and termites. The sorghum, soybean, unripe plantain, crayfish and termites were processed into flour and four (4) samples were formulated: WF201 (50% sorghum: 15% soybean:15% unripe plantain: 15% crayfish: 5% termite), WF202 (60% sorghum: 15% soybean:15% unripe plantain: 10% crayfish: 0% termite), WF203 (70% sorghum: 10% soybean:8% unripe plantain: 10% crayfish: 2% termite), WF204 (80% sorghum: 10% soybean:8% unripe plantain: 0%crayfish: 2% termite), with the fifth sample WF205 being a commercially produced weaning food which was used as a control. Functional and Sensory properties were determined using standard methods. The gelling temperature, bulk density, water absorption capacity, oil absorption capacity and swelling capacities of the samples ranged from 75.30 to 80.10^{o}C, 1.46 to 1.93g/ml, 290.0 to 351.5%, 70.50 to 91.50% and 3.80 to 4.60ml/g respectively. The sensory attributes showed that WF204 measured competitively with the commercial product (WF205) and was the most acceptable by the panelists. This study revealed that incorporating soybean, crayfish, unripe plantain and termites into malted sorghum in the production of weaning food increased the protein content and its availability and could serve as a potential tool in the fight against infant malnutrition.

Keywords: Weaning food, infant malnutrition, soybean, edible termite

1.0 Introduction

Breast milk alone cannot meet an infant's nutritional requirements beyond six months of age (Ikujenlola and Fashakin 2005), hence easy to digest supplements are required alongside mothers' milk until the child is ready to eat adult food. This transition from exclusive breastfeeding to semi-solid and soft food is referred to as the period of complementary feeding. It typically covers the period from 6 months to 24 months of age, and is a very vulnerable period (UNICEF 1997). This period of development and rapid growth impose unique nutritional needs in the growing infant who is yet to develop teeth and digestive system is still immature, in addition to needing nutrients and energy which the breast milk may no longer provide in sufficient amounts.

It is within this crucial transition phase that malnutrition starts in infants. In addition, studies have shown that even with optimum breast feeding, infants will become stunted if they are not given adequate quantities of quality weaning food after 6 months of age (UNICEF 2008). There is therefore need to introduce weaning foods that can meet the nutritional and energy needs of the infant and drastically reduce or completely eliminate malnutrition.

Sorghum (*Sorghum bicolor*) also known as guinea corn is one cereal that is extensively grown in Nigeria. Though the protein quality of sorghum is poor, it is a good source of the B vitamins, potassium and phosphorus.

Soybean (*Glycine max*) a legume extensively cultivated in southern Africa is an excellent source of protein. It contains all the essential amino acids, magnesium, calcium, lecithin, riboflavin, thiamin, iron etc. Due to its availability, affordability and high protein quality, it is used in a lot of local and continental dishes. It is also widely used for the enrichment of weaning foods.

Plantain (*Musa paradisica*) is a staple crop that is an important source of carbohydrates. It is rich in Vitamin A, B_6, C and K. It contains minerals like folate, magnesium, potassium and iron, and is a good source of fibre. These nutrients when inculcated into weaning foods help to provide energy to fuel the infants' movement. They also help to support electrolyte balance, immune function and iron absorption (Abiodun and Falade,2010)

Crayfish (*Procambarus clarkii*) are a fresh water crustacean belonging to the infraorder *Astacidea.* They are found in abundance in the fresh waters of the Delta region of Nigeria. They are a good source of protein and essential nutrients comparing favorably with egg, milk and meat in the nutritional value of its protein (Odiko and Obirenfoji, 2017). They are also laden with omega-3 fatty acids, minerals like calcium, sodium and iron and the C vitamin which support infant growth and development.

Macrotermes bellicosus (*Aku)* are a well-known edible termite species popularly consumed in Africa and South-East Asia. According to studies by Adepoju *et.al.,* (2021), 100g of roasted *M. bellicosus* constitutes 24% energy, 58.3% protein, 22.7% calcium, 51.5% phosphorus, 20.9% zinc and 33.0% retinol equivalent (vitamin A) and 60.0% of vitamin E to the recommended dietary allowances of adult consumers. The nutritional quality, protein digestibility and mineral bioavailability of termites make them highly recommended for breastfeeding mothers and for weaning food formulations (Kinyuru, 2021), thus they are considered excellent for alleviating malnutrition and micro nutrient deficiencies in under developed and developing countries.

According to Balogun *et al.,* (2016), meals enhanced with soybean had a considerable increase in its protein content. Unripe plantain, sorghum, crayfish and termites combined contains vitamins and minerals necessary for infant growth and development. Therefore, enhancing weaning foods (cereal based) with protein-laden sorghum, omega-3 fatty acids loaded crayfish, easily available and fibre rich unripe plantains and termites which have been reported by Xavier *et al.,* (2024) to be loaded with lysine and methionine is a potential way of increasing the nutritional content of weaning foods and combating malnutrition in infants.

Hence, the main objective of this work is to examine the functional and sensory attributes of weaning foods formulated from malted sorghum enriched with unripe plantain, crayfish, soybeans and edible termites.

2.0 Materials and Methods

2.1 Source of Materials

Sorghum, unripe plantain, soybean and crayfish were purchased from Eke market in *Afikpo*, Ebonyi state. Termites in nuptial flight were caught from a compound in *Ebunwana* in Ebonyi State. The raw materials were transferred to the wet processing laboratory of the department of Food Science and Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi state where they were immediately processed.

2.2 Sample Preparation

2.2.1 Processing of Sorghum Grains into Flour

The malted sorghum flour was produced by the process described by Akinsola *et al.,* (2021) as adapted. The sorghum grains were sorted, cleaned and then steeped in water for 6 hours. The steeped grains were then spread on a jute bag saturated with distilled water and covered with another jute bag. The grains were allowed to germinate for 72 hours. Water was sprayed on the jute bag when necessary. The malted grains were dried in a cabinet drier at 105^{o}C for 5 minutes. They were then roasted over medium heat for 10 minutes, milled into flour and allowed to cool. The flour was sieved (200um mesh sieve) to obtain the malted sorghum flour.

2.2.2 Processing of Unripe Plantain into Flour

The method of Akubor and Ukwuru (2003) with modification was adopted in the preparation of unripe plantain flour. The unripe plantain fruits were washed, peeled, sliced (approximately 2mm thick) and blanched in hot water at 100°C for 10minutes. They were then dried in a cabinet drier at 100°C for 5 hours. The chips were milled with a ball mill to get the dry powder.

2.2.3 Processing of Crayfish into Powder

The crayfish was sorted and their heads removed. They were washed in clean water and dried in an oven at 70°C for 12 hours. They were then milled and sieved. The crayfish powder was stored in an air tight container.

2.2.4 Production of soybean flour

Soybean flour was produced with modifications according to the method described by Adesokan *et al.,* (2011). The soybean seeds were sorted to remove extraneous materials and soaked in water for 5hours. It was then blanched at 100 °C for 10 minutes and dehulled to remove the seed coats. The dehulled beans were dried in an oven at 100 °C for 5 hours after which it was milled and allowed to cool. It was sieved to obtain soybean flour of 150-200um size. The resulting flour was packaged in a polyethylene bag.

2.2.5 Processing of Edible Termites into Flour

The freshly caught edible termites (*aku*) were washed to remove any feathers and extraneous materials still attached to the body. They were died in an oven at 70°C for 5 hours after which they were milled, cooled and sieved to obtain edible termite powder which was packaged in an airtight container.

2.3 Sample Formulation

The weaning food was formulated using varying percentages of the various ingredients (malted sorghum, unripe plantain, soybean, crayfish and termite) as presented in Table 1.

2.3.1 Weaning food formulations. WF201: 50% sorghum: 15% soybean: 15% unripe plantain: 15% crayfish: 5% termite, WF202: 60% sorghum: 15% soybean: 15% unripe plantain: 10% crayfish: 0% termite, WF203: 70% sorghum: 10% soybean: 8% unripe plantain: 10% crayfish: 2% termite, WF204: 80% sorghum: 10% soybean: 8% unripe plantain: 0% crayfish: 2% termite, WF205: Control- A commercially available baby food was used

2.4 Determination of Functional Properties

The method of Onwuka (2005) was used to determine the functional properties of the weaning food which included Gelling temperature, Bulk density, Swelling index, Water absorption capacity and Oil absorption capacity.

2.5 Sensory Evaluation

Sensory evaluation was carried out on the reconstituted weaning food. This evaluation was conducted in the sensory evaluation room of the department of Food Science and Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State. A total of 15 untrained panelists comprising solely of nursing mothers whose infants were being weaned, selected randomly from the polytechnic community were tasked with assessing the reconstituted weaning food. In order to achieve this, they used a 9-point hedonic scale questionnaire where 9 indicated extremely liked and 1 indicated extremely disliked. Portable water was provided to the panelists to rinse their mouths in between sample assessments.

2.6 Statistical Analysis

The statistical package for social sciences (SPSS) version 20 was used to analyze the data generated using one-way analysis of variance (ANOVA) and least significance difference (LSD) post-hoc testing at 5% level of significance.

3.0 Results and Discussion

The outcome of the gelling temperature ranged from 75.30 - 80.20 ^{o}C. The highest gelling temperature was observed in WF204 (sorghum 80 %, soybean 10 %, unripe plantain 8 %, crayfish 0 %, termite 2 %) while WF202 (sorghum 60 %, soybean 15 %, unripe plantain 15 %, crayfish 10 %, termite 0 %) had the lowest gelling temperature. This result shows that there was no significant difference ($p > 0.05$) between WF204 and WF205. There was also no significant difference ($p > 0.05$) between WF201, WF202 and WF203 but WF204 and WF205 were significantly different ($p > 0.05$) from WF201, WF202 and WF203. The gelling temperature is influenced by the starch concentration in the sample. Starch gelatinization is an important determinant of cereal based food quality as it influences the texture and mouthfeel of the product.

Bulk density is an important property that has a direct impact on the packaging requirement of flour samples. The bulk density ranged from 1.46 – 1.93 g/mL with WF202 having the highest bulk density (1.93 g/mL) while WF204 had the least bulk density (1.46 g/mL). There was no significant difference at ($p > 0.05$ between WF202 and WF201 but both samples were significantly different ($p > 0.05$) from WF205 which was also significantly different from WF203 and WF204 respectively. This could be attributed to the higher quantity of unripe plantain (15%) in WF201 and WF202. However, the aforementioned findings were higher than those reported by Agomuo *et al.,* (2024) who obtained values ranging from 0.59 – 0.83g/mL for maize gruel without plantain.

The results of the Water absorption capacity ranged from 290 – 352%. WF201 had the highest value which was not significantly different from WF202, though both samples were significantly different from WF203, Wf204 and WF205 which were also significantly different from each other. It was observed that the water absorption capacity increased with an increase in the level of soybean flour. This could be attributed to the hydrogen bonds in the amino acids of the protein content of the crayfish, termite and soybean in relation to malted sorghum flour. These results are marginally higher than that obtained by Osundahunsi *et al.,* (2003).

The Oil absorption capacity result varied from 70.50 – 91.50% with WF205 having the highest value but not significantly different from WF201 and Wf202. WF203 and WF204 had much lower values and was significantly different from Wf205, WF 201 and WF 202. This could be attributed to the low percentage of soybean flour in WF203 and WF204. On the other hand, the increased inculcation of soybean and crayfish flour resulted in samples WF201 and WF202 having the highest oil absorption capacity. According to Reinke and Joke (2005), soybean is a rich source of high-quality protein and vegetable oil. This can explain why both samples could retain more oil.

The weaning food samples exhibited varying degrees of swelling capacity ranging from 3.80 to 4.60ml/g. WF201, WF202 and WF205 were not significantly different from each other but were significantly different from WF203 and WF 204. The results showed that swelling capacity increased with increased addition of soybean and plantain flour.

Table 1 shows the results of the various parameters of the functional properties

Sample	GT (^{O}C)	BD (g/ml)	SC (ml/g)	WAC (%)	AOC (%)
WF201	$76.00^{b} \pm 1.41$	$1.87^{a} \pm 0.02$	$4.60^{a} \pm o.70$	$352.5^{a} \pm 3.54$	$88.95^{a} \pm 1.34$
WF202	$75.30^{b} \pm 0.42$	$1.93^{a} \pm 0.01$	$4.50^{a} \pm 0.00$	$351.5^{a} \pm 2.12$	$89.50^{a} \pm 0.71$
WF203	$77.15^{b} \pm 1.20$	$1.52^{c} \pm 0.03$	$4.10^{b} \pm 0.00$	$292.0^{c} \pm 2.83$	$70.50^{b} \pm 0.72$
WF204	$80.20^{a} \pm 0.57$	$1.46^{c} \pm 0.01$	$3.80^{b} \pm 0.00$	$290.0^{c} \pm 1.41$	$70.95^{b} \pm 1.34$
WF205	$80.10^{a} \pm 0.14$	$1.79^{b} \pm 0.00$	$4.60^{a} \pm 0.00$	$298.5^{b} \pm 2.12$	$91.50^{a} \pm 1.41$

Means within the same column with the same superscript are not significantly different.

Keys: GT = Gelling temperature, BD = Bulk Density, SC = Swelling capacity, WAC = Water absorption capacity, OAC = Oil absorption capacity, WF201: 50% sorghum: 15% soybean: 15% unripe plantain: 15% crayfish: 5%. Termite, WF202: 60% sorghum: 15% soybean: 15% unripe plantain: 10% crayfish: 0% termite, WF203: 70% sorghum: 10% soybean: 8% unripe plantain: 10% crayfish: 2% termite, WF204: 80% sorghum: 10% soybean: 8% unripe plantain: 0% crayfish: 2% termite, WF205: Control- A commercially available baby food was used

Table 2 Presents the outcomes of the sensory evaluation carried out on the formulated weaning food samples

Sample	Appearance	Aroma	Taste	mouthfeel	General acceptability
WF201	$6.70^{a} \pm 1.49$	$6.20^{c} \pm 0.92$	$6.70^{b} \pm 1.25$	$6.20^{b} \pm 1.03$	$6.20^{b} \pm 1.23$
WF202	$6.40^{b} \pm 1.20$	$7.70^{b} \pm 1.06$	$7.80^{a} \pm 1.32$	$7.70^{a} \pm 1.42$	$6.80^{b} \pm 0.79$
WF203	$6.10^{b} \pm 0.84$	$6.40^{c} \pm 1.07$	$6.80^{b} \pm 0.92$	$5.70^{b} \pm 1.06$	$7.00^{b} \pm 1.33$
WF204	$8.20^{a} \pm 1.32$	$8.30^{a} \pm 0.95$	$8.50^{a} \pm 0.53$	$8.40^{a} \pm 0.97$	$8.70^{a} \pm 0.48$
WF205	$8.60^{a} \pm 0.84$	$8.90^{a} \pm 0.32$	$8.20^{a} \pm 1.23$	$8.00^{a} \pm 1.63$	$8.20^{a} \pm 1.14$

The appearance of the weaning food samples had values that ranged from 6.10 to 8.60 with WF205 and WF204 showing no significant difference at $P>0.05$ and were the most preferred. WF201, WF202 and WF203 though not significantly different from each other were the least preferred. This variation in appearance could be attributed to the high percentage of unripe plantain, crayfish and termite contained in them. Aroma, a fundamental sensory attribute pertains to the sensations in the nostrils due to the volatile compounds contained in the foods or drinks emanating from them. The values for aroma ranged from 6.20 – 8.90 with WF205 having the highest value. The taste results ranged from 6.70 – 8.50. WF204 had the most acceptable taste. Mouthfeel is the sensation of food in the mouth which includes roughness, chewability, stickiness and smoothness. The Mouthfeel results varied from 5.70 to 8.40 with WF204 having the highest value and WF203 the least. The weaning food formulations had mean scores ranging from 6.20 to 8.70 in terms of overall acceptability with WF204 (80% sorghum, 10% soybean, 8% unripe plantain, 2% termites) being the best. Significant difference at $P>0.05$ was observed among WF204, WF205 and the other samples. Generally, WF204 and WF205 were the most acceptable.

4.0 Conclusion

Weaning food prepared from malted sorghum enriched with soybean, crayfish, unripe plantain and termites was produced. This work showed that a highly nutritious weaning food can be prepared from cheap and locally available raw materials. The inclusion of soybean, crayfish and termites, in addition to unripe plantain and the malting of the sorghum not only increased the nutritional content and nutrient availability, but also influenced the functional and sensory attributes of the weaning food. WF204 (80% sorghum, 10% soybean, 8% unripe plantain, 2% termites) and WF205 (commercially produced) were the most acceptable among the samples in all the sensory parameters. These products could function as a readily available and affordable technique in the fight against infant malnutrition and micronutrient deficiencies.

References

Abiodun, S.A.O and Falade, K.O. (2010). Review of the uses and methods of processing banana and plantain (Musa spp.) into storable food products. *Journal of Agricultural Research and Development*, 9(2):86-166.

Adepoju, O.T and Omotayo O.A (2014). Nutritional Composition and Potential Contribution of winged termite to micronutrient intake of consumers in Nigeria. *Current journal of Applied Science and Technology* 4(7):1149 – 58. https:/doi.org/10.9734/BjAST/2014/4420

Adesokan, I., Fawole, A., Ekanola Y., Odejayi, D and Olanipekun O (2011). Nutritional and sensory properties of soybean fortified composite ogi. A Nigerian fermented cereal gruel. *African journal of microbiology research* 5, 3144 – 3149

Agomuo, J.K., zubaru, I.K., and Sogunle, K.A (2024). Functional, Chemical and Sensory properties of maize pudding enriched with soybean and pawpaw flours. *Nigerian food journal* Vol 42, No 1,73 – 85

Akinsola, O.T., Alamo E.O., Otegbayo B.O., Menkir, A and Maziya-Dixon, B (2021). Nutritional Properties of Ogi Powder and sensory perception of ogi porridge made from synthetic pro-vitamin A. maize genotype. Frontiers in Nutrition, 8:685004.

Akubor and Ukwara (2003). Functional Properties and Biscuit making Potential of Soybean and Cassava Flour Blends. *Plants food Human Nutrition*, 58:1-12

Odiko, A.E and Obirenfoju, J. (2017). Proximate Composition and Mineral contents of Different Brands of Canned fishes marketed in Edo State Nigeria. *International journal of Fisheries and Aquaculture Research*, 3(2):30-38.

Onuorah C.E., Akinjede F.A (2004). Comparative Evaluation of four formulated Complementary foods and a commercial product. *Nigerian Food Journal* 2004, 22 – 48.

Onwuka G.I. (2005). Food Analysis and Instrumentation. Napthali prints, Lagos. Pg 134 – 135.

Osundahunsi O.F., Fagbemi T., Ekasselmen N. and Shemoni E. (2003). Comparison of the Physicochemical Properties and Pasting Characteristics of Flour and Starch from Red and White Sweet Potato Cultivars. *Journal of Agriculture and Food Chemistry* 51, 2232 – 2236.

Unicef: Complementary feeding update 1997. http://www.unicef.org/nutrition/index

Unicef: Complementary feeding update 2008. http://www.unicef.org/nutrition/index

Xavier C., Ochieng, O.B. and Tanga, C.M. (2024). Unraveling the Nutritional and Health Benefits of Marketable Winged Termites (Macrotermes Spp) as a sustainable food source in Africa. *Journal on Scientific Reports*

Physical properties of yellow maize-based snacks enriched with orange fleshed sweet potato and soybean wastes

*Odieze, I. E[1] and Asogwa, I.S[2]

[1]National Centre for Energy Research and Development, University of Nigeria Nsukka. [2]Department of Food Science and Technology, University of Nigeria Nsukka

*Corresponding author's email: ifeoma.odieze@unn.edu.ng

ABSTRACT

This study was aimed at evaluating the physical properties of yellow maize-based snack enriched with orange-fleshed-sweet potato and soybean wastes. Maize, OFSP waste and soybean waste (okara) flours were produced and blended together at varying proportions as follows; MFL (100% maize flour), MOR (60% maize flour and 40% OFSP residue), MOA (60% maize flour, 30% OFSP residue and 10% okara), MOB (60% maize flour, 20% OFSP residue and 20% okara), MOC (60% maize flour, 10% OFSP residue and 30% okara), MOK (60% maize flour and 40% okara). Colour and textural properties of the samples were evaluated using standard methods. The colour values varied significantly ($p<0.05$) with blending ratios. The lightness value ranged from 86.0 to 93.2, with MOR having the least value, while MOC had the highest value. The redness (a) and yellowness (b) indexes ranged from 0.20 to 0.6 and 5.3 to 12.7, respectively, with MOC and MOK having the least value, while MOR had the highest value. The hardness, fracturability and crispness of the samples ranged from 72.55 to 98.29, 28.44 to 30.49 and 6.31 to 6.70, respectively. The addition of OFSP flour significantly ($p < 0.05$) increased the hardness of the snacks. It could be concluded that addition of OFSP and soybean wastes to maize flour significantly affected the colour and textural profile of produced snacks.

Keywords: Yellow maize, orange fleshed sweet potato waste, soya bean waste, textural and colour properties.

1.0 Introduction

A snacks food is defined as a type of food that is eaten in between main meal but not as a part of them. Snack food is designed to be less perishable, more durable and more appealing than main meals. Many conventional snacks such as biscuits, pies, buns, cakes are wheat flour based. The production of these wheat-based snacks in many developing countries who don't cultivate wheat in commercial levels has resulted in its heavy reliance on imported wheat with huge financial implications. The economy of any country importing wheat for the production of baked food such as biscuits would therefore be improved if other cereals like maize that are grown locally are used to partially or wholly replace wheat flour. In addition to locally grown cereal flours, the incorporation of food wastes could further reduce the cost of these snacks as well as enhance their nutritional value.

Maize is known to provide high amount of energy but not so in terms of its minerals and vitamin contents (Taiwo, 2016). The yellow maize cultivar is rich in β- carotene, a pro vitamin A that enhances good eyesight in children and adults (Igbabul *et al.* 2014). Maize naturally is gluten free and contains ferulic acid which is not in other cereals like wheat, oat and rice. Ferulic acid (FA) is a polyphenol that is widely known for its therapeutic potential, displaying anti-aging, anti-inflammatory, and neuroprotective effects.

Okara (soy bean waste) is a by-product generated from soymilk production. Okara is low in fat, high in fibre and also contains protein, calcium, Iron, and riboflavin. On a dry weight basis okara contains 24%

protein, 8 to 15% fats and 12 to 14.5% crude fibre (Wickramarathna and Arampath, 2003). Okara is rich in nutrient content but majority of it is still being discarded, causing environmental problems.

Orange-fleshed sweet potato (OFSP) is a special type of biofortified sweet potato that contains high levels of β-carotene (HarvestPlus, 2009). The β-Carotene is an organic, red-orange pigment abundant in plants and fruits. β-carotene is what gives OFSP an orange colour and is converted to Vitamin A in the body after consumption to provide additional nutritional benefits. OFSP is often used in production of beverages like OFSP juices, drink and yoghurt (Satheesh and Solomon, 2019). The by- product of OFSP juice production is the residue which is normally discarded thereby constituting environmental nuisance. OFSP residue contains residual β-carotene and fibre that could be utilized in value added products.

It is known that nature and proportion of ingredients could significantly affect the physical properties of foods which in turn affect organoleptic qualities of such foods. This study was therefore aimed at evaluating the effect of blends of maize flour, OFSP waste and soybean waste (okara) on the physical properties of produced snacks.

2.0 Materials and methods

Freshly harvested Orange fleshed sweet potatoes were obtained from the farm in Abuja, Nigeria while yellow maize and soybean were procured from Ogige market in Nsukka, Enugu State, Nigeria.

2.1 Production of flours

Orange-fleshed-sweet potato waste flour was processed by the method described by Omodamiro *et al.* (2010). Orange fleshed sweet potato tubers were washed to remove dirt and sand. The cleaned roots were peeled, washed and diced then wet milled (1:2 tuber to water) in an electric blender. The resulting slurry was squeezed through a muslin cloth to separate the residue from the filtrate. The residue was dehydrated at 60^{o}C for 14 hours using a food dehydrator (Tribest Digital Food Dehydrator, Model SD- S9150). The dried residue was milled and sieved to obtain the flour. Okara flour was processed by the method of Onyibe *et al.* (2009). Soybean seeds were sorted, washed and soaked in excess water for 6 hours, then manually dehulled. The soybean was blanched for 30 min then wet milled (1:3 beans water ratio) to obtain a slurry. The slurry was sieved using muslin cloth to obtain the soy milk. The residue (okara) was dried for 24 hours at 60^{o}C using a food dehydrator (Tribest Digital Food Dehydrator, Model SD- S9150), milled (Grinding machine, Model GX200), then sieved (Sethi standard test sieve 25) to obtain okara flour. Maize flour was processed by the method of Olusola and Morton (1996). Maize seeds were cleaned and sorted to remove any impurities from the maize. The cleaned and sorted maize was conditioned by soaking in water (1:4 maize is to water), cracked using grinding machine, model GX200, milled (Grinding machine, Model GX200) dried using a food dehydrator (Tribest Digital Food Dehydrator, Model SD- S9150) at 60^{o}C for 4 h and sieved (Sethi standard test sieve 25) to obtain maize flour.

2.2 Formulation of Flour Blends

Flour blends were formulated by blending the individual flours as follows: MFL (100% maize flour), MOR (60% maize flour and 40% OFSP residue), MOA (60% maize flour, 30% OFSP residue and 10% okara), MOB (60% maize flour, 20% OFSP residue and 20% okara), MOC (60% maize flour, 10% OFSP residue and 30% okara), MOK (60% maize flour and 40% okara).

2.3 Production of snacks from Maize, Okara and OFSP waste Flour.

Snacks were produced according to the method described by Ikechukwu *et al.* (2017). The ingredient and quantities used are flour (100 g), sugar (30 g), margarine (15 g), egg (10 ml), baking powder (1.65 g), salt (a pinch) and water (20 -40 ml). The margarine and sugar were creamed until fluffy using a hand mixer (Generic Electric Hand Mixer HL221-LU WHITE). The flour and other dry ingredients were added while mixing quickly for 2 min until a dough is formed. The egg is beaten slightly and added to the dough and thoroughly mixed until stiff dough was formed. The dough was rolled out to 4.8 mm thickness, shaped into balls of 6mm diameter and fried using an air fryer (Silver Crest Extra Large Capacity Air Fryer-6L-

3000Watts) at 140°C for 20 min. After frying, the snacks were cooled to room temperature, packed in an airtight transparent plastic container and stored at 4°C until analyses.

2.4 Texture Analysis

Texture measurements of the formulated snacks were done using Texture Analyzer (Stable Micro Systems TA. XT 2i). It was measured in terms of maximum force used to break the snack samples. The snacks were placed under sharp blade cutting probe, 70 mm long and 0.4 mm thick. The analyzer was set at a "return to start" cycle, a speed of 1 mm/s and a distance of 3 mm, and pre- test speed 5 mm/s and post -test speed 10 mm/s. The maximum force was expressed in N. Stress was calculated by dividing the maximum force by area of blade, and strain was expressed as the maximum distance travelled by probe to break the snacks (Mazumder *et al.* 2007). All measurements were replicated three times, and the mean values are reported.

2.5 Colour Determination

Pastes were made by creating a suspension of sample and water at l5 %w/w and heated to a maximum temperature of 91°C. The colour properties of the sample were determined using a CR-10 chromameter (Konica Minolta Sensing Inc., Tokyo, Japan). The CIELAB values were determined using the intergrated scale, L * (white=100 and black=0), a * (positive=red and negative=green) and b * (positive=yellow and negative=blue) were recorded (Singkhornart *et al.* 2014). The chroma, yellowness and flour colour index (FCI) were calculated using Equations, respectively.

$$\text{Chroma} = \sqrt{a\wedge 2 + b\wedge 2}, \qquad \text{Yellowness} = \frac{142.86 \times b}{L}, \text{FCI} = L - b \qquad (1)$$

3.0 Results and Discussion

3.1 Colour properties of the formulated snacks.

The colour values of the formulated snacks are presented in Table 1. Addition of okara and OFSP residue caused significant ($p < 0.05$) differences in the colour parameters: L*, a*, b* values. The colour values of the snacks for the lightness(L) ranged from 86.0 to 93.2 with MOR (60:0:40) having the least value and MOC (60:10:30) having the highest value. This was because MOC had more of okara which was creamy white unlike OFSP residue and yellow maize flour. The value of L^* for the sample MFL (100:0:0) was 88.2. There was, however, significant difference ($p < 0.05$) between the MFL (100:0:0) which serve as control and the formulated snacks.

The redness (a*) and yellowness (b*) values of the formulated snacks ranged from 0.20 to 0.6 and 5.3 to 12.7, respectively, with MOC (60:10:30) and MOK (60:0:40) having the least value, while MOR (60:40:0) had the highest value. The increase in redness value in OFSP residue containing snacks suggests higher β-carotene content. The carotenes are the major chemicals that confer redness to fruits and vegetables. The OFSP contain high amounts of β-carotene, hence, they are orange in colour.

The a*-values and b*-values were also observed to be decreasing with increasing okara inclusion which may be as a result of the natural creamy colour of the okara. The flour colour intensity of the snacks (FCI) ranged from 75.5.to 86.6 with MOR (60:0:40) having the least value, while MOC (60:10:30) had the highest value. The value of FCI for the control MFL (100:0:0) was 75.5. There was, however, significant differences ($p < 0.05$) between the MFL (100:0:0) which serves as a control sample and the formulated snacks.

Table 1: Colour properties of the formulated snacks.

Sample code	L	a*	b*	FCI
MFL	88.20±0.2^{b}	0.50±0.1^{c}	12.70±0.6^{e}	75.50±0.5^{a}
MOR	86.00±0.2^{a}	0.60±0.1^{d}	10.40±0.3^{e}	75.60±0.5^{a}
MOA	86.60±0.2^{a}	0.30±0.1^{b}	10.90±0.6^{d}	75.70±0.3^{a}
MOB	88.40±0.2^{b}	0.30±0.1^{b}	8.50±0.3 ^{c}	79.90±0.3^{b}
MOC	93.20±0.2^{d}	0.20±0.1^{a}	6.60±0.2^{b}	86.60±0.5^{d}
MOK	90.40±0.2^{c}	0.20±0.1^{a}	5.30±0.1^{a}	85.10±0.3^{c}

Values are mean of duplicate determinations ± SD. Means with the different superscripts within the same column are significantly different ($p<0.05$). L-lightness index, a-redness index, b-yellowness index and FCI-flour colour intensity.

MFL- 100% Maize Flour, MOR- 60% Maize Flour and 40% OFSP residue. MOA- 60% Maize Flour and 30% OFSP residue and 10% okara, MOB- 60% Maize Flour and 20% OFSP residue and 20% okara, MOC- 60% Maize Flour and 10% OFSP residue and 30% okara, MOK- 60% Maize Flour and 40% Okara

3.2 Textural properties of the formulated snacks

The texture values of the formulated snacks are presented in Table 2. The texture of the snacks was described using the attributes of hardness, crispness, fracturability and Cohesiveness. The results obtained showed that they were significant ($p<0.05$) variations in the textural properties of the samples.

The hardness, fracturability and crispness of the samples ranged from 72.55 to 98.29, 28.44 to 30.49 and 6.31 to 6.70, respectively. The addition of OFSP flour significantly ($p<0.05$) increased the hardness of the snacks. Hardness can be related to the force necessary to break the snacks with the incisors during mastication (Garcıa-Segovia *et al.*, 2008). There were no significant ($p < 0.05$) differences in the fracturability of the snack samples. Fracturability is the ability to break food into pieces when it is bitten using the incisors.

There were significant differences ($p<0.05$) in crispness of the samples with increase in okara. Crispiness is an important quality parameter for foods such as biscuits and breakfast cereals. Crispiness is associated with noise of food during mastication.

The cohesiveness increased with an increase in okara addition. It ranged from 0.49 to 0.57 for MFL and MOC, respectively. Cohesiveness (or consistency) indicates the strength of internal bonds within snacks and the degree to which it can be deformed before rupture (Andrew J. Rosenthal and Paul Thompsom 2021). The high soluble fibre content of okara could have played a role in enhancing cohesiveness since soluble fibres have excellent water binding capacities. The increased hardness and cohesiveness of the snacks by added OFSP residue and okara could negatively impact the acceptability of the snacks as consumers normally prefer snacks that are not too hard to crush.

Table 2: Textural properties of the formulated snacks.

.

Sample code	Hardness (g)	Fracturability (mm)	Crispness	Cohesiveness
MFL	$87.77^{b}\pm0.01$	$29.60^{a}\pm0.01$	$6.43^{b}\pm0.02$	$0.49^{a}\pm0.01$
MOR	$98.29^{e}\pm0.01$	$28.44^{a}\pm0.01$	$6.31^{a}\pm0.01$	$0.51^{a}\pm0.01$
MOA	$92.68^{d}\pm0.02$	$30.33^{a}\pm0.02$	$6.39^{a}\pm0.01$	$0.50^{a}0.01$
MOB	$90.44^{c}\pm0.02$	$30.41^{a}\pm0.02$	$6.45^{b}\pm0.02$	$0.56^{b}\pm0.02$
MOC	$88.58^{b}\pm0.01$	$30.49^{a}\pm0.01$	$6.70^{c}\pm0.01$	$0.57^{b}\pm0.01$
MOK	$72.55^{a}\pm0.02$	$30.44^{a}\pm0.01$	$6.60^{c}\pm0.01$	$0.56^{b}\pm0.01$

Values are mean ± SD of duplicate determinations.. Means with different superscripts within the same column are significantly different ($p<0.05$). MFL- 100% Maize Flour, MOR- 60% Maize Flour and 40% OFSP residue, MOA- 60% Maize Flour and 30% OFSP residue and 10% okara, MOB- 60% Maize Flour and 20% OFSP residue and 20% okara, MOC- 60% Maize Flour and 10% OFSP residue and 30% okara, MOK- 60% Maize Flour and 40% Okara

4.0 Conclusion

This study highlighted physical properties of yellow maize-based snacks enriched with okara and orange fleshed sweet potato waste. The colour parameters were significantly affected with the incorporation of both okara and OFSP residue flours. The lightness value increased with okara addition, while the redness value increased with increase in OFSP flour. There were significant variations ($p<0.05$) in textural profile of the snack samples as observed. While fracturability, crispiness and cohesiveness increased with okara addition, hardness increased with OFSP flour. The addition of OFSP residue and okara had significant effect on the physical properties of the snacks and this could affect the acceptability of the snacks.

References

García-Segovia, P., Andres-Bello, A., and Martínez-Monzo, J. (2008) Textural Properties of Potatoes (*Solanum tuberosum* L., cv. Monalisa) as Affected by Different Cooking Processes. Journal of Food Engineering, 88, 28-35.

HarvestPlus OFSP (2009). Pro- vitamin A sweet potato. *A handbook by the international potatoes centre on breeding crops for better nutrition.* Accessible online via http//www.harvestplus_sweet _potato_strategy.pdf. Accessed January 2025

Igbabul, B. D., Num, G., and Amove, J. (2014). Quality Evaluation of Composite Bread Produced from Wheat, Maize and Orange fleshed Sweet Potato flours. American Journal of Food Science Technology, 2, 4: 109-115

Olusola, O. and Morton, I.D. (1996). Development by extrusion of soya bean snack sticks: Anutritionally improved soya-maize snack (*Kokoro*). International Journal of Food Science and Nutrition. 47:5-13.

Onyibe, J.E., Ojeniyi, S., Bankole, A.O., Teniola, D.O., Ugokwe, P.U., Mordi, J.I. and Etoamaibe, M. (2009). Production and Quality evaluation of Probiotic soy milk. Nigeria Food Journal, 27, 1: 66-74.

Omodamiro, R. M., Oti, E. Afuape, S., and Ettudaiye, H.A. (2010). *Sensory Evaluation of Orange- Fleshed Sweet potato Extract Drinks*. In: Proceedings of the 34th Annual Conference and AGM of Nigeria Institute of Food Science and Technology. River State University of Science and Technology, Port Harcourt.18th-22nd October, 2010. Pp171-172.

Peter-Ikechukwu, A., Okafor, D. C., Kabuo, N. O., Ibeabuchi, J. C Odimegwu, E. N., Alagbaoso, S. O., Njdeka, N. E., and Mbah, R. N. (2017). Production and Evaluation of Cookies from Whole Wheat and Date Palm Fruit Pulp as Sugar Substitute. International Journal of Advancement in Engineering Technology, Management and Applied Science, 4, 4: 1-31.

Satheesh, N., and Solomon, W. (2019). Review on Nutritional Composition of Orange-Fleshed Sweet Potato and Its Role in Management of Vitamin A Deficiency. Food Science and Nutrition, 7, 1920-1945.

Taiwo, N. (2016). Chemical evaluation of the effect of roasting on the nutritive value of maize. Food Chemistry, 12, 135–147.

Wickramarathna, G.L., and Arampath, P. C. (2003). Utilization of Okara in Bread making. Journal of Bioscience, 31, 29-33.

Mazumder, P., Roopa, B. S., and Bhattacharya, S. (2007). Textural attributes of a model snack food at different moisture contents. *Journal of Food Engineering*, *79*(2), 511–516.

Singkhornart, S., Edou-ondo, S., and Ryu, G.-H. (2014). Influence of germination and extrusion with $CO_{(2)}$ injection on physicochemical properties of wheat extrudates. *Food Chemistry*, *143*, 122–131.

Andrew J. Rosenthal and paul Thompsom (2021). What is cohesiveness? —A linguistic exploration of the food texture testing literature. *Journal of texture studies,* 52(3)*,* 294-302

Entrepreneurial Exploration in Food Business Operations Using Innovative Business Model Strategies for Sustainable Food Businesses: A Review

***Oyarebu A.O.,[1] Agbadua S A.[2]; Agbata P. C.[3]; Nwabugwu K. T.[1]**

[1]Technical Division, National Board for Technology Incubation, Technology Incubation Centre, Nnewi,
[2]National Engineering Design and Development Institute, [3]Uninova Enterprises
***Corresponding author's email: ahmedoyarebu@gmail.com**

ABSTRACT

There are various innovative business models that are key to food Science and Technology, that when employed in food businesses would make the venture viable and sustainable. This study synthesizes secondary data from scholarly journals, industry reports, white papers, and case studies published between 2010 and 2025, using thematic analysis to report prevailing entrepreneurial trends and strategies. Entrepreneurial exploration with the knowledge of the various innovative business models to meet consumer demands for health, sustainability, and convenience while enhancing operational efficiency and market reach. Entrepreneurial ventures in food science and Technology deploying innovative business model strategies for sustainability of food businesses. The study underscores the importance of assessing community needs, economic viability, regulatory frameworks, and demographic trends before venture initiation. This paper tends to identify major innovative business models used in food entrepreneurship and how they enhance performance and customers engagement. Findings revealed that the emergence and application of Direct-to-Consumer, subscription-based, farm-to-table, circular economy, and tech-enabled business models would make food businesses sustainable. The discussion emphasizes the resilience and adaptability of entrepreneurs in addressing modern food system challenges. The paper concludes that aligning food science and Technology entrepreneurship with innovative business models fosters scalable, socially responsive, and economically viable food ventures.

Keywords: Food Science, Entrepreneurial Exploration, Business Models Strategy, Innovative Business, Socially Responsive

Introduction

Most food businesses failed due to the business models deployed. Most entrepreneur do not have the requisite knowledge of Food Science and Technology as such they go into food businesses not equipped of the rudiments. Entrepreneurial exploration of Food Science and Technology would expose the intricacies and business model strategy to deploy considering the environment the business would be located. The food industry is undergoing a dynamic transformation driven by technological advancements, changing consumer preferences, sustainability imperatives, and health consciousness (Sarkar and Costa, 2020). In this context, entrepreneurial ventures in food science have become increasingly significant. These ventures often leverage innovative business models to achieve competitive advantages and address contemporary challenges (Goyal and Pitt, 2022). This paper explores entrepreneurial approaches in food science, focusing on the deployment of innovative business model strategies to enhance food businesses. The review also identifies key factors entrepreneurs consider before investing in food businesses, including community needs, economic potential, and market dynamics (Anderson, 2019).

Most of the food businesses are not sustainable because most entrepreneur are not ground in the venture, and some do not explore with the required knowledge of food science. The earliest known of Food Science business was fermentation of rice, fruits, and honey to produce alcoholic beverages in China and wines in Georgia which took place as far back as 7000 to 6600 BC. Fermentation was practiced virtually in all the continents with German producing Sauerkaut, Yoghurts, and Cheese, Korean Kimchi (Dimitrios A.A. and Dimitrios T., 2019).

Food Science and Technology is a discipline with a vast profession that for an entrepreneur to invest in any of its area should be abreast of the business model to apply to be able to make fortune from the business. It is an interdisciplinary field which combines the following disciplines: Biology, Biochemistry, Chemistry, and Chemical Engineering and for in-depth knowledge of food processes to improve food products for the public (Saguy I., 2018). It studies the physical and chemical properties of foods and the changes that may occur during processing and storage. The following are the branches of Food Science: Engineering and processing; Sensory science; Nutrition; Food Chemistry; and Microbiology.

This paper employed a qualitative research methodology, analyzing secondary data from academic journals, industry reports, case studies, and white papers published between 2010 and 2025. Thematic analysis was used to identify trends in business model innovation within the food sector. Key areas of focus included entrepreneurial motivations, strategies deployed, business model typologies, and socio-economic impact assessments (Miles and Huberman, 2014).

Invention is the art of bringing something new into existence, when an invention is brought to light the art that sustains it is innovation, and innovation births sustainability. A business model innovation strategy involves the process of building on inventions to make it appealing to the customers always. Innovation brings competitive advantage that foster new opportunities for economic growth and development. There are two types of innovations namely: Sustaining; and Disruptive.

Entrepreneur is a risk taker and sometimes ventures into a business with little or no knowledge, this art is Entrepreneurial Exploration. Entrepreneurial exploration in food science businesses is vital due to the fact that it builds new products and processes, solves problems in the food supply chain, and drives innovations because it drives innovation. Entrepreneurial exploration in food science, when aligned with innovative business model strategies, offers a powerful means to enhance food businesses by focusing on direct consumer engagement, sustainability, and technological integration, address modern challenges and create scalable, impactful ventures.

Business Strategy is the approach implored to solving business problems. Strategies deployed in food business depends on the enterprise's overall actions to preserve higher-level services offer to fulfill customer needs better compared with its competitors. A good strategy should be based on planning enterprise using interior and exterior environment.

The conservation use of resources is Sustainability. The narratives of voracious consumption with regards to future has been discourage since the year 2010. In Food Science and Technology, the consumption of food and the reduction of waste that turns to pollutants and sometimes, recycled to produce bioethanol or biogas.

Food Science and Technology

Food Science and Technology (FST) is the application of Scientific concept to investigate and enhance the food system from raw to the processed its professionals are involved in development of new food products, inventing improved varieties and existing ones, and guarantee the ingenuity of the worldwide food supply chain (IFT, 2025). The following are the roles of FST:

- **Developing new food products:** FST professionals invent, innovation of recipes and formulations, research new ingredients and processing techniques.
- **Understanding food composition: Carry out physical, compositional, and nutritional analysis aspect of products to ascertaining its behaviour and optimization.**
- **Ensuring food safety: Control the quality of food in stock is free from contamination and safe for consumption.**
- **Design and optimization of food processing methods: Development of safe and efficient methods of processing, p**ackaging, and preserving food.
- **Use of technology to extend shelf life: The extension of shelf life of products using innovative preservation and packaging techniques.**

- **Conducting sensory evaluation: Evaluation of taste, appearance, and texture of food products employing sensory analysis to meet consumers' desire.**
- **Conducting research on food science: The following areas of research, food chemistry, nutrition, and** food microbiology; and
- Regulatory and Legal Aspects: Interpretation and enforcement of regulations by compliance to existing laws.

Why Entrepreneurial Exploration in Food Science

Entrepreneurial exploration is vital for the growth of the food businesses in Nigeria, to ensure food surplus, creates opportunities for employment, boost innovations, Value addition, Economic growth, improves agricultural sector, reduce waste, and enhance productivity. Entrepreneurial Exploration is a vital process for entrepreneurs to build business, innovate and remain in the business. This aspect of entrepreneurship entails venturing into new opportunities, adapting to changing conditions of the market, analyse the environment and development of strategies to capitalize on opportunities. It equally involves information gathering, building and analyzing business models, and testing, before execution. The following are the major aspects of exploration:

- **Opportunity Recognition:** Identification of Gaps in the market and Customers.
- **Experimentation:** Carry out a survey for the model that is most suitable, Testing the new product, and subjecting the services to scrutiny, services.
- **Networking:** Establishing connections with identified customers, investors, and partners.
- **Market Survey:** Collection of information about the market, and competition.
- **Learning and Adaptation:** Application of market trends, feedback and data analyses for refining the business model; and
- **Testing pricing strategies:** Application of different pricing strategies for a product or service to ascertain the highest sales.

The following are what an entrepreneurs should consider before investing in food Science and Technology ventures:

- **Demographic Trends**: Targeting specific age groups or lifestyle segments, such as vegan or gluten-free consumers (Kumar *et al*., 2021).
- **Community Needs**: Understanding cultural food preferences, health issues, and local sourcing opportunities (Anderson, 2019).
- **Economic Viability**: Analysis of market demand, pricing strategies, funding availability, and profitability potential (Sarkar and Costa, 2020).
- **Regulatory Environment**: Compliance with food safety laws, labeling requirements, and environmental regulations (Martin and Liu, 2020).

Why Innovation in Food Science and Technology?

Human needs are insatiable, because of the greedy nature of man's thirst, the call for innovation. Innovation is the continuous upgrade on what has been invented. Innovation strategy is a thorough plan with various steps that helps the establishment to achieve its emerging goals. Invention precede innovation, Innovation is brought by request from the need of users, Technology, and Business Competitors. The following are the major types of innovation; Sustaining; and Disruptive.

Innovation is about assembly of the evolving needs and demand of customers and delivery value to society, and the jobs to be done (Stefan, D.,2023). Innovation is either creating new or improving on the existing products, services, business strategies, and Technologies. To remain in business there is need for continuous

innovation, and to bring forward a positive change to their customers'. A thriving innovation needs a combination of strategic thinking, experimentation, creativity, and a disposition to take risks.

Business models' innovation refers to the process of developing new or improving on existing products, services, or processes to meet the changing needs and requirement of customers. Business brings increased value to the business and its stakeholders through generation and execution of new ideas, and innovative technologies. Innovation can also be employed to find new paths to optimize present resources, reduce cost, enhance efficiency, and boost profitability.

Business Models

Model is a physical representation of what is conceived. Oxford Dictionary defines a model as a three-dimensional creation of a proposed structure, typically on a smaller scale compared to the original. Start-ups businesses explore models like: Freemium; Subscription; Marketplace; Reseller models; and On-demand. The following are other innovative business model strategies in entrepreneurial food ventures:

- **Direct-to-Consumer (DTC) Models:** Entrepreneurs use online platforms to sell directly to consumers, reducing dependence on intermediaries and enhancing customer relationships. DTC models provide opportunities for personalized marketing, faster feedback loops, and greater control over brand identity (Kumar *et al*., 2021; Mazar and Chouinard, 2020). Nigerian examples include Eden Life and PricePally, which utilize e-commerce and mobile apps to deliver food products and groceries directly to consumers, particularly in urban centers such as Lagos and Abuja (Wilson, 2021).

- **Subscription-Based Models:** Regular delivery of meal kits or specialty foods fosters customer loyalty and predictable revenue (Martin and Liu, 2020). This model appeals to modern consumers seeking convenience and customization. Local Nigerian ventures such as Soupah Farm-en-Market and MyFoodAngels have adopted subscription services to deliver fresh produce, soups, and ready-to-cook ingredients. These models provide consistent cash flow, enable demand forecasting, and reduce food waste by aligning production with pre-planned consumption (Wilson, 2021). The feedback loop from recurring customers enhances innovation and continuous product improvement (Martin and Liu, 2020).

- **Farm-to-Table Models**: This model emphasizes locally sourced ingredients, minimal processing, and direct partnerships between producers and consumers. It aims to shorten the food supply chain, increasing transparency and traceability while supporting local economies (Gonçalves and Campos, 2023). Entrepreneurs adopting farm-to-table strategies often collaborate with small-scale farmers, organic producers, and local markets to deliver fresher, seasonal, and ethically grown products. In Nigeria, ventures such as Fresh Direct Nigeria and Veggie Victory have advanced this model by supplying locally grown, organic produce and plant-based meals directly to urban consumers. This approach aligns with rising consumer interest in sustainability, animal welfare, and health-conscious eating (Anderson, 2019).

- **Circular Economy Models**: Circular economy models emphasize minimizing waste and reusing resources by recycling food waste into valuable new products. Nigerian startups such as Releaf and ColdHubs exemplify this approach. Releaf focuses on reducing post-harvest loss by developing tech-based agricultural processing systems, while ColdHubs uses solar-powered cold storage to extend the shelf life of perishable food, reducing spoilage. Other examples include local initiatives that turn fruit peels into compost or use food byproducts in animal feed or new food formulations. These practices not only contribute to environmental sustainability but also generate additional revenue streams and employment opportunities (Borrello *et al*., 2017).

- **Tech-Enabled Models** Integration of AI, IoT, and blockchain technologies has revolutionized food business operations. These technologies improve traceability across supply chains, reduce spoilage through predictive analytics, and enhance personalization of food products to suit individual preferences (Galvez *et al*., 2018). In Nigeria, tech ventures like Vendease and Hello Tractor have employed IoT and AI to streamline food procurement and agricultural logistics, respectively. Blockchain ensures transparency in sourcing and processing, helping businesses build trust with consumers and comply with regulatory standards. Personalized nutrition platforms are also emerging,

using AI-driven dietary assessments to offer tailored food recommendations based on health data. These models foster data-informed decision-making and operational efficiency.

The influence of the Deployment of Innovative Business Models

The deployment of innovative business models in the Nigerian food sector illustrates the adaptability and resilience of local entrepreneurs. DTC and subscription models have gained traction due to digital transformation and urbanization. Circular economy and farm-to-table models align with Nigeria's sustainability goals and the increasing consumer emphasis on health and ethics. Tech-enabled innovations improve supply chain transparency and business efficiency.

Sustainability-focused models:

Business models that prioritize sustainability focus on reducing food waste by encouraging circular economies, drive the acceptance of technologies that enhance resource efficiency and reduce the pollution of the environment. The strategies that placed emphasis on sustainability would change the perception of the entrepreneur and consumers on the value on food., and possibly lead to enhanced demand for foods that are ethically developed, nutritionally advantageous, and environment friendly.

Conclusion

Entrepreneurial exploration in food science, when aligned with innovative business model strategies, would offers a powerful means for enhancing food businesses with a focus on direct consumer engagement, sustainability, and technological integration, entrepreneurs can address modern challenges and create scalable, impactful ventures. The success of these initiatives depends on a holistic understanding of community needs, economic conditions, and evolving consumer behaviors. Future research should explore hybrid models and longitudinal impacts to further inform strategic development in food entrepreneurship.

Recommendation

Policy makers and industry stakeholders should support food entrepreneurs through funding, capacity-building programs, and technology infrastructure. Encouraging local innovations and investing in digital literacy, supply chain logistics, and sustainability education can help scale successful models and expand access to nutritious, affordable food. Universities and research institutions should also collaborate with entrepreneurs to pilot tech-enabled and sustainable solutions tailored to local contexts.

References

Anderson, D. (2019). *Food entrepreneurship and community development: Case studies in local sourcing*. *Journal of Food Systems*, 15(3), 78-89.

Borrello, M., Caracciolo, F., Lombardi, A., Pascucci, S., and Cembalo, L. (2017). Consumers' perspective on circular economy strategy for reducing food waste. *Sustainability*, 9(1), 141.

Darek M. H., Ricardo C.C., (2023). Five Dimensions of Business Model Innovation: A Multi Case Exploration of Industrial Incumbent firms Business Model Transformations. *Journal of Business Research. SciencDirect* vol154: 113352, pg 1-12

Dimitrios A.A., and DimitriosT., (2019). Fermented Foods and Beverage *Innovations in Traditional Foods, Elseveir,* pg 258-291

Galvez, J. F., Mejuto, J. C., and Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *Trends in Analytical Chemistry*, 107, 222-232.

Gonçalves, E., and Campos, M. (2023). Farm-to-table entrepreneurship: Localism, sustainability, and the food economy. *Journal of Agribusiness Innovation*, 10(1), 33-45.

Goyal, T., and Pitt, L. (2022). Disruptive innovation in the food industry: Lessons from startups. *Journal of Strategic Innovation*, 14(2), 105-120.

IFT (2025). About Food Science and Technology. https://www.ift.org/career-development/learn-about-food-science/food-facts/about-fs-and-t. Accessed: January, 15, 2025.

Kumar, A., Yadav, R., and Singh, N. (2021). Understanding the growth of direct-to-consumer business models in the food industry. *International Journal of Business Research*, 12(4), 119-135.

Martin, D., and Liu, Y. (2020). Subscription economy and consumer loyalty: The case of meal-kit services. *Journal of Business Models*, 8(1), 45-59.

Mazar, H., and Chouinard, J. (2020). Building trust through DTC platforms: Implications for food startups. *Journal of Consumer Insights*, 6(2), 88-97.

Miles, M. B., and Huberman, A. M. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). *SAGE Publications*.

Saguy I.S., Yrjo H.R., Eli C., (2018). Food Engineering and Food Science and Technology: Forward-Looking Journey to Future New Horizons. *Journal of Innovative Food Science and Emerging Technologies. Elseveir,* Vol 47, pg 326-334

Sarkar, A., and Costa, A. A. (2020). Rethinking food business models: Innovation towards sustainability and digitalization. *Food Policy Review*, 25(2), 144-158.

Stefan D., (2023). Types of Innovation: How the Four Innovations types can help your business. *Digital Leadership.*

Wilson, C. (2021). E-commerce strategies in emerging food brands: A direct-to-consumer perspective. *Journal of Digital Retailing*, 5(1), 23-38.

Proximate and sensory qualities of bread produced from blends of locally cultivated and commercial wheat flours

*Asogwa, I. S[1], Ezenwuba, C. J[1]., Odieze, I. E[2].

[1]Department of Food Science and Technology, University of Nigeria Nsukka. [2]National Centre for Energy Research and Development, University of Nigeria Nsukka

*Corresponding author's email: ifeyinwas.asogwa@unn.edu.ng

ABSTRACT

This study evaluated the proximate and sensory qualities of bread produced from blends of commercial wheat and *Triticum aestivum* flours. Local wheat grains were milled, sieved into flour and blended with commercial wheat at varying ratios: 100:0, 90:10, 80:20, 70:30, and 60:40. The samples were labeled CAB1 (control), CAB2, CAB3, CAB4, and CAB5, respectively. The proximate analysis and sensory evaluations were conducted on each bread sample using standard methods. The proximate composition values of the bread samples for moisture, crude protein, crude fibre and ash contents ranged from 21.23 to 24.51%, 7.38 to 7.92%, 0.26 to 1.6% and 0.90 to 1.59%, respectively. The protein, moisture, fat and crude fibre contents increased with increased levels of local wheat flour addition. The appearance, texture and overall acceptability scores ranged from 5.60 to 8.33, 5.40 to 8.00 and 5.73 to 8.60, respectively. The sensory parameters of the bread samples decreased with increase in local wheat flour. The sensory scores showed that the bread samples were acceptable even at the highest substitution level (40%). This study has shown that acceptable protein and fibre enriched bread can be produced by incorporating local wheat flour into commercial wheat flour at up to 40% substitution level.

Key words: *Triticum aestivum,* commercial wheat flour, proximate composition and sensory parameters.

1.0 Introduction

Many countries are currently attempting to improve their economy by agricultural development policies to reduce their dependency on imported foods. Nigeria is not left out from this global trend as efforts to cultivate wheat is experiencing renewed attention from the government, the African Development Bank, and researchers, and in certain parts of the country, is yielding positive results (Boluwade, 2022). By prioritizing food self-sufficiency, Nigeria can strengthen her food sector, improve food security, and contribute to the overall economic growth and well-being of its population.

In an attempt to reduce the high importation cost of wheat flour, the Nigerian government has embarked on programs to promote local wheat cultivation and utilization in the country. Unfortunately, attempts to utilize these locally grown wheat flours in bread production has not yielded expected results as these bread samples produced from these flours alone exhibited lower quality than those from the conventional flours (Abubakar *et. al.*, 2020). This poor performance could be attributed to the higher fibre and lower gluten content of locally milled wheat flours when compared to the imported ones (Abubakar *et. al.*, 2020). Blending the flours of the locally grown wheat flour with the conventional flour could therefore be a good option for improving the quality of produced bread, while at the same time promoting the utilization of the local flours thereby reducing the cost of bread, which is a major staple food in the country.

This study was designed to evaluate the effect of blending locally grown wheat flour with conventional wheat flour on the proximate and sensory properties of produced bread.

2.0 Materials and Methods

2.1 Procurement of materials

Local wheat grains, commercial wheat flour (Golden Penny Classical wheat flour), yeast, sugar, margarine and powdered milk were purchased from *Ogige* Market in Nsukka Local Government Area, Enugu State.

2.2 Production of local wheat flour

The method described by Bolaji *et al.* (2022) was used to produce the wheat flour. The wheat kernels were cleaned to remove impurities like stones, dirt, or other foreign materials. The cleaned wheat kernels were coarsely milled by process described by Babalola *et al.* (2021).

2.3 Bread production

Flour blends were formulated by substituting conventional wheat flour with locally cultivated wheat flour as follows: 100: 0, 90:10, 80:20, 70: 30 and 60:40. The flours were labeled CAB1, CAB2, CAB3, CAB4 and CAB5 respectively. Bread samples were produced from the various flour blends using the straight dough method (Igbabul *et al.,* 2014). This method involved the mixing of all the ingredients (400 g flour, 50 g sugar, 100 g margarine, 9 g yeast, 20 g milk powder, 5 ml vegetable oil and 200 ml water.) and then kneading to obtain the dough. The dough was cut, weighed, molded and panned in greased baking pans and was covered for 30 min for proofing to take place. After proofing, the dough was baked for 45 min at a temperature of 180°C. The baked bread was carefully removed from the oven and de-panned, allowed to cool for 20 min and then packed in polyethylene bags.

2.4 Determination of proximate composition of the bread samples

All proximate parameters were determined using the AOAC (2010) methods.

2.4.1 Sensory evaluation

Sensory evaluation was used to score for appearance, taste, flavor, aroma, aftertaste, mouth feel and general acceptability of the bread samples. This was done using a 9-Point Hedonic Scale where 9 was equivalent to like extremely and 1 stand for dislike extremely.

2.4.2 Experimental Design and Data Analysis

The experiment was laid out in a Completely Randomized Design (CRD). The means and standard deviations of the data were calculated from duplicate determination of each parameter. One Way Analysis of Variance (ANOVA) in SPSS (version 25) was used to analyze the data. Mean separation was done using Duncan's Multiple Range Test. Significance was accepted at $p < 0.05$.

3.0 Results and Discussion

The effect of blending ratio on the proximate composition of commercial wheat and locally grown wheat (*Triticum aestivum*) flour blends are presented in Table 1. Addition of locally grown *Triticum aestivum* flour caused significant ($p < 0.05$) differences in the proximate composition parameters.

The moisture content value of the bread samples ranged from 21.23 to 24.51%, with the highest value observed in CAB5, while the least value was observed in the control sample, CAB1. The moisture content of the bread increased with an increasing substitution level of with the local wheat flour. This higher moisture content can be attributed to the higher water-holding capacity of local wheat, primarily due to its high fibre content, resulting in increased retention of water within the dough. The increased moisture content could reduce the shelf life of the bread by promoting microbial and mold growth leading to spoilage.

The protein value of the bread samples ranged from 7.38 to 7.92%, with the highest value observed in CAB5 but the least value was observed in the control sample. As the quantity of local wheat flour increased, the protein content in the bread samples increased. This suggests that the local wheat flour had a higher protein content compared to the commercial wheat flour. This difference may be attributed to

the refining process of commercial wheat, where the bran, containing a higher percentage of the protein is typically removed. In contrast, the local wheat milled whole hence retaining most of its bran.

The crude fibre content value of the bread samples ranged from 0.26 to 1.68%, with CAB5 having the highest fibre content, while the sample CAB1 had the least protein content. There was significant ($p<0.05$) increase in crude fibre content as the local wheat flour increased. This higher fibre content can be attributed to the higher bran content of the locally processed wheat grains when compared to the commercial flour. Fibre content in foods is beneficial as it has been associated with reduced risk of cardiovascular disease, regulation of glucose and lipid metabolism and enhanced gut health (Layla, 2024). Despite the health benefits, fibre may have a negative effect on the physical quality of bread.

The ash content values ranged from 0.90 to 1.59%, CAB1 had the highest value, while CAB5 had the least ash content. There was a decrease in ash content with local wheat flour inclusion. This could be attributed to the presence of food additives such as fortificants and preservatives in the commercial wheat flour.

Table 1: Proximate composition of bread samples from blends of commercial wheat and locally grown wheat flour blends

Bread sample	Moisture (%)	Protein (%)	Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrate (%)
CAB1	$21.23^{d}\pm0.38$	$7.38^{c}\pm0.07$	$9.62^{c}\pm0.40$	$0.26^{d}\pm0.1$	$1.59^{a}\pm0.00$	$59.93^{a}\pm0.71$
CAB2	$22.35^{c}\pm0.34$	$7.70^{b}\pm0.02$	$10.66^{b}\pm0.27$	$0.42^{d}\pm0.21$	$1.14^{b}\pm0.08$	$57.74^{b}\pm0.01$
CAB3	$22.13^{c}\pm0.25$	$7.74^{b}\pm0.01$	$11.04^{a}\pm0.02$	$0.85^{c}\pm0.00$	$1.00^{c}\pm0.07$	$57.25^{b}\pm0.28$
CAB4	$23.39^{b}\pm0.38$	$7.72^{b}\pm0.01$	$11.65^{a}\pm0.13$	$1.03^{b}\pm0.10$	$0.99^{c}\pm0.00$	$55.22^{c}\pm0.34$
CAB5	$24.51^{a}\pm0.30$	$7.92^{a}\pm0.00$	$11.96^{a}\pm0.02$	$1.68^{a}\pm0.12$	$0.90^{d}\pm0.00$	$53.04^{d}\pm0.21$

Values are means of duplicate determinations ±standard deviation. Means with different superscript in the same column are significantly ($p<0.05$) different. CAB1 (100% commercial wheat flour), CAB2 (90% commercial wheat flour + 10% *Triticum aestivum* flour), CAB3 (80% wheat flour + 20% *Triticum aestivum* flour), CAB4 (70% commercial wheat flour + 30% *Triticum aestivum* flour), CAB5 (60% commercial wheat flour + 40% *Triticum aestivum* flour).

The effect of blending ratio on the sensory characteristics of bread from commercial wheat and locally grown *Triticum aestivum* flour blends are presented in Table 2. There were significant ($p<0.05$) variations among the samples in all the sensory parameters evaluated.

All sensory scores decreased as the level of locally grown *Triticum aestivum* flour increased. The scores for appearance, aroma, taste, aftertaste, texture, mouthfeel and overall acceptability range from 5.6 to 8.33, 5.60 to 8.2, 5.8 to 8.33, 5.4 to 8.00, 5.73 to 8.00 and 5.73 to 8.60, respectively. This indicates that higher levels of locally grown *Triticum aestivum* flour in the blend generally resulted in lower sensory scores across all parameters evaluated. This implies a possible negative impact on consumer acceptability of the bread.

All scores were, however, above 5 which means all were liked to an extent. Acceptable bread loaves can therefore be produced by substituting wheat flour with locally grown wheat flour substitution even up to 40% level.

Table 2: **Sensory characteristics of bread samples from blends of commercial wheat and locally grown wheat flour blends**

Bread sample	Appearance	Aroma	Taste	Aftertaste	Texture	Mouth feel	Overall acceptability
CAB1	$8.33^{a}\pm0.72$	$8.20^{a}\pm0.86$	$8.33^{a}\pm0.72$	$8.33^{a}\pm0.90$	$8.00^{a}\pm1.00$	$8.00^{a}\pm1.00$	$8.60^{a}\pm0.63$
CAB2	$7.33^{b}\pm0.72$	$7.4^{ab}\pm0.74$	$7.47^{ab}\pm0.92$	$7.13^{b}\pm0.99$	$7.67^{a}\pm1.29$	$7.67^{a}\pm0.97$	$7.53^{b}\pm0.74$
CAB3	$7.00^{b}\pm0.85$	$6.87^{bc}\pm1.51$	$6.73^{bc}\pm1.75$	$6.07^{c}\pm1.53$	$6.13^{b}\pm0.92$	$6.80^{b}\pm1.08$	$7.13^{b}\pm0.92$
CAB4	$6.67^{b}\pm1.29$	$6.07^{cd}\pm1.63$	$6.33^{c}\pm1.84$	$6.00^{c}\pm1.89$	$5.87^{b}\pm1.46$	$6.47^{bc}\pm1.25$	$6.4^{c}\pm1.12$
CAB5	$5.60^{c}\pm0.99$	$5.60^{d}\pm1.24$	$5.80^{c}\pm1.57$	$5.67^{c}\pm1.35$	$5.40^{b}\pm1.35$	$5.73^{c}\pm1.16$	$5.73^{c}\pm1.22$

Values are means of duplicate determinations ±standard deviation. Means with different superscript in the same column are significantly ($p<0.05$) different. CAB1 (100% commercial wheat flour), CAB2 (90% commercial wheat flour + 10% *Triticum aestivum* flour), CAB3 (80% wheat flour + 20% *Triticum aestivum* flour), CAB4 (70% commercial wheat flour + 30% *Triticum aestivum* flour), CAB5 (60% commercial wheat flour + 40% *Triticum aestivum* flour

4.0 Conclusion

This study evaluated the proximate and sensory qualities of bread produced from blends of local wheat and commercial wheat flours. The different levels of substitution resulted in significant ($p<0.05$) changes in all the quality parameters evaluated. Moisture, protein and crude fibre contents increased with increased level of substitution. The scores of sensory evaluation parameters like appearance, taste, texture and overall acceptability decreased significantly ($p<0.05$) with an increase in local wheat flour. All bread samples, however, scored above neither liked nor disliked values. The study had shown that an acceptable protein enriched bread can be produced by substituting commercial wheat flour with locally grown wheat flour, even up to 40% level.

References

Abubakar, F., Badau, M. H., Idakwo, P. Y. and Danbaba, N. (2020). Physicochemical characteristics and baking quality of Nigerian grown rain-fed wheat varieties. American Journal of Food Science and Technology, 8(5): 196-205.

AOAC. (2010). Official Method of Analysis. Association of Analytical Chemists, 18th edition. Gaithersburg, Maryland, USA.

Babalola, J. O., Adesina, D. A., Alabi, O. O., Adepoju, M. R., Bamisaiye, Y. O., and Awotunde, B. R. (2021). Effect of processing method on proximate, minerals, phytochemicals, and antinutrients present in Baobab seeds (*Adansonia digitata*). *GSC Advanced Research and Reviews,* 6(3): 1–10.

Bolaji, O. T., Adeyeye, S. A. O. and Akinboyo, B. E. (2022). Quality evaluation of bread produced from wheat flour (*Triticum aestivum*) fortified with date flour (*Phoenix dactylifera* L.). Asian Journal of Dairy and Food Research, 258: 1-7.

Boluwade, E. (2022). Grain and Feed Annual (Report No. NI2022-0005). Lagos, Nigeria: United States Department of Agriculture.

Igbabul, B., Num, G. and Amove, J. (2014). Quality evaluation of composite bread produced from wheat, maize and orange fleshed sweet potato flours. American journal of food science and technology, 2(4): 109-115.

Layla A. A. (2024). Dietary fibre influence on overall health, with an emphasis on CVD, diabetes, obesity, colon cancer and Inflammation. *Frontiers in Nutrition,* Volume 11

Agricultural Products and Packaging, Panacea for Food Safety: The Agribusiness Approach.

Okpeke, A. G.

Department Of Agribusiness Management, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria

Correspondence: okpeke4god1972@gmail.com

ABSTRACT

This study examined the effect of packaging on food safety and income realized in the agricultural industry. Primary data was collected using a structured questionnaire. The questionnaires were administered to the selected consumers of packaged agricultural products in the three LGAs. A sample size of 120 consumers of packaged agricultural product were been selected using the Taro Yamane formula and allocated to the three LGAs using the Bowley allocation method, which takes into account the population size of each L.G.A. The results show that labeling has a significant positive effect on food safety (p-value 0.002) the hypothesis tested indicated that packaging has significant effect on food packing (p-value 0.002< 0.05), the findings suggest that proper labeling and packaging practices are crucial for ensuring food safety and minimizing costs, Annual income generated amounted to(₦ 700,000), The mean age was 40 years old., Majority of the respondents were male (57.5%), Education showed secondary level (34.2%). Business tycoon and Married were found to be (46.7%) and (69.7%) respectively. The study recommends education and awareness campaigns, proper labeling and packaging practices, and cost-effective packaging solutions to promote safe food handling practices and reduce losses.

Keyword: Food safety, agricultural products, packaging, agribusiness.

Introduction

Food safety has become a huge concern among health authorities due to its serious impact. Foods can be mishandled during preparation, processing, or storage, especially in food service environments. Various factors may be causing foodborne diseases, including foods from unsafe sources, inadequate cooking, contaminated equipment, and poor personal hygiene (Abdullah and Siow, 2014 in Rohin *et al., 2024*). Despite the health authorities' efforts, foodborne illness cases are still happening throughout the country (Mustafar, 2018 in Rohin *et al., 2024*). A human can acquire several diseases by ingesting some pollutants, including poisons, chemical compounds, toxic gases, and bacterial toxins. It is important to know that poisoning is the cause of morbidity and mortality worldwide (Hernández-Cortez *et al.*, 2017 in Rohin *et. al. 2024*).

Packaging is considered as a differentiation tools, thus, it helps consumers to make a choice among a wide range of similar products, and also incites consumers' purchasing behaviour (Wells *et al.*, 2007 in Kwaku and Fan, 2020) Product design and packaging is very crucial to the marketability of products. Design and packaging are the product's first sales pitch, which is of key importance to its market positioning. The form, colours, design and texture of packaged products incite sensations in the consumer to draw closer, lift it up for a closer look, read it, handle it, purchase it and take it home for use (Kwaku and Fan, 2020). Studies have indicated that despite the huge effort in mass-media advertising to influence consumer purchase, a more of purchases are to a large extent influenced by the environment of the market place. About 66% of all supermarket decisions to buy are taken in the store (Annan, 2018 in Kwaku and Fan, 2020). This research asks the following are the research question;

what is the socio-economic characteristics of consumers of packaged agricultural products? what is the effects of packaging on food safety? What is the cost and return of packaged agricultural products?

Research Objectives

The broad objective is to evaluate the effect of agricultural products packaging of food safety. While the specific objectives are to identify the socio-economic characteristics of consumer of food and agricultural packaged products, evaluate the effects of packaging on food safety and estimate the cost and returns of packaged food and agricultural products.

Hypotheses of the study

$H0_1$: packaging does not affect food/agricultural product significantly in terms of safety.

Methodology

Research Design

This study employed a survey research design to examine the impact of packaging of agricultural products on food safety in Benue State, Nigeria.

Population of the Study

The population of the study consists of all consumers of food/agricultural products in Benue State, Nigeria. The study focused on consumers of packaged agricultural products in three selected L.G.As namely Makurdi, Otukpo, and Katsina Ala.

Sampling and Sampling Technique

A sample size of 120 consumers of packaged agricultural product were been selected using the Taro Yamane formula. The sample were been allocated to the three LGAs using the Bowley allocation method, which takes into account the population size of each LGA. This was to ensure that the sample was a representative of the population.

Method of Data Collection

Primary data was collected using a structured questionnaire. The questionnaires were administered to the selected consumers of packaged agricultural products in the three LGAs. The questionnaires captured data on the socio-economic characteristics of the consumers, their preferences for different packaging designs, their willingness to pay for agricultural products with different packaging designs, and their perceptions on the effects of packaging on food safety.

Method of Data Analysis

Descriptive statistics (means, frequencies, and percentages) was used to analyze the socio-economic characteristics of the consumers and their perceptions on the effects of packaging on food safety. Inferential statistics (regression analysis and correlation analysis) examined the relationship between packaging elements and food safety.

Measurement of Variables

The variables were measured as follows:

Socio-economic characteristics: age, income, education, and occupation.

Consumer preference: measured on a Likert scale (1-5) to capture the degree of preference for different packaging designs.

Willingness to pay: measured as the premium price consumers are willing to pay for agricultural products with different packaging designs.

Food safety: measured as the consumers' perceptions of the safety of agricultural products in different packaging designs.

Sex: Sex was measured as Male is 1, Female is 2.

Marital Status: Marital Status was measured as Married = 1, Single= 2, Widow=3, Widower =4 and Divorcee = 5

Model Specification

Mathematical Expression

The Ordered Probit Model can be specified as follows:

$$Y^* = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \varepsilon$$

Where:

Y* = Latent variable representing the level of confidence in food safety (ordinal)

X1 = Packaging material (e.g., plastic, glass, paper)

X2 = Packaging design (e.g., vacuum-sealed, aseptic)

X3 = Labeling (e.g., clear, unclear)

β0 = Intercept

β1-β3 = Coefficients of the independent variables

ε = Error term

Dependent Variable

The dependent variable is the level of confidence in food safety, measured on an ordinal scale (1-4).

Independent Variables

The independent variables are the packaging design elements, including:

- Packaging material
- Packaging design
- Labeling
- Storage conditions

Results and Discussion

Table 1 is the Socio-economic Characteristics of Consumers of packed food/agricultural product.

Age: The majority of consumers (30%) are between 35-44 years old, indicating that this age group is more likely to purchase packaged agricultural products. This finding is consistent with studies that suggest that middle-aged adults are more likely to prioritize convenience and quality in their food choices (Farrell, 2019).

Sex: More males (57.5%) consume packaged agricultural products than females (42.5%). This finding is supported by research that suggests that men are more likely to be involved in food purchasing decisions (Daugherty, 2024).

Education: Consumers have varying levels of education, with 34.2% having secondary education and 28.3% having tertiary education. Studies have shown that education level can influence food choices and purchasing decisions (Manoj et. al. 2022).

Occupation: The majority of consumers (46.7%) are business tycoons, followed by those with combined occupations (27.4%). This suggests that entrepreneurs and individuals with multiple income streams are

more likely to purchase packaged agricultural products due to their busy lifestyles and need for convenience.

Annual Income: The mean income of 700,000 naira was report for the respondents as money realized annually. This amount indicates some level of financial freedom and ability to buy agricultural packed product freely. A sizeable number were also involved in business of food/ agricultural packed product like (buying and selling of paddy rice, cassava processing –garri, and other kinds of agricultural products).

Table 1. Socio-economic characteristics of consumers of packaging Food/ agricultural products

Age	Frequency	Percent	Mean
18-24	20	16.7	
25-34	17	14.2	
35-44	36	30.0	**40**
45-54	22	18.3	
55 and above	25	20.8	
Total	**120**	**100**	
Sex			
Male	69	57.5	
Female	51	42.5	
Total	**120**	**100**	
Education			
Primary	12	10.0	
Secondary	41	34.2	
Tertiary	34	28.3	
Non formal education			
	33	27.5	
Total	**120**	**100**	
Occupation			
civil servant	11	9.2	
Business tycoon	56	46.7	
Farmer	20	16.7	
combined occupation			
	33	27.4	
Total	**120**	**100**	
Marital status			
Married	80	66.7	
Single	17	14.2	
Widow	6	5.0	
Widower	10	8.3	
Divorcee	7	5.8	
Total	**120**	**100**	
Annual Income			
300001-400000	14	11.7	
400001-1000000	72	60.0	**700,000**
above 1000000	34	28.3	
Total	**120**	**100**	

Source: Field Survey, 2024

Table 2 is the effect of packaging on food safety. The probit regression results revealed the effect of packaging on food safety.

Labeling of Pack

The significant positive effect of labeling on food safety (p-value 0.002) suggests that improper labeling can lead to food safety issues. This may be due to inadequate information on packaging materials, handling instructions, or expiration dates.

Packaging Material and Design

The non-significant effect of packaging material and design on food safety (p-values 0.158) and (p-values 0.158) respectively may indicate that these factors are not as crucial in determining food safety. However, it is essential to note that packaging material and design can still impact food safety in other ways, such as contamination or damage during transportation.

Table 2. Probit regression result for the effect of packaging on food safety

Parameter		Estimate	Std. error	Z-value	Sig.	95% confidence interval	
						Lower bound	Upper bound
PROBITa	*LABELLING*	-.516	.168	-3.067	0.002	-.846	-.186
	PACKGMAT	106	.075	-1.411	.158	-.254	.041
	PACKDESIG	.224	.158	1.412	.158	-.087	.535
	INTERCEPT	-.135	.401	-.344	.731	-.539	.263

a PROBIT model: PROBIT(p) = Intercept + BX

Probability= 0.05, Significant difference P-value= 0.002, LABELING = labeling of packs (Bag), PACKGMAT = packaging Material, PACKDESIG = Pack Design

Hypotheses Testing

$H0_1$: Packaging does not affect food/agricultural product significantly in terms of safety.

The probit regression results show that labeling of packs has a significant effect on food safety-value ($0.002<0.05$), so we reject the null hypothesis. This suggests that packaging can impact food safety, particularly if labeling is inadequate.

Conclusion

The study's findings highlight the significance of packaging in the agricultural industry, particularly in terms of food safety and price. The results show that packaging can impact food safety, with labeling being a critical factor.

Recommendation

Farmers should Invest in proper packaging materials and techniques to reduce losses, ensure food safety, and add value to products. Also, Farmers should ensure that labels are accurate, clear, and comply with regulatory requirements. Lastly, consumers should Pay attention to packaging and labeling when purchasing agricultural products, and choose products with proper labeling and packaging.

References

Rohin, M.A.K., Mohd Najib, N.A.A., Ridzwan, N., Abd Hadi, N., Ishak, R. and Baig, A.A. (2024). Safe Food Handling Knowledge and Practices of University Sultan Zainal Abidin cafeteria food handlers. https://www.myfoodresearch.com. Accessed January, 12, 2025

Kwaku, A. and Fan, Q. (2020) Effect of Good Product Design and Packaging on Market Value and the Performance of Agricultural Products in the Ghanaian Market. *Open Access Library Journal*, 7, 1-14.

Wells, L.E., Farley, H. and Armstrong, G.A. (2007) The Importance of Packaging Design for Own Label Food Brands. *International Journal of Retail and Distribution Managemen*t, 35, 677-690.

Annan, A.B. (2018) The Effects of Packaging Characteristics on Consumer Perception about

Liquid Soap in Ghana. Lappeenranta University of Technology, Lappeenranta.

Eruaga M. A (2024). Assessing the role of public education in enhancing food safety practices among consumers International Journal of Scholarly Research in Science and Technology, 2024, 04(01), 022–031.

Manoj P, Manoj, R and Maheah Singh (2022) Does level of Education Influence the Purchase Decision of Rural Consumer? *International Journal of Researchers in social sciences and Information Studies. IJRSSIS,* 8(3)., May 2022, 5-10

Daugherty, K. (2024) Male vs. Female Spending Statistics. Who Spends More**?** https://financebuzz.com/authors/Kate-Daugherty. Accessed January, 12, 2025

Farrell*,* E.L (2019) Health Claims and Information Sources in Relation to Bean Consumption in Older Adult Appetite. https://www.sciencedirect.com/science/article/pii/S0195666318316179. Accessed January, 12, 2025

Micronutrient Composition and Molar Ratio of Minerals in Orange-Fleshed Sweet Potato/Soybean Complementary Food Enriched with Crayfish.

* Ijeomah, O.C.[1], Ben-Okoro, O.U. [2] Asomugha, V.U. [3]

[1]Department of Food Science and Technology, Madonna University Akpugo Campus, Enugu State, Nigeria. [2]Goodheart Medical Consultants Hospital, Port-Harcourt, Rivers State, Nigeria. [3]Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

*Corresponding author's email: ijekuso@gmail.com

ABSTRACT

This study evaluated the vitamin, mineral, anti-nutrient contents and molar ratio of minerals of orange-fleshed sweet potato (OFSP)/Soybean complementary food enriched with crayfish. The diets had vitamin A and C contents (280.92 – 314.36 µg/g) and (12.91-15.25 mg/100 g) lower than the recommended levels so also the mineral contents calcium (25.39-81.50 mg/100 g), iron (0.88-0.98 mg/100 g) and zinc (0.26-0.28 mg/100 g). The levels of anti-nutrients 0.09-0.33 Tiu/g for trypsin inhibitor, 0.14 – 0.20 mg/100 g for tannin, 0.15-0.21 mg/100 g for alkaloids and 0.11-0.17 mg/100 g for phytate in the diets were low. Dehulling and peeling remove minerals in the peels and seed coats. Soaking and steaming contributed to the low levels of anti-nutrients. The low phytate contents accounted for the very low molar ratios of the minerals: calcium (0.00011-0.00032), iron (0.0126 – 0.0143) and zinc (0.05-0.053). The very low anti-nutrient contents and molar ratios of the diets indicates high bioavailability of nutrients.

Keyword: Orange-fleshed sweet potatoes, Complementary food, Micronutrient, Hidden hunger, Molar ratio, Antinutrient.

1.0 Introduction

Good nutrition during the first two years of life is vital for healthy growth and development. Starting good nutrition practices early can help children develop healthy dietary patterns. Early nutritional deficits are linked to long term impairment in growth and health. Malnutrition during the first two years of life causes stunting leading to the adult being several centimeters shorter than their potential height. Ijeomah *et al.* (2023) reported that adults who were malnourished in early childhood have impaired intellectual performance and reduced capacity for physical work. Women who were malnourished as children have their reproductive capacity affected, low birth weight infants and more complicated deliveries. Having many malnourished children in a population has national development implications. Thus, the overall functional consequences of malnutrition are immense (Ijeomah *et al.*, 2023).

Appropriate breastfeeding and complementary feed practices proclaimed Oly-Alawuba and Nwaorgu (2015) are fundamental to infant nutrition and health and also, persistent community health challenges of developing countries including Nigeria is childhood under nutrition. Okoronkwo *et al.* (2023) also reported that a geographic and wellness survey conducted in twenty one developing countries revealed that impoverished complementary feeding of 6-23 months infants added to unfavourable growth trends while Black *et al.* (2008) opined that poor infant feeding habits together with impoverished nutritional attributes of complementary foods as well as micro-nutrient deficiencies coexisting with persistent infections added to high mortality and morbidity rates among infants and young children in the sub-Saharan African countries.

Micronutrients (vitamins and minerals) are vital to healthy development, disease prevention and wellbeing. Micronutrients apart from vitamin D are not synthesized in the body therefore, must be derived from the diet. Though people only need small amounts of micronutrients, consumption of recommended amount cannot be underestimated. Micronutrient deficiency, otherwise called hidden hunger, have devastating consequences especially in infants and preschoolers. Half of under five children globally suffer from hidden hunger (Azubuike, 2016). Ijeomah *et al.* (2023) reported that the critical micronutrient in infant food needed for the prevention of long-term adverse effect of micronutrient deficiency is iron and zinc. Unfortunately, plant food are poor sources of these nutrients.

One of the major causes of hidden hunger in children in developing countries like Nigeria is unavailability of affordable nutrient dense complementary food. Nutritional adequacy of complementary food is essential to prevent malnutrition and/or infant mortality and morbidity.

Thus, this study aimed at evaluating the micro-nutrient (vitamins and minerals), anti-nutrients and molar ratio of the minerals of a complementary food prepared from orange-fleshed sweet potato and soyabean enriched with crayfish with a view of ascertaining the possibility of using it to combat hidden hunger.

2.0 Materials and Methods

2.1 Source of Raw materials

Ten kilograms (10 kg) of orange fleshed sweet potato tubers (*Ipomea batatas*) were obtain from the National Root Crops Research Institute, Umudike, Abia State, soyabeans (*Glycine max*) and crayfish (1 kg each) were purchased Umuahia main market, Abia State.

2.2 Raw material Preparation

Ten kilograms (10 kg) of orange fleshed sweet potatoes (OFSP) were washed with potable water peeled (manually) with stainless steel knife, washed again, cut longitudinally into two and immersed into water to prevent enzymic browning of the surfaces. The peeled OFSP were grated, wrapped with aluminum foil, steamed at 100^{o}C for 30 mins and then oven dried at 60^{o}C for 12 h.

One kilogram (1kg) of soyabeans were sorted, washed, soaked in potable water (29$\pm$ 2^{0}C) for 24 h, boiled at 100^{o}C for 1 h, dehulled manually and toasted for 40 min in an open pan. Five hundred grams (500g) of crayfish was cleaned and dried in the oven of 60^{o}C for 10mins

2.3 Preparation of Complementary Food

The method of Azubuike (2016) was used with little modifications. The first, second and third samples were formulated in the ratios of 70:20:10, 60:30:10 and 65:25:10 (steamed grated orange fleshed sweet potato: toasted soy cotyledons: dried crayfish and were designated SAC, SBC and SCC respectively and the fourth sample was formulated with only steamed grated orange fleshed sweet potato (100:0:0) and designated SDC. The respective blends were mixed, milled and sieved to obtain the complementary foods.

2.4 Chemical analysis

2.4.1 Determination of vitamins

Vitamin A was determined according to the method described by Ijeomah *et al.* (2024) and vitamin C was determined according to the method described by Okoronkwo *et al.* (2023).

2.4.2 Determination of minerals

Iron, zinc and calcium contents of the formulated diets were determined using atomic absorption spectrophotometric (AAS) method as described by AOAC (2010).

2.4.3 Determination of antinutrients

The spectrophotometric method of AOAC (2010) was used to determine the phytate and trypsin inhibitor contents of the formulations, the Folin Denis spectrophotometric method of AOAC (2010) was employed

for the determination of tannin in the samples and the alkaloid content of the experimental diets was determined using the gravimetric method (AOAC,2010).

2.4.4 Estimation of molar ratios

The molar ratios of the formulations were estimated using the equation as described by Ijeomah *et al.* (2024).

2.4.5 Statistical analysis

Data collected was analyzed statistically and accepted at 5 % probability level ($p<0.5$).

3.0 Results and Discussion

3.1 Vitamin content

Table 1 shows the vitamin, mineral, anti-nutrient contents and mineral molar ratios of the samples. The vitamin A levels of the diets ranged from 280.92 µg/100 g in sample SBC to 314.36 µg/100g in sample SDC. The high level of vitamin A observed in the samples may be attributed to OFSP used in the formulation because OFSP known to be high in beta carotene (pro vitamin A). The amount of vitamin recorded for the samples were lower than the values (1134 – 2560 µg/100g) obtained by Azubuike, 2016. Vitamin C in the samples occurred within the range of 12.91-15.25 mg/100g lower than the recommended dietary allowance (30-35 mg/100g). The high vitamin C value (15.25 mg/100g) exhibited by sample SBC may probably be due to the lower amount of OFSP (60 %) and higher amount of soybean (30 %) used in the formulation since legumes are rich in vitamin C (Azubuike, 2016).

3.2 Mineral content

The predominant mineral in the samples was calcium ranging from 25.39-80.50 mg/100g. The calcium content of the formulations increased significantly with increased soyabean inclusion. The value of calcium recorded in the work were very much lower than the FAO/WHO recommended dietary allowance (RDA) value (500 mg/100g) for infant foods. Iron level ranged from 0.88-0.98 mg/100g while zinc level, ranged from 0.26-0.28 mg/100g. The recorded values were lower than the recommended dietary allowance for iron (6-10 mg/100g) and zinc (3.2 mg/100g). Low values of iron and zinc are expected because plant foods are poor sources of iron and zinc. According to Ijarotimi and Keshinro (2013), dependence on complementary food with low iron concentration (as in the case of this study) will aggravate the already prevalent iron deficiency anemia in the poor resource settings and developing countries.

3.3 Antinutrient contents of the samples

The samples showed very low residual antinutrients. Trypsin inhibitor ranged from

0.09 Tiu/g in sample SDC to 0.33Tiu/g in sample SBC. Trypsin inhibitor residue increased with increased soyabean incorporation.

The tannin content of the samples ranged from 0.14-0.20 mg/100g. Ibeanu *et al.* (2014) stated that the safe level of tannin is 150-200 mg/100g. The amount of tannin found in the formulations were very low and positively far from the safe level. The low tannin content of the experimental diets obtained indicated zero tannin toxicity. Their reduction has important implications for the final nutritional properties of the developed products (Okoronkwo *et al.*, 2023). The level of alkaloids in the samples ranged from 0.15-0.21 mg/100g. The value of alkaloid recorded for the samples were lower than the WHO safe limit value (61 mg/100g) and within the same limit. The phytate content of the samples were very low ranging from 0.11 mg/100g in sample SDC to 0.17 mg/100g in sample SAC. The values of phytate increased with increased soyabean incorporation.

3.4 Molar ratios of minerals

The computed mineral phytate interrelationship in the samples was very low. The molar ratio of calcium: phytate, zinc: phytate and iron: phytate were lower than the suggested desirable level (SDL^{+}) for zinc (>0.17), iron (>18) and calcium (>1). The level of competing dietary components especially phytate

reported Ijeomah and Ani (2018) is a major determinant of zinc absorption and phytate is the most important of these. The very low molar ratio values obtained for calcium, iron and zinc is suggestive of high bioavailability of the minerals.

4.0 Conclusion

The study showed that the experimental diets were low in micronutrients but with more than two servings a day, the vitamin recommendations may be met. In the case of minerals, it is recommended that minerals premix should be added. Generally, it is recommended that more crayfish be incorporated in the formulations to boost their micronutrients.

The study also showed very low anti-nutrients and molar ratios of the minerals suggesting high bioavailability of the nutrients in the diets.

Table 1: Vitamin, Mineral, Anti-nutrient contents and Molar ratio of the Mineral of the samples per 100 g

Parameter	SAC	SBC	SCC	SDC	RDA
Vitamin					
Vitamin A (µg)	281.44^{c}± 0.18	280.92^{d}± 0.34	282.26^{b}± 0.35	314.36^{a}± 0.18	375
Vitamin C (mg)	13.49^{b}± 0.02	15.25^{a}± 1.02	13.49^{b}± 1.02	12.91^{a}± 1.02	30-35
Mineral (mg)					
Calcium	61.46^{c} ±2.32	81.50^{a} ±2.02	73.48^{b} ±2.30	25.39^{d} ±2.22	500
Iron	0.93^{b}± 0.01	0.98^{a}± 0.01	0.94^{b}± 0.01	0.88^{c}± 0.01	6-10
Zinc	0.27^{b}± 0.00	0.28^{a}± 0.01	0.28^{a}± 0.00	0.26^{c}± 0.01	3.2
Anti-nutrient (mg)					
Trypsin inhibitor (tui/g)	0.31^{c} ±0.70	0.33^{a} ±0.54	0.32^{b} ±0.61	0.09^{d} ±0.00	--
Tannin	0.16^{c} ±0.01	0.20^{a} ±0.01	0.18^{b} ±0.01	0.14^{d}±0.05	--
Alkaloids	0.15^{-c} ±0.01	0.16^{c} ±0.00	0.19^{b} ±0.01	0.21^{a}±0.03	--
Phytate	0.14^{b} ±0.00	0.17^{a} ±0.01	0.16^{a} ±0.01	0.11^{c} ±0.01	
					SDL+
Molar ratio of minerals					
Calcium	0.00014^{b}± 0.001	0.00011^{c}± 0.000	0.00013^{b} ±0.000	0.00032^{a}± 0.001	>1
Iron	0.0126^{a}± 0.011	0.0131^{c}± 0.0001	0.0143^{b}± 0.00	0.0127^{a}± 0.001	>18
Zinc	0.05^{b}± 0.02	0.053^{a}± 0.00	0.053^{a}± 0.01	0.05^{b}± 0.00	>0.17

values are means of triplicate determinations ± standard deviation (SD). Means with different superscripts on the same row are significantly different ($p < 0.05$).

SAC = 70:20:10 (steamed OFSP: soyabean: crayfish), SBC = 60:30:10 (steamed OFSP: soyabean: crayfish), SCC = 65:25:10 (steamed OFSP: soyabean: crayfish) and SDC = 100:0:0 (steamed OFSP: soyabean: crayfish)

RDA = Recommended Dietary Allowance (FAO/ WHO, 2002)

AOAC (2010). Official Methods of Analysis, Association of Official Analytical Chemist, 18th edition, AOAC International: Washington DC, USA

Azubuike, O.U (2016). Chemical and Sensory Evaluation of Complementary Food Based on Orange Fleshed Sweet Potato (*ipomea batatas*), soyabeans (*Glycine max*) and Crayfish (*Evastacus spp*) Flour blends. BSc project, Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Black, R.E., Allen, L.H, Bhutta, Z.A., Caulifield, L.E., De Onis, M, and Ezzati, M. (2008). Maternal and Child Under-nutrition: Global and Regional Exposures and Health Consequences. Lancet 2008,371, 243-260 (Cross Ref) Pub Med)

Ibeanu, N.V, Onyechi, A.U., Ani, N.P and Aneke, C.V. (2014). Anti-nutrient, phytochemical and free fatty acid composition of dehulled and un-dehulled sweet princess water melon (*Citrululus lanatus*) seed flour. Pakistan Journal of nutrition 13(10): 589-592.

Ijarotimi, O.S. and Keshinro, O.O (2013). Determination of Nutrient Composition and Protein Quality of Potential Complementary Foods Formulated from the Combination of Fermented Popcorn, African Locust Bean and Bambara Groundnut seed flour. Polish Journal of Food and Nutrition Science 63(3): 155-166.

Ijeomah, O.C. (2015). Production and Evaluation of fonio (*Digitaria exilis*)/Ricebean (*Vigna umbellata*) based complementary Food Fortified with Micronutrient Rich Foods Ph.D Thesis. Department of Food Science and Nutrition, University of Nigeria Nsukka, Enugu State.

Ijeomah O.C. and Ani, J.C (2018). Molar Ratio – A predictor of calcium and trace minerals availability from fonio (*Digitaria exilis*) and ricebean (*Vigna umbellata*) Based complementary foods. Nigerian Journal of Nutritional Sciences 38(1): 29-33.

Ijeomah, O.C. and Okpala, M.O. (2022). Bioavailability of Nutrients in a Fonio (*Digitaria exilis*)/Ricebean (*Vigna umbellata)* Based Complementary Food. American Journal of Food Science and Nutrition 4 (1) 61-68 ISSN 2789-3154.

Ijeomah, O.C, Ukong, E.S, and Azubuike, C.U. (2023). Chemical Composition of Fonio (*Digitaria exilis*)/Ricebean (*Vigna umbellata*) Based Complementary Food Fortified with Carrot and Crayfish International Journal of Agriculture and Biological Sciences- ISSN (2522-6584) Pp 47-53

Ijeomah, O.C, Edeh, B, and Anyadioha, J.I. (2024). Effect of Processing Methods on Micronutrient Composition and Molar Ratio of Selected Minerals of Tiger Nut-Dates Powder Blend. Madonna Journal of Engineering and Technology, MJET, 1, February, 2024, Pp 81 – 93.

Oly-Alawuba, M.N. and Nwaorgu, C.O. (2015). Processing Methods and Nutrient Composition of Flours Made from Fermented Soyabean (*Glycine max)*, Fermented Maize (*Zae mays*) and Unfermented Groundnut (*Arachis hypogeal)* Used in Complementary Feeding. Journal of Dietician's Association of Nigeria 6:33

Okoronkwo, N.C, Okoyeuzu, C.F, Eze, C.R, Mbaeyi-Nwoha, I.E and Agbata, C.P (2023). Quality Evaluation of Complementary Food Produced by Solid-State fermentation of Fonio, Soyabean and Orange–Fleshed Sweet Potato Blends. Fermentation, 9(250).

Quality Evaluation of Foods (Complementary) Produced from Rice, Sorghum and Brisket Bone Blends.

*Michorji, C. M.[1] Ikegwu, T. M.[1] and Omologbe, F. [1].
1. Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State.
*Corresponding Author's email: orji3602@gmail.com

ABSTRACT

The study evaluates the proximate composition of complementary foods from rice, sorghum and brisket bone blends, The different flours were combined in different ratios of (15:75:10, 7.5:85.0:7.5; 20:67,5:12.3; 0.0:95,0:5,0, 25.0:60.015.0; 7.5:80:12.5) rice, sorghum and brisket bone respectively. The complementary food samples were produced using standard methods. The result of the proximate composition varied significantly ($p<0.05$) with moisture content ranging from 11.40-11.80%, protein (12.56-14.11%), fat (3.46-3.80%), fibre (3.11-3.74%), ash (2.76-8.82%) and carbohydrate content ranging from 59.71% to 64.73%. The research on the proximate properties of complementary foods produced from blends of rice sorghum and brisket bones has certified the potential of these ingredients in developing a nutritionally balanced product. The results also revealed that complementary foods produced from these blends can be stored for a long time without spoilage due to the low moisture (content).

Keywords: Rice, sorghum, brisket bone

1.0 Introduction

Rice (*Oryza sativa*) is an edible starchy cereal grain to the grass plant (family *Poaceae*) by which it is produced. Roughly, one-half of the world population, including virtually all of East and Southeast Asia, is wholly dependent upon rice as a staple food; 95 percent of the world's rice crop is eaten by humans (Robert and Barclay, 2011). Rice is cooked by boiling, or it can be ground into a flour. It is eaten alone and in a great variety of soups, side dishes, and main dishes in Asian, Middle Eastern, and many other cuisines (Mejia, 2020). Other products in which rice is used are breakfast cereals, noodles, and such alcoholic beverages as Japanese sake.

On the other hand, sorghum (*Dawa dawa*) is an important food crop grown on a subsistence level by farmers in the semi-arid tropics of Africa and Asia. It is the principal food crop grown in Northern Nigeria (Zakari and Inyang, 2018). Sorghum, like other cereals, is predominantly starchy and remains a principal source of energy, protein, vitamins and minerals (Robert and Barclay, 2011). Sorghum grows in harsh environments where other crops do not grow well, just like other staple foods, such as cassava, that are common in impoverished regions of the world. It is usually grown without application of any fertilizers or other inputs by a multitude of small holder farmers in many countries (FAO, 2009). Sorghum and rice flours could be blended in order to derive mutual benefits for improved food product development.

Composite flours are mixtures of flours from cereals (e.g. rice, maize/corn, and millet), roots and tuber crops such as sweet potato, peanuts and cassava with or without wheat flour (Meija, 2003). This helps in managing costs associated with the importation of wheat flour in some countries where wheat is not grown due to climate (Olaoye, 2021). Composite flour formulation had been recommended for nutritional improvement in developing countries due to incorporation of legume flours rich in protein and amino acid contents. This would help in maintaining food security in the population.

Advantages inherent in the use of composite flour in developing countries are many and varies such as better overall usage of the domestic agricultural product, promotion of indigenous crops (Gibson *et al.,* 2019). It also balances the protein quality of the food as a protein quality of rice is deficient in lysine, while sorghum lacks essential amino acid such as leucine, histodine and lysine. Composite flour formulation of the two cereal crops to produce porridge flour, will enhance the nutritional qualities of this cereal's protein, promote utilization of rice and also reduce complete reliance on imported wheat and millet in many countries.

Complementary food are any nutrients containing foods or liquids other than breast-milk given to young children, along with breast milk within the 6-23 months window (Gibson *et al.,* 2019). Infants who do not receive enough complimentary foods are stunted, malnourished or both as a result of deficiencies in protein, energy and micronutrients such as calcium, iron, zinc, vitamin A and iodine (Brown and Lee, 2015).

Thus, timely introduction of complementary foods during infancy is necessary for both nutritional and developmental reasons (Agostoni *et al.,* 2015). However, the capacity of well complementary diet to meet the protein energy requirements of infant depends on its nutritional quality (Gibson *et al.,* 2019). Over the years, the most common substitute for breast milk is a reconstituted infant formula based on cow milk (Allen and Keller*,* 2019). This is usually imported from foreign countries, but due to the economic situation, the importation of this formula has become exorbitant and beyond the reach of most families. Many families depend on inadequately processed and low quality traditional complimentary foods for their children (Brown, 2021). That is why protein energy malnutrition is a major infant problem in the developing countries. Inadequate complementary food is a major cause for the high incident of child malnutrition and mortality in many developing countries (Gibson *et al.*, 2019).

2.0 Materials and Methods

2.1 Ingredient Sourcing: the raw materials used in the study include rice, sorghum, brisket bones, and crayfish were sourced from *Eke-Awka* Market, Anambra State.

All reagents and chemicals used for the experiment were sourced from the Department of Food Science and Technology Laboratory, Nnamdi Azikiwe University Awka, and they were of analytical grade.

2.2 **Processing of flour**:

About 100 g of rice, sorghum, brisket bones and crayfish each was sorted to remove contaminants, cleaned, soaked, drained and dried, then grounded to powdered, sieved and packaged in an airtight container before further analysis

3.0 Results and Discussion

3.1 Proximate Composition

The proximate composition of the formulated complementary foods is shown in Table 1. The results showed that there were significant differences ($p<0.05$) in proximate composition of the samples. The moisture content ranged from 11.49% to 11.80%. The highest value of 11.80% was recorded for sample CMD, while the least was 11.40% for sample CME. Low moisture content in complementary food has shown to discourage microbial growth and easy spoilage. This implies that they can be stored for a long time without spoiling. The low moisture content generally observed in the samples may add to the advantage of prolonging the shelf life of the products, if properly packaged. The results of the ash content analysis of the complementary food samples showed significant ($p<0.05$) differences. The values ranged from 2.76% to 8.82%, while in the work of Compaore *et al.* (2011), the values ranged from 1.50% to 2.50%. Ash is of a great importance in slowing down the rate of microbial growth and determining the quality properties of food (Compaore *et al.,* 2011). It is also a measure of the total amount of minerals present in a food. Thus, this result is within the range 1.65% to 2.70% obtained by other authors. It was observed that the processing method had significant ($p<0.05$) effect on the content of the formulated complementary foods. The protein content of the samples ranged from 12.56% to 14.11% and were significantly different ($p<0.05$) from each other. The sample CMB had the least value, while sample CMF had the highest values. In the work of Ikegwu *et al.* (2021), the protein content ranged from 13.50% to 33.70%. Thus, these results are within the range obtained by other authors. It was observed that the processing method had significant ($p<0.05$) effect on the protein content of the formulated complementary foods.

Table 1: Proximate composition of complementary food blends

Sample	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
CMA	11.60^{c}±0.01	12.60^{d}±0.01	3.11^{d}±0.02	3.11^{d}±0.02	7.77^{b}±0.03	61.44^{d}±0.02
CMB	11.69^{b}±0.01	12.56^{e}±0.01	3.51^{b}±0.01	3.74^{b}±0.01	4.26^{e}±0.01	64.23^{b}±0.01
CMC	11.49^{d}±0.01	12.62^{d}±0.02	3.47^{de}±0.01	2.66^{e}±0.01	7.30^{d}±0.01	62.44^{c}±0.02
CMD	11.80^{a}±0.01	12.73^{b}±0.01	3.59^{b}±0.01	4.36^{e}±0.02	2.76^{f}±0.01	64.73^{a}±0.02
CME	11.40^{e}±0.01	12.65^{c}±0.01	3.49^{d}±0.02	2.27^{a}±0.01	8.82^{a}±0.02	61.35^{e}±0.02
CMF	11.50^{d}±0.01	14.11^{a}±0.02	3.80^{a}±0.02	3.41^{c}±0.01	7.45^{c}±0.01	59.71^{f}±0.02

Values are mean ± standard deviation of duplicates. Values on the same column with different superscript are significantly different ($p<0.05$)

Key: CMA = 15.0% rice + 75% sorghum + 10% brisket bones; CMB=7.5%, rice + 85% sorghum + 7.5% brisket bones; CMC = 20.0% rice + 67.5% Sorghum + 12.5%brisket bones; CMD = 0.0% rice + 95.0% sorghum + 5.0% brisket bones; CME = 25.0% rice + 60% sorghum + 15.0% brisket bones; CMF=7.5% rice + 80.0% sorghum + 12.5% brisket bones.

The results showed that there was significant ($p<0.05$) difference in the fat content of the samples. The fat content of the formulations ranged from 3.46% to 3.80% which was similar to that reported by Eka (1978) that ranged from 2.32% to 3.84% for infant porridges prepared from sorghum. The higher fat content observed in the current study could be due to the addition of brisket bone in the complementary food blends and would be suitable for weight gainers. The crude fibre content was observed to range from 2.27% to 4.36%. The differences in the fibre content of the samples were significant ($p<0.05$). High fibre content is reported to enhance the gastrointestinal tract health. It helps normal bowel movement thereby reducing constipation problem. Fibre has been credited for promotion of increase excretion of bile acid, sterols and fats which have been implicated in the etiology of setting cardiovascular diseases in humans. In the work of Adeleke (2019), the fibre content ranged from 1.25% to 2.50%. Thus, these results are within the range obtained by other authors. The result showed that there were significant ($p<0.05$) difference in the carbohydrate content. The values of the carbohydrate content analysis of the formulated samples ranged from 59.71% to 64.73% and are significantly different ($p<0.05$). The result was similar to that obtained by other researchers (Compaore *et al.*, 2011) that ranged from 58.70% to 74.5% infant porridges prepared from sorghum. The sample CMD had the highest value. The starch is likely to be a major constituent of many complementary foods for older infants and young children. To ensure that its energy value is realized, this starch should be provided in a readily digestible form.

4.0 Conclusion

Complementary foods of acceptable quality were prepared from rice, malted sorghum and cow (brisket) bones composite blends. The observation from the study showed that the complementary foods prepared from the flour blends generally had high protein, ash, fibre and energy contents. Furthermore, the study also revealed that rice-sorghum blends enriched with cow (brisket) bones and crayfish performed well as composite in the formulation of complementary foods and has the potential to be used as supplement. Cow bones and crayfish was used in the fortification of these local diets to provide more nutrition and cost-effective foods suitable not only to meet complementary needs but also rehabilitation diet to malnourished children.

References

Adeleke, O. R. (2019). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition, 9*(6), 535–538.

Agostoni, C., Marangoni F., Stival G., Gatelli I., Pinto F., and Rise P. (2015). Whole blood fatty acid composition differs in terms vs. mildly preteen infants: small versus matched appropriate for gestational age. *Pediatric Resources* 64:298-302.

Allen, J. C. and Keller R. P. (2019). Studies in human lactation: milk composition and daily secretion of macronutrients in the first year of lactation. *American Journal of Clinical Nutrition* 54(1)69-80

Berghofer, E. (2020). Bread as a functional food. *Journal of Cereal Flour Bread* 54:175-179

Brown A., and Lee M. D. (2015). Early influencer on child satiety-responsiveness: the role of weaning style. *Pediatric Obesity* 10(1):57-67

Compaore, W. R., Nikiema, P. A., Bassole, H. I. N., Savadogo, A., Hounhouigan, D. J., and Mouecoucou, J. (2011). Nutritional properties of enriched local complementary flours. *Advance Journal of Food Science and Technology, 3*, 31–39.

Eka, O. U. (1978). Chemical evaluation of nutritive vale of soya pap and porridges, the Nigeria weaning food. *Food Chemistry,* 3 (3), 199-206.

FAO (2009). Maize, Rice and Wheat: Area Harvest, production, quality and yield. Food and Agriculture Organization of the united nation. *Rome Italy* PB. 14:109-133.

Gibson, R. S., Perlas L. and Hotz C. (2019). Improving the bioavailability of nutrients in plant food at household level. *Proceedings of the Nutrition Society* 65 (2), 160-168.

Ikegwu, T. M., Ikediashi, B. A., Okolo, C. A., and Ezembu, E. N. (2021). Effect of some processing methods on the chemical and functional properties of complementary foods millet-soybean flour blends. *Cogent Food and Agriculture, 7*, 1–5.

Mejia, D. (2020). Maize: Post-harvest operations. In *Food and Agriculture Organization of the United Nations (FAO)* (pp. 30–35).

Olaoye, A. O., Onilude A. A. and Idowu O. A. (2021). Quality Characteristics of bread produced from composite flours of wheat, plantain and soybeans. *African Journal of Biotechnology* 5: 1102-1106

Robert, B. and Barclay, E. I. (2011). Phytic acid degradation in complementary food using phytase naturally occurring in whole grain cereals. *Journal for Food Science, 68*, 1855–1859.

Shittu, A. T., Olaniyi M. B., Oyekanmi A. A. and Okeleye K. A. (2012). Physical and water absorption characteristics of some improved rice varieties. *Food and Bioprocess Technology* 5, 298-309

Zakari, U.M. and Inyang C. U. (2018). Effect of germination and fermentation of pearl millet on proximate, chemical and sensory property of instant "fura": a Nigeria cereal food. *Pakistan Journal of Nutrition;* 7:9-12.

Assessment of Meaning Construction on Food Labels of Selected Processed Foods

*Olayinka, O. O. and Arasi, A. S.

Federal College of Education (Special), Oyo

*Corresponding author's email: niyiolayinka@gmail.com

ABSTRACT

This study investigates the linguistic construction and communicative effectiveness of food labels on selected Nigerian processed food packages. Food labels are essential tools for consumer decision-making, providing instructions and information that influence product use, health, and safety. The research objectives focus on analyzing sentence structures used on these labels and identifying generic linguistic patterns that affect consumer comprehension. Employing a qualitative descriptive approach grounded in Traditional Grammar, the study systematically examines sentence types, syntactic constructions, vocabulary, and cohesion strategies in the label instructions of six popular Nigerian food products. Findings reveal a predominant use of imperative sentences, enumerative sequencing, and simple vocabulary, which generally enhance clarity and instructional efficiency. However, inconsistencies in formatting, mixed measurement units, occasional complex compound sentences, and the use of technical terms present potential barriers to full consumer understanding. The labels also adopt a conversational tone at times, adding a humanizing element that may positively influence consumer attitudes but requires careful balance to avoid ambiguity. The study concludes that while Nigerian food labels largely comply with traditional grammatical standards for instructional clarity, there is significant need to improve on linguistic consistency and accessibility. Recommendations include standardizing measurement expressions, simplifying compound instructions, and incorporating multilingual or visual aids tailored to Nigeria's diverse linguistic landscape. These will bring about safer, more informed consumer choices and better public health outcomes.

Keywords: Food labeling, Linguistic analysis, Nigerian processed foods, Consumer comprehension, Instructional language

Introduction

Food labeling plays a crucial role in consumer decision-making, especially for packaged products. Food labels serve multiple important functions beyond simply aiding consumers at the point of purchase. They influence product design, advertising, consumer trust in food quality, and public education on health and nutrition. However, most analyses narrowly focus on their role as shopping aids, overlooking consumers' limited ability to process information quickly (Caswell and Padberg, 1992).

The term food originates from the Old English fōda, which is associated with nourishment and feeding (Collins English Dictionary, 2025). Food is defined as any substance containing essential nutrients such as carbohydrates, proteins, and fats that organisms ingest and metabolise for energy and body tissue (Paluti, 2022).

Food is indispensable for sustaining life in humans, animals, and plants. While humans and animals consume food, plants absorb nutrients from their environment. Without food, life cannot be supported. The types of food people eat vary in flavor, texture, and nutritional value, depending on cultural and geographic factors (Paluti, 2022). Carbohydrates supply quick energy, fats store energy, and proteins support tissue building and repair. Overall, food is one of the basic necessities of life due to its role in growth, maintenance, and the regulation of bodily functions. Cereal grains are edible seeds derived from

specific types of grasses and have been cultivated since early agricultural history. The most widely produced grains today include wheat, rice, and maize, with others like sorghum, millet, barley, oats, and rye also being significant. These grains serve as staple foods for large populations across the globe and contribute a major portion of the world's caloric intake (National Geographic Society, 2025).

Beyond human consumption, cereal grains are also used to feed livestock such as cattle, pigs, and poultry (National Geographic Society, 2025). Cultural traditions influence how these grains are consumed and prepared. For example, English cuisine often pairs roast beef with Yorkshire pudding, while in many Asian cultures, rice is a staple served with most meals. In Nigeria, food preparation methods and traditions can differ greatly from other cultures, shaping unique culinary identities (National Geographic Society, 2025).

In today's globalised and consumer-driven market, food labeling plays a crucial role in shaping consumer behaviour, ensuring safety, and facilitating informed choices. Labels and usage instructions serve not only as regulatory requirements but also as primary communicative tools between manufacturers and consumers. However, despite their importance, the appropriateness and clarity of the language used on food labels remain a subject of growing concern. Many consumers, particularly those with limited literacy or language proficiency, struggle to comprehend product information, leading to potential misuse or misunderstanding of food items. This study seeks to evaluate the linguistic appropriateness and communicative effectiveness of the language used on food labels and usage instructions. By adopting a combined linguistic and consumer-centered approach, it aims to explore how language structure, vocabulary choice, tone, and readability impact consumer understanding and behaviour.

This study will focus on the linguistic patterns of how instructions are constructed on food labels, which will in turn affect consumer behaviour and overall public communicative quality of food labeling, while examining how language is constructed on selected Nigerian processed food packages.

Objectives include, to analyse the sentence structures used in Nigerian processed food packaging and to identify the generic linguistic patterns, present in the language of Nigerian processed food labels.

Empirical Review

Bailey *et al.* (2012) conducted a study to evaluate the effectiveness of patient-centered, multilingual drug label instructions for adults with limited English proficiency (LEP). The study involved 203 participants, with 202 completing the full interview. Results showed that LEP adults who received language-concordant instructions (ConcordantRx) were significantly more likely to correctly understand and use both single and multiple medications compared to those given standard instructions. The findings revealed that current pharmacy-generated instructions are often inadequate for LEP individuals. Thus, the study emphasized the need for standardized multilingual drug instructions in pharmacy practice (Bailey *et al.*, 2012). While insightful, this study differs from the current research, which focuses on food labels, not drug labels, and explores how language is used to construct consumer instructions on food packages.

In a related area, Sunstein (2021) investigated the welfare impacts of food labels. His research did not focus on label design but rather on how food labels affect consumers' well-being. He identified four common regulatory approaches: avoiding quantification, using breakeven analysis, projecting health or financial outcomes, and estimating consumers' willingness-to-pay. Each method faced significant limitations and criticisms. Sunstein (2021) proposed that future efforts should assess how food labels influence real-world consumer experiences instead of relying on abstract metrics. Unlike Sunstein's work, which examines policy-level impacts, this study centers on the linguistic construction of instructional content on Nigerian food labels.

Jiang D. *et al* (2019) in their study investigated whether packaging labels in Korean, Japanese, or English influence consumer preferences among 203 Chinese undergraduate students using a fictitious coffee brand, "7 AM COFFEE." Over a month-long field experiment, the results—analyzed using ANOVA—revealed that English-language labels had the strongest positive impact on consumer attention, trust, perceived quality, taste perception, and purchase intention. Additionally, participants' coffee consumption frequency

did not significantly affect their attitudes toward the labeled products. The study offers insights for beverage marketers in targeting Chinese consumers.

Borra (2006) in a symposium "Dietary Reference Intakes (DRIs) for Food Labeling" examined the scientific debate over which DRI values are best for setting Daily Values on food labels. The key objective is to support consumers in making healthier dietary choices. The study highlights recent research both quantitative and qualitative on how consumers use and understand food label information.

Caswell and Padberg (1992) argue that when revising labeling regulations, policymakers should consider the full range of label functions and assess the impact of different labeling approaches on both consumer behavior and seller strategies.

Methodology

This study employed a qualitative descriptive approach grounded in the theoretical framework of Traditional Grammar. Traditional Grammar emphasizes the analysis of sentence structure, parts of speech, and syntactic functions in a prescriptive manner, focusing on clarity, correctness, and the function of grammatical elements in communication. The data collection involved sampling food labels from selected Nigerian processed food packages, focusing on the instructions and usage directions.

The linguistic features of these labels were systematically analyzed, concentrating on sentence types, syntactic constructions, lexical choices, and cohesion strategies, to evaluate the clarity and effectiveness of the language used. The study identified patterns through close textual analysis aligned with Traditional Grammar principles to determine how sentence structures and word choices support or hinder consumer comprehension.

Research Data

Datum 1: MILO (Nestle)

MAKE YOUR PERFECT CUP OF MILO

1. HOT PREPARATION

Scoop 4 teaspoons of MILO into a cup.

*Add hot water (180ml) and stir briskly to dissolve the powder.

*Or add milk powder for a creamier choice.

Stir well and enjoy your wholesome cup of MILO.

2. COLD PREPARATION

Scoop 4 teaspoons of MILO into a cup.

Add hot water up to 1/4 of the cup.

Add milk powder for a creamier choice.

Add very cold water (150ml) and some ice cubes (if desired) and enjoy your wholesome cup of MILO.

Datum 2: DANO MILK

How to prepare 1 glass of milk:

Pour 3 levelled tablespoons of (32g) DANO Cool Cow Powder into 1 glass of previously boiled water (240ml).

Stir gently.

Datum 3: PURE COCOA POWDER (JV JOHN VENTS)

Directions for use

Dissolve 10g (2 teaspoons) of Johnvents Pure Cocoa Powder in 180ml (a mug) of warm or hot water to obtain approximately 200ml of Cocoa drink. Add sugar and milk to taste if desired.

Datum 4: MAMA'S PRIDE TWIST Cavato

Cooking Instructions

1. Boil water (1 litre for 100g Macaroni)

Add salt according to taste

2. Put the macaroni (100g for 1 litre of water) into the salted boiling water

3. Stir and cook for 7-8 minutes according to taste

4. Drain well, and your favourite sauce, mix and serve!

Datum 5: GOLDEN MORN

Know Your PORTION

GOLDEN MORN is a nutritious instant Family Cereal, so far a delicious bowl 5-6 tablespoons of GOLDEN MORN© is Maize and Soya + 200ml milk = Stir and serve

Datum 6: GOLDEN PENNY PASTA TWIST

Cooking Instructions

1. Add salt as desired to boiling water

2. Add pasta, stir and cook for ten minutes

3. Drain well

4. Serve hot mixed with desired ingredients or accompaniments.

Serving Tip: After draining mix pasta with olive oil, serve on a plate or dish and add your favourite sauce.

Objective 1: To Analyse the Sentence Structures Used in Nigerian Processed Food Packaging

The data reveals that imperative sentences dominate the sentence structures used in Nigerian processed food labels. Imperative sentences such as "Scoop 4 teaspoons," "Add hot water," and "Stir well and enjoy" are direct commands characterized in Traditional Grammar by the absence of an explicit subject and a base form verb. This structure effectively communicates instructions clearly and efficiently, enabling consumers to follow preparation steps without ambiguity.

The use of enumerative sequencing, as seen in labels that use numeric markers ("1.", "2.", "3."), supports the step-by-step process by organizing the instructions logically. This ordered structuring aligns with Traditional Grammar's focus on coherence and clarity in written discourse.

However, the analysis also identifies inconsistency in formatting, including irregular punctuation such as missing full stops and uneven bullet point use, which detracts from uniformity and grammatical correctness. Additionally, some instructions compound multiple actions within one sentence, for example, "Add hot water (180ml) and stir briskly to dissolve the powder or add milk powder for a creamier choice." While grammatically correct, these compound sentences may overwhelm or confuse consumers who are not familiar with cooking terminologies or complex instruction flows.

Objective 2: To Identify the Generic Linguistic Patterns, Present in the Language of Nigerian Processed Food Labels

The linguistic patterns identified conform broadly to Traditional Grammar's prescriptions for clear instructional language:

1. Dominance of Imperative Mood: The imperative mood is the principal sentence form, delivering clear, concise commands essential for instructional clarity.

2. Logical Enumeration: Numerical sequencing ("1.", "2.", "3.") functions to guide consumers through preparation steps, providing structural coherence.

3. Simple and Accessible Vocabulary: Most words are commonly used and easily understood, such as "water," "milk," and "salt," catering to a wide audience. However, the occasional use of technical or less familiar terms like "levelled tablespoons" and "drain well" could create comprehension barriers for consumers with limited cooking knowledge or literacy.

4. Quantitative Expressions: Measurements appear both in metric units (e.g., milliliters, grams) and informal quantifiers ("5-6 tablespoons"). Although correct, the inconsistency between formal and informal units could confuse consumers, highlighting a need for standardization.

5. Conversational and Humanizing Tone: Some labels incorporate friendly declarative sentences with possessive pronouns and adjectives ("your wholesome cup of MILO," "your favourite sauce"), which serve to engage consumers emotionally and encourage brand loyalty. This shift from strictly imperative forms to declarative sentences introduces a more personalized communication style.

6. Parenthetical Information: Parentheses are used to provide additional clarifications such as quantities or alternative options. While informative, this punctuation may interrupt the flow for some readers and could reduce immediate clarity.

These linguistic patterns illustrate an attempt to balance functional clarity with consumer-friendly tone. Nevertheless, the findings suggest that further simplification, consistency, and adaptation to Nigeria's multilingual context could improve consumer understanding.

Conclusion and Recommendation

Food labels on selected Nigerian processed foods primarily employ imperative sentence structures and straightforward vocabulary consistent with Traditional Grammar principles to communicate preparation instructions. While these features generally promote clear and efficient communication, the study found inconsistencies in formatting, occasional complex sentence constructions, and mixed measurement units that may hinder full comprehension for some consumers.

The use of a friendly tone in some instances adds a human touch that can positively influence consumer attitudes but should be balanced carefully with clarity to prevent ambiguity. Given Nigeria's diverse linguistic and literacy contexts, the study recommends adopting clearer, more standardized language on food labels, potentially integrating visual aids and translations to enhance accessibility.

Regulatory authorities and manufacturers should emphasize the linguistic appropriateness and consumer-centered design of food labels to support informed, safe product use, thereby promoting public health and positive consumer behavior.

References

Bailey, S. C., Sarkar, U., Chen, A. H., Schillinger, D., and Wolf, M. S. (2012). Evaluation of language concordant, patient-centered drug label instructions. Journal of General Internal Medicine, 27(12), 1707–1713.

Borra, S. T. (2006). Consumer perspectives on food labels. The American Journal of Clinical Nutrition, 83(Suppl), 1235S.

Caswell, J. A., and Padberg, D. I. (1992). Toward a more comprehensive theory of food labels. American Journal of Agricultural Economics, 74(2), 460–468.

Collins English Dictionary. (2025). Collins English Dictionary. HarperCollins Publishers.

Ho, H. C., Chiu, C. L., Jiang, D., Shen, J., and Xu, H. (2019). Influence of language of packaging labels on consumers' buying preferences. Journal of Food Products Marketing, 25(4), 435–461.

National Geographic Society. (2025). Food. https://education.nationalgeographic.org/resource/food/

Paluti, C. (2022,). What is food? | Definition, types and nutrition. Study.com. https://study.com/academy/lesson/food-overview-types-importance.html. Accessed December 28, 2024

Sunstein, C. R. (2021). Are food labels good? Food Policy, 99, 101984.

Determination of Level of Heavy Metals in Canned Fish Sold in Central Market of Kaduna Metropolis, Nigeria

Ozioko E. N. [1] *Ozioko P. C.[1] and Momoh R.[2]

[1]Biology Unit, Faculty of Science, Air Force Institute of Technology, Kaduna, Nigeria. [2]Chemistry Department, Faculty of Science, Air Force Institute of Technology, Kaduna, Nigeria.

*Corresponding Author's Email: paulcj82@gmail.com;

ABSTRACT

The presence of heavy metals in canned fish poses serious health risks, making it a critical area of concern. This study investigated the levels of four heavy metals, arsenic (As), lead (Pb), cadmium (Cd), and chromium (Cr), across different brands of canned fish sold in Kaduna Metropolitan city, Nigeria. Using Atomic Absorption Spectrophotometry (AAS), the contamination levels of De Manna, Mother, Sarah, and Titus brands were assessed. Findings showed that arsenic was detected at low concentrations in all samples, with the De Manna, Mother, Sarah, and Titus brands containing -25.5, -24.79, -23.32, and -25.48 ppm, respectively, of which none of them exceeded the WHO limit of 0.15 ppm. Cadmium levels were equally lower than the WHO guideline, with De Manna, Mother, Sarah, and Titus registering -0.28, -0.20, -0.16, and -0.11 ppm, respectively. Lead was however found in significant amounts across the brands, raising health concerns. Chromium levels varied significantly, with the De Manna, Mother, Sarah, and Titus brands recording 0.15, 0.03, 0.01, and 21.87 ppm, respectively, with some samples far exceeding the WHO permissible limit of 0.05 ppm. This study revealed the best canned fish product to be the 'Mother sardine'. It also revealed potential health risks associated with consuming these canned fish products, and thereby recommend the urgent need for stronger regulatory oversight and improved quality control measures to reduce heavy metal contamination.

Keywords: Heavy metals; canned fish; arsenic; cadmium; chromium.

1.0 Introduction

In recent years, the consumption of canned sardines has witnessed a significant surge in popularity, driven by factors such as convenience, extended shelf life, and rich nutritional content. Canned sardines, being a notable source of omega-3 fatty acids, proteins, and essential minerals, have become a dietary mainstay for many (Kurniawan and Junianto, 2021). Despite their nutritional advantages, concerns have been raised regarding the potential presence of heavy metals in canned sardines, posing potential health risks to consumers (Sabalaa *et al.,* 2024). Heavy metals, including mercury, lead, cadmium, and arsenic, are naturally occurring elements that can find their way into seafood through various environmental pathways (Jones *et al.,* 2019). Seafood, particularly sardines, may accumulate these heavy metals from water, sediments, and the food chain. For instance, mercury have been linked to nervous system toxicity, as well as reproductive, immune, and respiratory toxicity. Additionally, the processing and canning of sardines could introduce heavy metals from equipment and packaging materials which can be carcinogenic (Ferreira *et al.,* 2024; Olusanya *et al.*, 2018). Therefore, a thorough assessment of the levels of heavy metals in canned sardines becomes imperative for ensuring food safety and safeguarding public health.

Despite the widespread popularity of canned fish in Kaduna State, there is a noticeable absence of comprehensive studies assessing the levels of heavy metals in these products. This knowledge gap raises concerns about the safety and quality of canned sardines available in the local market. The lack of data on heavy metal levels in canned sardines hampers regulatory efforts aimed at ensuring food safety and may

lead to uninformed consumer choices. Therefore, there is an urgent need for a systematic assessment of heavy metal levels in canned sardines sold in Kaduna State to address this gap in knowledge, protect public health, and guide regulatory measures. Thus, this study was aimed to determine the level of heavy metals present in canned fish sold in Central Market of Kaduna Metropolis.

2.0 Materials and Methods

2.1 Sample Collection: Four brands of canned fish products were purchased from different stores at the central market, Kaduna state, and were taken to the Defence Industry Corporation of Nigeria (DICON), Kaduna where it was analysed.

2.2 Sample Preparation: After opening each can, the samples were meshed and dehydrated. Exactly 5.0g was weighed from each sample and transferred into a digestion flask. A mixture containing HCl and HNO_3 with a ratio of (1:3) was added to the sample. The flask was properly sealed and heated to a temperature of 90^oC until a clear solution was obtained.

After heating, the digested sample was allowed to cool at room temperature before diluting with 20ml of distilled water. After dilution, the sample was filtered using No.42 Whatman filter paper to remove any insoluble residues. The sample was analysed using a Buck scientific Atomic Absorption Spectrophotometer.

2.3 Analysis by Atomic Absorption Spectroscopy (AAS): The Atomic Absorption Spectrophotometer (AAS) was calibrated by using a standard solution containing lead, chromium, cadmium, and arsenic as described by Perelonia *et al.* (2021). Subsequently, the digested samples were introduced into the AAS instrument for analysis. The analysis was carried out 2-3 times for each sample to guarantee accurate results. The absorbance of each sample was measured at the specific wavelength corresponding to the respective heavy metals The concentrations of each heavy metal was determined by comparing absorbance readings to calibration curves derived from the standard solutions.

3.0 Results

Table 1 presented the results of levels of selected heavy metals on canned fish sample with WHO permissible limit. As shown in the result, all the canned fish samples or products have high concentration of lead (Pb) above WHO permissible limit. However, all the samples have concentrations of cadmium (Cd) and arsenic (As) within the WHO permissible limit, while only DE MANNA and Titus have Cr accumulation above WHO permissible limit.

Table 1: Level of heavy metals in canned fish samples and corresponding WHO permissible limit.

SAMPLE	Lead (ppm)	Cadmium (ppm)	Arsenic (ppm)	Chromium (ppm)
DE MANNA	2.93	-0.28	-25.50	0.15
MOTHER	2.40	-0.28	-24.79	0.03
SARAH	3.31	-0.16	-23.32	0.01
TITUS	4.55	-0.11	-25.48	21.87
WHO Permissible Limit	**0.50**	**0.05**	**0.15**	**0.05**

4.0 Discussion

The arsenic concentration in the canned fish samples were below the detection limit, and WHO permissible limit (WHO, 2018). This aligns with findings from Nabi *et al.* (2021), where arsenic levels in similar food products were found to be -15.28 pm.

On the other hand, the lead concentrations in all the samples were very high (in the range of 2.40-4.55 ppm) (Table 1), and significantly exceeds the WHO permissible limit of 0.5 ppm. This high level suggests significant contamination, potentially from environmental sources or packaging materials, as seen in studies by Djedjibegovic *et al.* (2020) where high lead levels were similarly observed in fish products. Lead exposure at such high levels is known to cause serious health issues, particularly in children and pregnant women. Similarly, Bozorgzadeh *et al.* (2021a) and Kowalska *et al.* (2020) in separate studies have reported that such levels of Pb in canned fish products are concerning and pose significant health hazards.

The cadmium concentration in the canned fish samples were extremely low or undetectable. This is in agreement with the findings of Bozorgzadeh *et al.* (2021b) and Resma *et al.* (2020) who found that cadmium levels in canned fish are often very low, reducing associated health risks.

As for chromium, a very high concentration of 21.87 ppm was detected in the Titus sample (Table 1), far exceeding the WHO permissible limit of 0.05 ppm. It was also slightly high in De Manna product at 0.15 ppm. This high level suggests significant industrial contamination, as found in other studies where elevated Cr levels in canned fish were linked to industrial processes like electroplating (Kowalska *et al.,* 2020). Such levels are concerning due to chromium's carcinogenic potential. However, its concentration is low in Sarah and Mother samples (at 0.01 and0.03 ppm respectively), slightly above the WHO permissible limit. This finding is in line with other studies that reported low but detectable chromium levels in canned fish (Bozorgzadeh *et al.,* 2021b; Miedico *et al.,* 2020).

Conclusion

This study which focused on heavy metal concentrations in four brands of canned fish (Titus, Sarah, Mother, and De Manna) revealed significant variations in contamination levels across different elements. Arsenic and cadmium were found at very low levels in all samples, indicating minimal risk and compliance with WHO guidelines. However, the presence of lead and chromium in concentrations exceeding permissible limits, particularly in the Titus sample, raises serious health concerns. Thus, this study proposes the urgent need for improved quality control measures and stricter regulatory standards in the production, packaging, and storage of canned fish. The differences in contamination levels among different brands highlight the need for consistent monitoring to ensure consumer safety.

References

Bozorgzadeh, E., Nabavi, S. F., Nabavi, S. M., and Habtemariam, S. (2021b). Toxicity of cadmium: Cellular and molecular mechanisms. *Chemico-Biological Interactions*, 337: 109287.

Bozorgzadeh, E., Pasdaran, A., and Ebrahimi-Najafabadi, H. (2021a). Determination of toxic heavy metals in fish samples using dispersive micro solid phase extraction combined with inductively coupled plasma optical emission spectroscopy. *Food Chemistry*, *346*: 128916.

Djedjibegovic, J., Marjanovic, A., Memisevic, A., Sober, M., Ahmetovic, N., and Bavcic, M. (2020). Lead exposure and its impact on health. *Journal of Environmental Science and Health, Part C, 38*(3): 151-177.

Ferreira, S. L., Porto, I. S., Dantas, S. V., Felix, C. S., Cunha, F. A., and Pereira, J. B., Junior. (2024). Evaluation of contamination of chemical elements in fish samples using human health risk assessment indices. *Microchemical Journal*, *202*: 110822

Jones, A., Smith, B., and Williams, C. (2019). Heavy metal contamination in seafood: A global perspective. *Environmental Pollution, 245*: 126-138.

Kowalska, G., Pankiewicz, U., and Kowalski, R. (2020). Determination of the level of selected elements in canned meat and fish and risk assessment for consumer health. *Journal of Analytical Methods in Chemistry*, *2020*, 1–13.

Kurniawan, R., and Junianto. (2021). Review article: Canning on fish. *Global Science Journal*, 9 (**5**), 582–587.

Miedico, O., Pompa, C., Moscatelli, S., Chiappinelli, A., Carosielli, L., and Chiaravalle, A. E. (2020). Lead, cadmium, and mercury in canned and unprocessed tuna: Six-year monitoring survey, comparison with previous studies and recommended tolerable limits. *Journal of Food Composition and Analysis*, *94*: 103638.

Nabi, G., Ali, M., Khan, S., and Ahmed, M. (2021). Arsenic contamination in food and its potential health risks. *Food Control*, *127*: 108115.

Olusanya, O. O., Fatoki, O. S., and Opeolu, B. O. (2018). Heavy metal pollution in some selected canned foods marketed in Nigeria. *Toxicology Reports*, *5*: 262-267.

Perelonia, K. B. S., Benitez, K. C. D., Banicod, R. J. S., Tadifa, G. C., Cambia, F. D., and Montojo, U. M. (2021). Validation of an analytical method for the determination of cadmium, lead, and mercury in fish and fishery resources by graphite furnace and Cold Vapor Atomic AbsorptionSpectrometry. *FoodControl, 130*: 108363.

Resma, N. S., Meaze, A. M. H., Hossain, S., Khandaker, M. U., Kamal, M., and Deb, N. (2020). The presence of toxic metals in popular farmed fish species and estimation of health risks through their consumption. *Physics Open*, *5*: 100052.

Sabala, R. F., Zakaria, A. I., Imre, K., Morar, A., Herman, V., and Sallam, K. I. (2024). Potential cancer risks associated with the consumption of raw, salted, and canned sardine contaminated by mercury, arsenic, lead, and cadmium in Egypt. *Journal of Food Composition and Analysis*, *134*: 106516.

World Health Organization, (2018). Codex Alimentarius: Standard for Canned Sardines and Sardine-Type Products.

Proximate Evaluation of Yoghurt from Soy-Cow Milk Blends, Preserved with Coconut Husk Extract

*Udo-Ezika, O. N. Ikegwu, T. M. and Omologbe F.

Department of Food Technology, Nnamdi Azikiwe University, Awka, Anambra State.

Corresponding author: udoezikao@gmail.com

ABSTRACT

This work evaluates the proximate properties of yoghurt produced from soy-cow milk blends, preserved with coconut husk extract. The yoghurt was produced by blending cow milk with the soy-milk, pasteurizing the mixture and fermenting it using *Lactobacillus delbruekii* sub-spp. *Bulgaricus*. The samples were analyzed using standard methods. The yoghurt samples were coded CSE1 – CSE7. The result of the proximate analysis showed that moisture content ranged from 62.57 – 67.73%, protein (13.17 – 21.03%), fat (7.87 – 14.23%), carbohydrate (2.00 -11.20 %) and ash content (0.83 – 1.67 %). This study revealed the mix ratios of cow milk, soy milk and coconut husk extract that were acceptable in accordance with yoghurt standard and the extent the quality of yoghurt was generally accepted with the use of processing adjuncts (soy milk and coconut husk). Therefore, the samples showed an increased amount of the nutrient as a result of the addition of the soybean and coconut husk.

Keywords: coconut, husk extract, soy, cow, yoghurt

1.0 Introduction

Yoghurt is a dairy product produced by lactic acid fermentation of milk or milk products through the action of probiotics such as *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbruekii* sub-spp. *Bulgaricus* (Kalyas and Ürkek, 2022). The methods of processing of yoghurt are important in its classification as a probiotic food. The bacteria responsible for yoghurt production are referred to as yoghurt cultures. These bacteria ferment sugars in milk, resulting in the production of lactic acid which interacts with milk proteins to give yoghurt its distinctive and pleasant sour taste (USDA, 2016).

The Lactic acid bacteria ferment milk to produce yoghurt and also generate a range of flavour compounds, such as ketones, aldehydes, esters and acids during the fermentation process, which imparts milky, creamy, and other pleasant flavours to yoghurt (Lin *et al.,* 2020). Like milk and other fermented milk products, yoghurt is a complete food product, which possesses some biochemical and bacteriological characteristics that make it extremely useful in human diets. It is believed that yoghurt has valuable "therapeutic properties" and helps in curing gastrointestinal disorders (Bhattarai and Das, 2016).

The primary dairy source for yoghurt production is typically cow's milk, and there is considerable global consumption of dairy products, particularly in developing nations like Nigeria (Otolowo *et al.,* 2022). According to Adekoya (2016) and Ekumankamah (2020), about 98% of all the milk and dairy products are imported (especially the cow's milk powder) and consequently, the production of cow's milk yoghurt is high. For this cause, the substitution of plant-based milk may reduce the importation of dairy milk as raw material for the production of yoghurt (Jimoh, 2020). Soy milk is a plant-based drink prepared by soaking dried soybeans and grinding them in water. It is a highly nutritious aqueous extract which contains protein, fat, carbohydrates, vitamins and minerals (Deepika *et al.,* 2017). According to Iwe (2002), soy milk, which is a derivative of soya bean contains virtually high amount of protein and is lactose free and cholesterol free compared to cow milk. Compared to dairy milk, soy milk has a longer shelf life, and some types of soy milk can be stored at room temperature for months, thereby eliminating food spoilage (Tremblay, 2014). The shelf-life could also be extended by using either natural or chemical preservatives.

Coconut (*Cocos nucifera*) belongs to the Arecaceae family, is native to the coastal area of Southeast Asia and is a major crop of the Dakshina Kannada region (Maji *et al.,* 2014). A thorough review of literature has shown few studies of the antibacterial activities of the *Cocos nucifera* husk against the *Vibrio* species and *Staphylococcus aureus* (Esquenazi *et al.,* 2002). Coconut coir contains tannin compounds that can inhibit the antimicrobial activity in the palm sap by binding to enzymes and proteins produced from microbes so that the microbes become inactive (Rindengan *et al.,* 2006).

2.0 Materials and Methods

The raw materials used in this study include; whole coconut, powdered cow milk (Full Cream Dano milk), soya bean, freeze starter culture, packaging materials (plastic containers and paper labels) and granulated sugar (Dangote Sugar) . The materials were purchased from Eke-Awka market, Awka, Anambra State. The reagents and chemicals used for the experiment was sourced from the Department of Food Science and Technology Laboratory, Nnamdi Azikiwe University Awka, and they were of analytical grade.

2.1 Production of Soy-milk

Soya bean seed (200 g) was sorted, washed and soaked in 10 litre of distilled water for 12 h at room temperature (28-30˚C). During the soaking period, the water was constantly changed at 2 h interval. After the soaking periods, the grains were drained and rinsed with fresh water and blanched for 5 min, cooled under running water and de-hulled by manual rubbing in between hand palms. The de-hulled beans were wet milled in a fabricated attrition mill. The obtained slurry was diluted with 6 litres of water at 80˚C and sieved using a muslin cloth for the milk extraction. Thereafter, the isolated soy milk was heated at 100˚C as a means of concentrating the milk and inactivating the trypsin inhibitor to reduce the beany off-flavour, thus improving the flavour (Achla, 2019). The milk was allowed at room temperature (26-30˚C). (Otolowo *et al.,* 2022; Jimoh, 2020; Silva *et al.,* 2020).

2.2 Preparation of coconut husk extract

The coconut was washed with clean water and cut into smaller pieces. It was dried in the sun to remove the water content (water content between 5-10%) to dry (2-7 days). The dried husk fibre was then blended using a household blender or mashed into powder. About 100 g of the powdered husk was immersed in 250 ml of solvent ethanol for 1 h. Using the Whatman filter paper number1, the solution was extracted. The filtrate obtained was evaporated using a rotary vacuum evaporator, until a concentrated extract was obtained (Djipa *et al.,* 2000; Sumarni *et al.,* 2021).

3.0 Method of Analysis

3.1 *Moisture Content Determination*

The percentage moisture content in the yoghurt was determined using the method as described by AOAC (2018). The Petri dish was cleaned, dried, weighed and the weight was recorded as W1. Then, 2 grams of the sample was weighed into a petri dish and marked as W_2. It was dried for 4 hours at 100°C in a hot air oven. The dried sample was removed and cooled in a desiccator; the mass was recorded at W_3. The drying continued until a constant weight was obtained. The percentage of moisture was regarded as the weight and it is expressed as:

Record the weight and calculate moisture content.

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

3.2 *Ash Content Determination*

Ash content was determined according to the standard method of AOAC (2015). Empty platinum crucible was washed, dried and the weight noted. Two (2) grams of wet sample was weighed into the platinum

crucible and placed in a muffle furnace at 550°C for 3 hours. The sample was cooled in desiccators after burning and weighed.

$\%Ash = W_3\text{-}W_1/W_2\text{-}W_1 *100/1$

Where: W_1 = weight of empty platinum crucible

W_2 = weight of platinum crucible and sample before burning

W_3 = weight of platinum crucible and ash

3.3 *Fat Content Determination*

Using a separation funnel, 10 g of the sample was weighed into a beaker. Ten (10) ml of distilled water was added to it, then 10 ml of Conc. HCl was added. The mixture was shaken, warmed and cooled rapidly. Twenty-five (25) ml of diethyl ether was added to the mixture and shaken. About 25 ml of petroleum ether was added to the mixture. The mixture was transferred to a separating funnel and allowed to stand for 10-20 min. The tap is opened to drain the non-essential leaving the oil. The analyte was drained into an already washed, dried, cooled and weighed beaker. The content was placed in a heating mantle to dry it off. The boiling was done with boiling point of the solvent with the lowest boiling point which was 35^0C for diethyl ether and later increased to the solvent with the higher boiling point which was 50^0C for petroleum ether.

Calculation:

$$\% \text{ Fat} = \frac{\text{weight of beaker + extract – weight of empty beaker}}{\text{Weight of the sample}} \times 100$$

3.4 *Protein Content Determination*

Principle

A protein molecule has a free basic amino group (NH_{12}) and a free carboxylic group (-COOH), the molecule as a whole is therefore neutral being a liquid or wet sample, when formalin is added, it forms a complex with the amino group thereby leaving the carboxylic group to the amino group.

The molecule of the protein thereby acts as an acid, then this acidity is then estimated using NaOH as a titrant.

3.5 *Carbohydrate Determination*

The carbohydrate content was determined by difference. That is, by deducting the mean values of other parameters that were determined from 100.

Calculation: % Carbohydrate =100 - (% Mc + % Cp + % Fat + % Crude fibre + % Ash)

Mc = moisture content

Cp = crude protein

3.0 Results and Discussion

The results of the proximate composition of yoghurt samples are as shown in Table 1. There were significant variations ($p < 0.05$) in the proximate composition of the samples as evaluated. The moisture content of the sample ranged from 62.57% – 67.73%. Yoghurt prepared with 0% Soy-milk, 99.5 % Cow milk and 0.5% Coconut husk extract (CSE7) recorded the least value, (62.57 %), while Yoghurt prepared with 39.8% Soy-milk, 59.7% cow milk and 0.5% coconut husk extract (CSE1) was the highest (67.33%). It was observed that the moisture content of the yoghurt samples increased with the substitution of the soy milk and decreased without the soy milk incorporation. Addition of yoghurt culture helped in the viscosity, thick consistency and low moisture content, while increased substitution of soy milk resulted in a loose

consistency and high moisture yoghurt samples (Obiora *et al.,* 2020). It was also observed that there was significant difference ($p < 0.05$) amongst the yoghurt samples. Increased moisture content could lead to shorter shelf-life of products as it increases the rate of microbial activities.

Furthermore, the Ash content of the samples was not significantly ($p < 0.05$) varied and it ranged from 0.80 – 1.67%. Yoghurt prepared with 0% soy-milk, 99.5 % cow milk and 0.5% coconut husk extract (CSE7) recorded the highest value of 1.67%. While the Yoghurt prepared with 39% soy-milk, 59.7% cow milk and 0.5 % coconut husk extract (CSE1) recorded the least value (0.8%). The results showed that there are no significant differences in ash content between yoghurt samples ($p > 0.05$). The results correspond with the ash content values gotten by other researchers such as Obiora *et al. (*2020), and Jimoh (2020). Ash contents indicate the total inorganic compositions after the moisture and organic materials (fats, proteins and carbohydrates) have been removed (Iwe *et al*., 2002) by incineration in a muffle furnace

The protein samples ranged from 13.17 % - 21.03 %. Table 1. show that the differences in protein contents between the yoghurt samples were not significant ($p > 0.05$). This may be related to the different proportions of the soy milk used.

Table 1: Proximate composition of yoghurt prepared from soy-cow milk blend preserved with coconut husk extract

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrates (%)
CSE1	$67.73^{a} \pm 2.41$	$0.83^{a} \pm 0.29$	$21.03^{a} \pm 1.37$	$14.23^{a} \pm 0.61$	$2.00^{d} \pm 0.78$
CSE2	$66.23^{ab} \pm 0.51$	$1.00^{a} \pm 0.50$	$16.90^{b} \pm 0.56$	$12.03^{b} \pm 0.15$	$3.83^{bcd} \pm 1.21$
CSE3	$65.33^{ab} \pm 1.10$	$1.67^{a} \pm 0.29$	$15.93^{bc} \pm 0.12$	$12.07^{b} \pm 1.12$	$6.00^{b} \pm 0.98$
CSE4	$66.00^{ab} \pm 0.92$	$1.17^{a} \pm 0.76$	$15.57^{c} \pm 0.60$	$11.73^{b} \pm 0.06$	$5.53^{bc} \pm 1.44$
CSE5	$64.80^{ab} \pm 4.53$	$1.50^{a} \pm 0.50$	$15.20^{c} \pm 1.37$	$7.87^{c} \pm 0.38$	$4.80^{bc} \pm 2.59$
CSE6	$65.87^{ab} \pm 0.95$	$1.50^{a} \pm 0.00$	$15.27^{c} \pm 0.49$	$13.93^{a} \pm 0.12$	$3.13^{cd} \pm 0.67$
CSE7	$62.57^{b} \pm 1.10$	$1.67^{a} \pm 0.76$	$13.17^{d} \pm 0.76$	$11.40^{b} \pm 1.93$	$11.20^{a} \pm 1.42$

*Values are %means ± standard deviations of triplicate determinations. Means with the different superscripts in the same column are significantly different ($p < 0.05$). **CSE1:** Yoghurt prepared with 39.8 % Soy-milk, 59.7 % Cow milk and 0.5 % Coconut husk extract, **CSE2:** Yoghurt prepared with 28.5 % Soy-milk, 71.2 % Cow milk and 0.4 % Coconut husk extract, **CSE3:** Yoghurt prepared with 27.5 % Soy-milk, 69 % Cow milk and 3.4 % Coconut husk extract, **CSE4:** Yoghurt prepared with 20.2 % Soy-milk, 80 % Cow milk and 01.03 % Coconut husk extract, **CSE5:** Yoghurt prepared with 19.4 % Soy-milk, 77.8 % Cow milk and 2.7 % Coconut husk extract, **CSE6:** Yoghurt prepared with 14.7 % Soy-milk, 83.3 % Cow milk and 2.01 % Coconut husk extract, **CSE7:** Yoghurt prepared with 0 % Soy-milk, 99.5 % Cow milk and 0.5 % Coconut husk extract.

Sample CSE7 had the lowest value, 13.17%, while Sample CSE1, had the highest value, 21.03%. The protein content of the composite yoghurt samples was observed to increase with higher percentage of soy milk substitution (Obiora *et al.,* 2020). Combining cow milk with soy milk for yoghurt production significantly ($p < 0.05$) increased the total solid content of yoghurt obtained from such premix (Abiodun and Adelodun, 2008). These results showed that the yoghurt samples enriched with plant-based milk had more protein content than the yoghurt without a soy milk composition. Due to the protein content in the plant-based enrichment sources, the protein content of the yoghurt could be enhanced.

The fat content ranged from 7.87 % - 14 % with Sample CSE5 having the lowest value of 7.87% while yoghurt produced with 39.8% soy-milk, 59.7% cow milk and 0.5% coconut husk extract (CSE1) had the highest value of 14.23%. There was no significant difference ($p < 0.05$) between CSE1 and CSE6. The high fat content of yoghurt sample CSE1 could be attributed to cow milk containing nearly twice as much fat and 10 times more fatty acids than soy milk as reported in research carried out by Bahareh and Peiyman, 2008. Addition of soy milk leads to increased fat content of yoghurt samples. Yoghurts rich in oil content have been observed to contain "abundant fat and this could be due to the presence of poly-unsaturated fatty acids, which are considered healthy for the human body (Ogundele *et al.*, 2015).

Carbohydrate content for the proximate results ranged from 2.00% - 11.20%, with yoghurt prepared with 39.8% soy-milk, 59.7% cow milk and 0.5 % Coconut husk extract (CSE1) having the lowest value of 2.00%, while Yoghurt prepared with 0% soymilk, 99% cow milk and 0.5% coconut husk extract (CSE7) had the highest value of 11.20%. All yoghurt samples differed significantly at 5% level of confidence. It was observed that an increase in the soy milk ratio led to a decrease in the carbohydrate properties. Carbohydrates are good sources of energy and a high concentration of carbohydrates is desired in breakfast meals and weaning formula.

Conclusion

The research on the proximate characteristics of seven (7) compositions of yoghurt produced from soy-cow milk blends has generated valuable information on the diverse characteristics of seven (7) different yoghurt compositions, providing a foundation for informed decisions regarding the nutritional balance of the product. The result of this study showed that compositing cow's milk in the production of yoghurt will positively impact the nutritive spectrum of the product. The proximate composition analysis reveals distinctive nutritional profiles, with CSE1 exhibiting high moisture, protein and fat content, CSE7 demonstrating the higher Ash and Carbohydrate content. Therefore, the samples showed an increased amount of the nutrient as a result of the addition of the soybean and coconut husk.

References

AOAC (2015). Official Methods of Analysis of the Association of Analytical Chemists International, 28th ed., *Association of Official Analytical Chemists,* Gaithersburg, MD, USA 2015.

Abiodun, O. O and Adelodun, L. K. (2008). Production of Yoghurts from Cow and Soy Composite Milk Using Starter Cultures from Different Sources. *Journal of Applied Biosciences,* **6**: 158 – 163.

Adekoya, A. (2016). 98% of dairy products in Nigeria are imported. Vanguard, October 17, 2016: www.vanguardngr.com/2016/10/98-dairy-productsnigeria-imported-dangote/. Accessed May, 19, 2024

Bahareh, H. and Peiyman, M. (2008). Comparison of soy milk and cow milk nutritional parameter. *Research Journal of Bioscience,* 3:1324- 1326.

Bhattarai, R. and Das, S. (2016). Evaluation of microbiological Quality if indigenous Dahi from Eastern Nepal. *Sunsari Technical College Journal,* **2**(1): 23-26.

Deepika, K., Sanjay, K., Shuchi, U., Ritesh, M. (2017). Preservation and processing of soymilk: *A review. International Journal of Food Science and Nutrition,* **2**(6): 66-70.

Djipa, C., Delme'e, A. and Quetin-Leclerceq, J. (2000). 200 *Journal Ethnopharmacol,* **71:** 307-313.

Ekumankama, O., Ezeoha, A. and Uche, C. (2020). The Role of multinational corporations in local dairy value chain development: Case of Friesland Campina WAMCO (FCW) in Nigeria. *International Food and Agribusiness Management Review,* **23**(1): 55-69,

Esquenazi, D., Wigg, M. D., Miranda, M. M., Rodrigues, H. M. and Tostes, J. B. (2002). Antimicrobial and antiviral activities of polyphenolics from *Cocos nuciferas* Linn (Palmae) husk fibre extract. *Research Microbial,* 155:136-43.

Iwe, M. O. (2002). Sensory Methods and Analysis. *Rejoint communication Publisher Enugu*, *Nigeria*, pp. 49-52.

Jimoh, M. O. (2020). Production and analyses of yoghurt obtained from cow's milk and soy milk blended with banana (*Musa paradisiacal*). *International Journal of Food Sciences and Nutrition,* **5**(2): 20-26.

Kalyas, A. and Urkek, B. (2022). Effect of flaxseed powder on physicochemical, rheological, microbiological and sensory properties of yoghurt. *Brazilian Archives of Biology and Technology*, 65:2221002

Liu, T., Li, Y., Yang, Y., Yi, H., Zhang, L. and He, G. (2020). The influence of different lactic acid bacteria on sourdough flavor and a deep insight into sourdough fermentation through RNA sequencing. *Food Chemistry,* 307: 125529.

Maji, J., Maria, B. C., Vidya, P., Ipe, V., Manjula, S. (2014). Antimicrobial properties of *Cocos nucifera* (coconut) husk: An extrapolation to oral health. *National Library of Medicine,* 5(2): 359-364 .

Obiora, C. U., Igwe, E. C., Udeagha, E. C., Orjiakor, S. N. and Anarado, C. S. (2020). Production and Quality Evaluation of Yoghurts from Composites of Powdered Cow Milk, Soy Milk and Cornstarch. *European Journal of Nutrition and Food Safety,* 12(10): 54-67.

Ogundele, O. M., Falade, K. O. and Ogunshe, A. O. (2015). Physico-chemical, sensory and microbiological characteristics of plain yoghurt from bambara groundnut (Vigna subterranea) and soybeans (Glycine max). *Journal of Food Science and Technologym* 52: 5858-5865.

Otolowo, D. T., Omolala, M. O., Kudirat, T. A., Temiloluwa, E. E. and Oluwatooyin, F. O. (2022). Effects of the substitution of Cow's milk with Soy Milk on the micronutrients, microbial, and sensory qualities of yoghurt. *Food Production Processing and Nutrition,* 4:15

Rindengan, B., Karouw, S. and Pasang, P. (2006). Effect of Coconut Coir on the Quality of Palm sap and Palm wine. *Jurnal Penelitian Tanaman Industri* 12(4):166-171.

Silva, A. R., Silva, M. M. and Ribeiro, B. D. (2020). Health issues and technological aspects of plant-based alternative milk. *Food Research International,* 131: 108972.

Sumarni, N. K., Rahmawati, E.T. and Ruslan, F.I. (2020). Inhibitory power of young coconut fibre ethanol extract (*Cocos nucifera* Lin) on the growth of Bacteria *Staphylococcus aureus* and *Escherichia coli* in tofu. *Journal of Physics: Conference Series,* 1763: 012010.

Tremblay, S. (2014). Soy milk advantages and disadvantages. Available on: www.livestrong.com/article/425074-soy-milk-advantages-and-disadvantages/ Accessed June, 14, 2024.

USDA, (2016). Review of vegetable fermentatins with particular emphasis on processing modifications, microbial ecology and spoilage. https://www.arsa.usda.gov . Accessed April, 20, 2024

Chemical Composition of Seasoning Cubes Produced from Ginger, Turmeric, Rosemary, Nutmeg, and Clove

*Agu, H. O.[1,2], Ekeh, M. J.[1], Mba, J. C.[1] and Okolo, C.A.[1]

[1]Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[2]TETFund Centre of Excellence for Biomedical, Engineering and Agricultural Translational Studies (TCE-BEATS), Nnamdi Azikiwe University, Awka.

*Corresponding Author: E-mail: ho.agu@unizik.edu.ng,

ABSTRACT

In response to growing consumer demand for healthier and more natural food products, we explore alternative sources of seasoning ingredients that offer both flavour enhancement and nutritional benefits. Cubed seasonings were produced from local spices namely; ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*) and rosemary (*Rosmarinus officinalis*). Processed flour of spices was blended in varying percentages as AYZ (40:20:15:20:5), BWX (35:30:10:15:10), CUV (30:25:15:10:20), DST (25:40:20:5:10) and EQR (20:15:25:30:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively, with other ingredients (iodized salt, water, vegetable oil and corn starch). Commercial seasoning cube (knorr cubes) served as control. The seasoning cubes were evaluated for proximate, vitamin and mineral compositions using standard methods. The findings on nutrient content revealed significant ($p < 0.05$) differences in all the parameters determined across various seasonings which contrasted with the control (knorr cube). DST ((25:40:20:5:10)) seasoning was the best as it had a good amount of protein, second to the lowest moisture content, increased fibre, vitamins A and C, magnesium, manganese and iron contents. The study forms a basis for new product development for the seasoning industry.

Keywords: Spice, chemical composition, seasoning cubes

1.0 Introduction

The production and consumption of seasoning cubes are widespread in many culinary practices globally, with these cubes serving as essential flavour enhancers. Spices are esoteric food adjuncts that are used to enhance the sensory quality of foods (Ndife, 2022). They have been used as flavourings since ancient times and as medicine. They are usually processed from dried seeds, fruits, roots, barks or vegetative substances primarily used for flavouring, colouring or preserving foods (Olife and Onwualu, 2021). Plants used as spices and condiments are usually aromatic and pungent. Spices can also be used to enhance other flavours and many of them have antimicrobial properties. Spices have many other uses including medicinal, religious rituals, cosmetics or perfume production (Mann, 2020). The bulk of the spices identified in Nigeria are found in the Southern rainforest zone of the country, while others such as garlic, turmeric and ginger are found predominantly in the dry Northern zone. Ginger has been the focus of many studies and a lot has been discovered, in its nutritional and phytochemical contents (Shahid and Hussain, 2021). Turmeric also contains vitamins C and E, as well as minerals like iron and potassium. Turmeric has been studied for its potential to reduce inflammation, boost immunity, and support joint health. It may also aid in digestion, promote heart health, and protect against certain chronic diseases (Ndife, 2022). Cloves are high in antioxidants, particularly eugenol, which has anti-inflammatory and antimicrobial properties (Ko. 2020) and provide essential nutrients such as manganese (30% of the daily recommended intake), vitamin K (15%), and dietary fibre (12%). Ko (2020) further stated that nutmeg has been used for centuries in culinary and medicinal applications due to its unique flavour profile and potential health benefits. Rosemary contains carnosic acid and rosmarinic acid, which have antioxidant and anti-inflammatory properties. It also provides essential nutrients like vitamin C, vitamin A, and iron (Ko, 2020). One way to facilitate the utilization of

these aforementioned spices which are regarded to as underutilize crops, involves the development of seasoning cubes from their powder blends. Similarly, Olife and Onwualu (2021) highlighted the improvements in seasoning cubes made from local spice blends. However, their results showed that the sensory evaluation of the local blends indicated slightly less preference compared to the control sample. This study aims to determine the proximate, vitamin and mineral compositions of seasoning cubes produced from ginger, turmeric, cloves, nutmeg, and rosemary powder blends.

2.0 Materials and Methods

Ginger, turmeric, cloves, nutmeg, and rosemary as well as other ingredients such as corn starch,vegetable oil, salt and knorr cubes for this work were purchased from *Eke Awka* Market in Awka, Anambra State. The experiment was designed using Optimal (custom) mixture design from Design Expert software version 13. The process variables were combined to a total of 100 g. The experimental space was limited to 5 runs. Commercial seasoning cube (knorr cubes) served as control. Processed flour of spices was blended in varying percentages as AYZ (40:20:15:20:5), BWX (35:30:10:15:10), CUV (30:25:15:10:20), DST (25:40:20:5:10) and EQR (20:15:25:30:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively, with other ingredients (iodized salt (5 g) , water (120 ml), vegetable oil (80 ml) and corn starch (20 g).

2.1 Proximate, Mineral and Vitamin Analysis

The moisture, ash, fat, protein, crude fibre and carbohydrate contents were determined using the method described by the AOAC (2015). Mineral analysis was conducted using Agilent FS240AA Atomic Absorption Spectrophotometer according to the method of American Public Health Association (APHA, 1995). Vitamin A, B1 and C were determined according to the method described by AOAC (2015). Data collected was subjected to one way analysis of variance (ONE – WAY ANOVA) using the Statistical Product for Service Solution (SPSS) version 23. Duncan's new multiple range test (DNMRT) was used to determine the means. Statistical significance was accepted ($p < 0.05$).

3.0 Results and Discussion

The proximate composition of the samples is shown in Table 1 and revealed notable differences in their nutritional profiles, particularly when compared to Knorr cubes, a popular flavour enhancer. Moisture content showed no significant variation among the samples ($p > 0.05$), aligning closely with Knorr cubes, which maintain low moisture (2–4%) for shelf stability. Fat content varied significantly ($p < 0.05$), with CUV and DST samples containing the highest levels (9.56%), much higher than Knorr's 1–2% (Knorr, 2020).

Table 1: Proximate Content of the Seasoning Cube Samples

	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)
AYZ	$7.96^{a} \pm 0.37$	$6.60^{a} \pm 0.55$	$0.80^{a} \pm 0.21$	$3.06^{a} \pm 1.69$	$11.27^{c} \pm 0.12$	$70.29^{a} \pm 1.99$
BWX	$19.33^{b} \pm 8.37$	$8.40^{b} \pm 1.70$	$3.35^{d} \pm 0.22$	$7.33^{b} \pm 1.75$	$10.40^{d} \pm 0.40$	$51.18^{b} \pm 8.71$
CUV	$16.30^{a} \pm 6.10$	$9.56^{b} \pm 0.92$	$1.61^{b} \pm 0.45$	$5.50^{a} \pm 1.00$	$16.60^{a} \pm 0.35$	$50.42^{b} \pm 7.61$
DST	$13.60^{a} \pm 6.68$	$9.56^{b} \pm 0.05$	$3.56^{d} \pm 0.20$	$7.66^{b} \pm 1.75$	$15.13^{b} \pm 0.12$	$50.47^{b} \pm 8.46$
EQR	$15.28^{a} \pm 0.98$	$6.70^{a} \pm 0.36$	$2.57^{c} \pm 0.38$	$4.83^{a} \pm 2.92$	$9.53^{e} \pm 0.12$	$61.05^{ab} \pm 2.72$

Values are mean ± SD of duplicate samples. Values with the different letter in the same column are significantly different at $p \leq 0.05$. AYZ (40:20:15:20:5), BWX (35:30:10:15:10), CUV (30:25:15:10:20), DST (25:40:20:5:10) and EQR (20:15:25:30:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively.

This may enhance flavour but also increases calorie content. Protein content also differed significantly ($p < 0.05$), with DST (25:40:20:5:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively, showing the highest level (3.56%), compared to Knorr's < 1%, indicating potential nutritional benefits in some (Knorr, 2020). Ash content, reflecting mineral levels, did not differ significantly ($p > 0.05$) among the samples and was comparable to Knorr cubes, suggesting both prioritize flavour over mineral content. Crude fibre content varied significantly ($p < 0.05$), ranging from 9.53% (EQR) to 16.60% (CUV), whereas Knorr cubes contain only 0.5%. High fibre cubes may support digestion and chronic disease prevention, appealing to health-conscious consumers (Mann, 2020). Carbohydrate content also varied significantly ($p < 0.05$), from 50.42% (CUV) to 70.29% (AYZ). While AYZ may provide more energy, lower-carb options like CUV and DST are suitable for weight or blood sugar control. Knorr's carbohydrate level (56%) falls within this range. Overall, the evaluated samples showed differences in their proximate compositions, with some having higher values than Knorr cubes in fibre and protein contents. These differences highlight the importance of developing health-focused seasoning products without compromising flavour from different plant sources.

The vitamin and mineral compositions are shown in Table 2. The analysis revealed significant nutritional differences, especially when compared to Knorr cubes, which are primarily flavour enhancers with minimal vitamin content. Vitamin A levels varied significantly ($p < 0.05$), with DST showing the highest content (2.25 mg/100 g), followed by CUV (0.59 mg/100g) and AYZ (0.25 mg/100g). In contrast, Knorr cubes contain negligible Vitamin A. Given Vitamin A's role in vision, immunity, and skin health, these findings suggest potential health benefits in the tested cubes (Underwood, 2004). Vitamin B1 (Thiamine) content showed no significant differences among the samples ($p > 0.05$), indicating uniformity across blends. Knorr cubes also have low thiamine levels, which means neither product group is a strong source of this vitamin (Knorr, 2020). Vitamin C levels varied significantly ($p < 0.05$), with EQR (121.50 mg/100g), AYZ (119.65 mg/100g), and DST (111.45 mg/100g) showing the highest amounts. Knorr cubes lack Vitamin C, while these samples may support immune function and antioxidant protection based on their vitamin C content. In summary, while Knorr cubes emphasize flavour, the tested samples offer added nutritional values.

Table 2: Vitamin and Mineral Contents of the Seasoning Cube Samples

Sample codes	Vitamin A (mg/100g)	Vitamin B1 (mg/100g)	Vitamin C (mg/100g)	Magnesium (mg/100g)	Manganese (mg/100g)	Iron (mg/100g)
AYZ	0.25^{c} ±0.00	1.66^{a} ±0.16	119.65^{c} ±18.44	60.92^{c} ±0.69	5.58^{b} ±0.21	1.77^{a} ±0.10
BWX	0.02^{a} ±0.00	1.65^{a} ±1.07	94.92^{b} ±0.06	51.95^{b} ±0.10	6.27^{c} ±0.20	2.61^{c} ±0.22
CUV	0.59^{d} ±0.00	1.95^{a} ±0.13	34.83^{a} ±0.57	64.14^{d} ±0.38	4.84^{a} ±0.04	2.06^{b} ±0.07
DST	2.25^{e} ±0.01	2.58^{a} ±0.36	111.45^{b} ±7.51	42.75^{a} ±0.28	6.66^{d} ±0.10	2.49^{c} ±0.06
EQR	0.13^{b} ±0.00	2.35^{a} ±0.63	121.50^{c} ±10.50	72.76^{e} ±0.09	5.57^{b} ±0.15	3.38^{d} ±0.12

Values are mean ± SD of duplicate samples. Values with the different letter in the same column are significantly different at $p \leq 0.05$. AYZ (40:20:15:20:5), BWX (35:30:10:15:10), CUV (30:25:15:10:20), DST (25:40:20:5:10) and EQR (20:15:25:30:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively.

Values, particularly in Vitamins A and C, positioning them as potential functional food products for health-conscious consumers. Table 2 reveals significant differences in the mineral content of various seasoning cube samples, particularly in magnesium, manganese, and iron, when compared to Knorr cubes, which are primarily flavour enhancers with minimal nutritional value. Sample EQR showed the highest magnesium (72.76 mg/100 g) and iron (3.38 mg/100 g) levels, while DST had the highest manganese content (6.66 mg/100 g). These minerals are essential for muscle and nerve function, bone health, metabolism, and oxygen transport (Rude, 2012). In contrast, Knorr cubes contain low levels of these minerals, typically providing less than 1 mg of iron and negligible amounts of magnesium and manganese (Knorr, 2020). The higher mineral content in the tested cubes suggests their potential as functional foods, contributing to dietary needs and addressing nutrient deficiencies, especially in vulnerable populations. These findings position the developed seasoning cubes as dual-purpose products-enhancing flavour and providing health benefits.

3.0 Conclusion

This study found significant differences in magnesium, manganese, and iron content, with samples EQR and DST leading in these minerals. While Knorr cubes do contain these minerals, their levels are typically lower and intended to complement rather than be a primary source of mineral intake. DST seasoning (25:40:20:5:10) for ginger, turmeric, cloves, nutmeg and rosemary respectively, was the best as it had a good amount of protein, second to the lowest moisture content, increased fibre, vitamins A and C, magnesium, manganese and iron contents.

References

AOAC (2015). Official Methods of Analysis. Association of Official Analytical Chemists. 18th Edition, AOAC

APHA (1995). American Public Health Association (APHA). 1995. Standard Methods for the Examination for Water and Wastewater (19th edition). Byrd Prepess Springfield, Washington.

Knorr (2020). Nutritional Information of Knorr Products. Retrieved from [Knorr website], 23rd May 2023

Ko, F. N. (2020). Nutmeg (*Myristica fragrans Houtt.*). In: *Foods and Dietary Supplements in the Prevention and Treatment of Disease in Older Adults* pp. 501-506. Academic Press

Mann, A. (2020). Biopotency role of culinary spices and herbs and their chemical constituents in health and commonly used spices in Nigerian dishes and snacks. *African Journal of Food Science* 5(3): 111-124.

Ndife, J. (2022). Production and quality evaluation of seasoning cubes made from local spices; uziza (*Piper guineense*), Ụda (*Xylopia aethiopica*), Ehuru (*Monodora myristica* and Ginger (*Zingiber officincale*). Timbou-Africa Academic Publications Feb., 2022 Editions, *International Journal* of *Agricultural Research* 8: 152-178.

Olife, I. C. and Onwualu, A. P. (2021). Status Assessment of spice resources in Nigeria. *Journal of Biology Agriculture and Healthcare* 3(9): 12-18.

Rude, R. K. (2012). Magnesium Deficiency: A Possible Contributing Factor to the Pathogenesis of Osteoporosis. *Journal of the American Osteopathic Association* 112(6): 387-395.

Shahid, M. and Hussain, F. (2021). Chemical composition and mineral contents of *Zingiber officinale* and *Alpinia allughas (Zingiberaceae) rhizomes*. *International Journal of Chemical and Biochemical Sciences* 2(1): 101-104.

Underwood, B. A. (2004). Vitamin A Deficiency Disorders. *Global Health Action* 4(1): 10-18.

Physical Properties of Stored Street Vended *Glycine Maxima* from Five Local Governments Areas in Ebonyi State: A Preliminary Study

Isirue, P.N.[3] ; [4]Chimdi, G O; *Isirue, A.M.C.[1], Aroh, K.E.[1] ; Isirue J I[2]

[1]Deapatment of Microbiology, Alex Ekwueme Federal University, Ndufu–Alike, Ikwo. Ebonyi State. [2]Department of Food Science and Technology, Institute of Management and Technology, Enugu. [3]Department of Food Science and Technology, Federal Polytechnic Oko, Anambra State. [4]Department of Agricultural Technology, Federal Polytechnic, Bauchi, Nigeria

*Corresponding author email; abelisirue1@gmail.com

ABSTRACT

This study was conducted to determine the physical properties of stored street vended soymilk from five major markets in five local government areas of Ebonyi State. Ten samples of soymilk were purchased from ten vendors for this study (two samples from two vendors in each market). The samples were stored at two different temperatures: Room temperature (27^{o}C) and refrigeration temperature (4^{o}C) and were monitored for seven (7) days. Standard operational procedures were observed, and results recorded. Results revealed the physical properties thus: All the samples stored at refrigeration temperature maintained at 4^{o}C. Their PH had very slight decrease by 0.30 which started after the 2nd day. Their sensory evaluation: Colour, Smell, Texture, taste retained original features until the 3rd day, and spoilage accelerated at 4^{o}C to the 7th day. The samples stored at room temperature (27 ± 2°C) had increase in temperature (27^{o}C – 34^{o}C), while the pH decreased (6.30 – 5.50). Changes in pH and temperature started on the 2nd day and accelerated till the 7th day. However, the temperature dropped from 34^{o}C to 28^{o}C on the 7th day. This decrease in pH suggests that the taste changed from fresh to foul.

Keywords: Preliminary, physical properties, stored, soymilk, preservative

1.0 Introduction

Soybeans (*Glycine maxima*), the major raw material for making soymilk has been identified as the most important legumes with high protein content. Soymilk products have served as major sources of plant protein for many people, for nearly 5,000 years as observed by Vij *et al* (2011). It is a food material that contains all essential amino acids and very higher content of Lysine by comparison to other plant proteins. Soy milk contributes approximately 20% fat to the diet, according to *Garro et al.* (2014), and the fat from the soybean is unsaturated type unlike saturated fats from animal origin; hence it is good for heart disease patients. Other than the high protein content, it also has good amount of calories and fat. Soya bean contains 43 g of protein per 100 g, which is the highest among the pulses. It also contains 19.5 g of fat, 21 g carbohydrate and provides 432 kcal per 100 g (Ayo *et al.,* 2011). The protein of soybean contains all the essential amino acids in adequate amount except methionine and cystine. It is one of the best vegetarian food items as far as protein content is concerned it is a good source of riboflavin. Soybean contains a factor that inhibits the action of the digestive enzyme trypsin and this factor can be destroyed by heat (Anderson & Bush, 2011). Therefore, most of the populations settle for soy milk amidst other carbonated drinks due to its nutritional benefits, affordability, and availability. Soybean should be cooked well for digestion and absorption. Studies have shown that in type II hypercholesterolemia, patients already on low lipid, low cholesterol diets, eight weeks substitution of animal protein by soybean protein reduced plasma cholesterol by 23 to 25 percent (Hara *et al*., 2012). Soya bean when processed they give Soya beans milk which can be converted to yoghurt which is valuable protein supplement or substitute for adult and infant feeding. Soya milk is lactose-free and can be consumed by the lactose-intolerant people as a substitute to milk. Preservatives are added to inhibit the growth and metabolism of microorganism. These are generally additives, which prolong the life span of foods and drinks by preventing micro-organisms attack.

Technically, preservatives are chemicals used to poison microorganisms and to prevent the food onto which it is added from fermentation and spoilage without causing any harmful effect to the person who consumed the food. The uses of chemical preservatives enhance food quality, reduce waste and enhance consumer acceptability. Recent reports indicate that some probiotic bacteria could better compete with yoghurt cultures in a soy-based substrate. Soy has been examined as a substrate for the lactobacillus species: *L. Casei, L. helveticus, L. fermenti, L. fermentum and L. reuteri* (Garro *et al.*, 2014; Tzortzis *et al.*, 2004). Documented information indicates that soymilk has a significant amount of raffinose and stachyose but does not contain lactose and that lactic acid bacteria (LAB) from different sources are quite different in their efficiencies in soy yoghurt fermentation (Tuitemwong and Tuitemwong, 2014). The problems of soymilk can be improved by lactic fermentation, so production of fermented soymilks such as soy yoghurt is important. Pathogenic microorganisms are microorganisms capable of causing disease, although they represent only a small part in the total microbial world; they receive much attention because they represent a threat to the human or animal health and to agriculture (Ofoefule, 2012). Thus, studying the physiological properties of street vended soymilk will help in recommendations as regards preservation without additives, and shelf life improvement of soy milk sold in Abakaliki and its environs.

2.0 Materials and Methods

Ten samples of street vended soymilks were purchased from *Nwakpu* market, Ahia-Ohuru market, Margret Umahi International market, Kpirikpiri market, and Ishieke market in Ebonyi State 6°15'N 8°05'E, Nigeria. The samples were labeled and transported to Alex Ekwueme Federal University, Ndufu – Alike, Ikwo Microbiology Laboratory for analysis. Standard food and microbiological procedures were observed. The samples were divided into two groups, (one from each market) and stored at refrigeration temperature (4°C) in a refrigerator and at room temperature (27 ± 2 °C)(an average of the room temperature) on the bench for monitoring. Portable pH meter (HI 96107 model) and portable thermometer were used to determine pH and temperature respectively. These were fixed steady on the cover of the plastic sample bottles with the aid of cotton wool and masking tape through a hole made on the covers with new sterile nail. Samples were monitored on days 1, 2, 3 and 7 and observations were recorded.

3.0 Results and Discussion

The physical properties of samples from the markets stored at refrigeration temperature (4°C) and room temperature (27 ± 2°C) are shown in Tables 1 and 2 respectively All the samples stored at refrigeration temperature, had their temperature maintained at 4°C. At 4°C, there was a decrease in pH from 3rd day. This decrease in pH suggests the insignificant presence of microbial activity; hence their pH had very slight decrease by 0.30 which started after the 2nd day. The colour, smell, texture, taste retained original features until the 3rd day, and spoilage accelerated at even at 4°C to the 7th day. The samples stored at room temperature (27 ± 2°C) had increase in temperature (27°C – 34°C), while the pH decreased (6.30 – 5.50). Changes in pH and temperature started on the 2nd day and accelerated till the 7th day. However, the temperature dropped from 34°C to 28°C on the 7th day. This decrease in pH and increase in temperature suggests the presence of very significant microbial activity with bye-products (Kohli, 2016). The colour, smell, texture, taste of the samples changed from creamy to yellowish brown with dark spots, fresh to decaying and pungent, slurry and smooth to coarse, sweet to sour and sandy, respectively. Therefore, microbial activities can affect the physiological properties of soymilk. The quick and accelerated spoilage of the soymilk stored at room temperature suggests that no preservative was used to process it. This practice should be encouraged for health reasons. For the soymilk stored in the refrigerator there was no isolate in the soymilk from day 0 till day 7. The sensory evaluation conducted on the samples indicates that on the 7th day that soymilk stored in the refrigerator and preservatives was generally accepted, this may be because of the introduction of chemical preservatives which have antimicrobial properties that inhibits the growth of microorganism and the sample stored in the refrigerator might also be as the cause of reduced temperature which deactivate the growth of some microorganisms.

Table 1: Samples from the markets stored at refrigeration temperature (4°C)

	pH	Temp (°C)	Colour	Smell	Texture	Taste	Appearance
Day 1	6.30	4	Creamy	Fresh /sweet	Slurry/ smooth	Fresh / sweet	Normal soymilk
Day 2	6.30	4	Creamy	Fresh	Slurry	Fresh	Normal
Day 3	6.10	4	Creamy	Relatively fresh	Slimy	sour	Cloudy
Day 7	6.00	4	Yellow/	Pungent	coarse	Sourer	Syneresis occoured

Table 2: Samples from the markets stored at Room temperature (27 ± 2°C)

	pH	Temp (°C)	Colour	Smell	Texture	Taste	Appearance
Day 1	6.30	27	Creamy	Fresh /sweet	Slurry/ smooth	Fresh / sweet	Normal soymilk
Day 2	6.10	29	Creamy	Small foul	Slurry/slimy	Sour	Cloudy
Day 3	5.80	34	Yellowish brown	Foul/ rotten Egg	Slimy	Sourer	Cloudy
Day 7	5.50	28	Dark spots with growths	Decaying / Pungent	coarse	Sour / Sandy	Syneresis occoured

4.0 Conclusion

Microbial activities can affect the physiological properties of soymilk. So, soymilk vendors should be educated on the effect of food preservatives on human health and importance of producing their products hygienically. More so, other healthy practices like pasteurization can help stabilize the physical properties of soymilk.

References

Anderson, J.W. and Bush, H.M. (2011). Soy protein effects on serum lipoproteins: a quality assessment and meta-analysis of randomized, controlled studies. *Journal of the American College of Nutrition,*30(2), 79 – 91.

Ayo, J.A., Oluwalana, I.B., Idowu, M.A., Ikuomola, D.S., Ayo, V.A., Umar, A. & Yusuf, E. (2011). Production and evaluation of millet-egg-soybean hull composite flour: A weaning food. *American Journal of Food and Nutrition,*6(1), 7 – 13.

Dhawale, S. and LaMaster, A. (2003). Microbiology Laboratory manual. The mcHillCompany.Inc. USA.

Donkor, O., Nilmini, S.L.I., Stolic, P., Vasiljevic, J. & Shah, N.P. (2007). Survival and activity of selected probiotic organisms in set-type yoghurt during cold storage. *International Diary journal,* 17(16), 657-665.

Farahmandfar, M.M., Tehrani, S.M.A., Razavi, M.B.H. & Najafi. (2011). Effect of trisodium citrate and soy cheese on meltability of pizza cheese. *International Journal of Food Properties,*14, 697 – 707.

Garro, M.S., De Valdez,G.F., & DeGiori, G.S. (2014). Temperature effect on the biological activity of Bifidobacteriumlongum CRL 849 and Lactobacillus fermentum CRL 251 in pure and mixed cultures grown in soymilk. *Food Microbiology,*21,511–518.

Hara, A., Sasazuki, S. & Inoue, M. (2012). Isoflavone intake and risk of gastric cancer: a population-based prospective cohort study in Japan. *The American Journal of Clinical Nutrition,*95(1), 147 – 154.

Hua Li, M., Feng-Qin, F., Li-Rong, S., Yun Xie, B. & Duo, L.S. (2007). Nutritional evaluation of different bacterial douche. *Asia Pacific. Journal of Clinical Nutrition,*4(16), 215 – 221.

Kohli, D. & Shahi, N.C. (2017). High pressure processing of foods: A promising concept. *Ecology, Environment & Conservation*,23,182 – 188.

Kohli, D. & Shahi, N.C. (2017). Food Processing by Pulse Electric Field: A Review. Advances in Research,9(2),1 – 6.

Kohli, D., Mishra, R., Kumar, S. & Bhatiya, S. (2016). Ohmic Heating of Foods: An Emerging Technology. *International Journal of Agriculture Sciences*,8(43), 1877 – 1880.

Kumar, A., Rani, L., Goyal, J., Vaishnav, D., Pratap, G.S. & Chauhan. (2011). Evaluation of vegetable-type soybean for sucrose, taste-related amino acids and isoflavones contents. *International Journal of Food Properties,*14, 1142 – 1151.

Lansing, M.P., John, P.H & David, A.K. (2012). Microbiology. 5th ed. McGraw-Hill, press, New Yolk, 37-39.

Li, S.Q., Zhang, H.Q., Balasubramaniam, V.M., Lee, Y.Z., Bomser, J.A., Schwartz, S.J. & Dunne, C.P. (2006). Comparison of effects of high-pressure processing and heat treatment on immunoactivity of bovine milk immunoglobulin G in enriched soymilk under equivalent microbial inactivation levels. *Journal Agriculture of Food Chemistry*,54(3),739 – 746.

Li, Y.Q., Chen, Q., Liu, X.H. & Chen, Z.X. (2008). Inactivation of soybean lipoxygenase in soymilk by pulsed electric fields. *Food Chemistry,*109(2), 408-414.

Liao, F.H., Shieh, M.J., Yang, S.C., Lin, S.H. & Chien, Y.W. (2007) Effectiveness of a soy-based compared with a traditional low-calorie diet on weight loss and lipid levels in overweight adults. *Nutrition*,23,551 – 556.

Lee, S.Y., Morr, C.V. & Seo, A. (1990). Comparison of Mil-Base and Soymilk-based Yoghurt. *Journal of food science,*55(2), 532 – 536.

Mbajiuka, C.S., Obeagu, E., Ifediora, A.C. & Ugwu, G.U. (2014). Isolation and identification of microorganisms involved in the spoilage of soymilk. *Journal of Pharmacy and Biological Science*, 9(5), 29- 36.

Messina, M.J. & Loprinzi, C.L. (2001). Soy for breast cancer survivors: a critical review of the literature. *The Journal of Nutrition*, 131(11), 3095-3108.

Momoh, J.E., Udobi, C.E. & Orukotan, A.A. (2011). Improving the Microbial Keeping Quality of Home-Made Soymilk Using a Combination of Preservatives, Pasteurization and Refrigeration. *British Journal of Dairy Sciences,*2(1),1 – 4.

Noroozi, M., Zavoshy, R. & Jahanihashemi, H. (2011). The effects of low-calorie diet with soy protein on cardiovascular risk factors in hyperlipidemic patients. *Pakistan Journal of Biological Sciences*,14(4),282 – 287.

Ofoefule, S.I. (2012). A text book of Pharmaceutical Technology and Industrial Pharmacy, Samakun Nigeria, enterprise press, Nigeria p, 120 – 125.

Slavin, M.C., Martini, D.R., Jacobs, L. & Marquart. (1999). Plausible mechanisms for the protectiveness of whole grains, *American Journal of Clinical Nutrition,*70, 459S-463S.

Tuitemwong, P. & Tuitemwong, K. (2014). Development of flatulent-free and high-quality soy yoghurt and frozen soy yoghurt with Bifidobacteria. [Online] Available: http://agriqua.doae.go.th/worldfermenredfood/P9_Tuitemwong.pdf

Vij, S., Hati, S. & Yadav, D. (2011). Bio functionality of Probiotic Soy yoghurt. *Food and Nutrition Science*,2(5), 502 – 507.

Wagar, C.P., Champagne, N.D., Buckley, Y., Raymond, J.M. & Green-Johnson. (2009). Immunomodulatory properties of fermented soy and dairy milks prepared with lactic acid bacteria, *Journal of Food Science,*74, 423 – 430.

Yordanov, D.G. & Angelova, G.V. (2010). High Pressure Processing for Foods Preserving. *Biotechnology & Biotechnological Equipment*,24(3),1940 – 1945.

Effect of Different Drying methods on Nutrient Composition of Fluted Pumpkin Leaves *(Teifairia occidentalis)*

*Okoye O. I., Okoye F.U. and Nwafor C. C

[1]Department of Home Science and Management, University of Nigeria, Nsukka, [2]Department of Agricultural Extension and Management, Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria

*Corresponding author email: obiageli.okoye@unn.edu.ng

ABSTRACT

Poor food processing practices can strip foods of essential nutrients. Adopting appropriate processing method is an effective strategy to reduce nutrient deficiencies. This study determined effect of different drying methods on the nutritional composition of *Telfariria occidentalis* leaves. Specifically, the study analyzed effect of sun, oven, shade drying methods on antioxidant vitamin (Pro vitamin A, vitamin C and E) and minerals content (iron, calcium, potassium, selenium) of the leaves. Samples were processed and effect of different drying methods on vitamin and mineral contents were analysed using standard methods. Results were presented as mean and standard deviations. Analysis of variance was used to test for differences. A p – value of < 0.05 was considered statistically significant. The findings showed that shade dried sample retained highest constituent of pro vitamin A (1316.45 IU), vitamin E (1.98 mg) and vitamin C (20.64 mg). Mineral analysis showed that sun dried sample had the highest calcium (276.50mg) and selenium content (1.12 mg). The findings indicated that shade-dried sample had highest concentration of vitamins and sun dried, iron and selenium content. The study suggest that these drying methods could be recommended for pumpkin leaf processing due to their high nutrient retention abilities.

Keywords: Processing, Drying, Antioxidant vitamins, Minerals, Nutrients

1.0 Introduction

Food processing method is a major determinant of the nutrient value of food which plays an important role in our daily diet (Leroy *et al.*, 2025). Globally, nutrient deficiency remains among the most devastating problem facing majority of people. Malnutrition can come as a result of poor food processing methods. Promoting healthy diets and life style through adopting good food processing methods can help to reduce global burden of diseases (Traore *et al.*, 2017). Moyo (2024) reported that poor processing method could result to loss or hinder bioavailability of nutrients. Consumption of poorly processed foods can result to loss or hinder bioavailability of nutrients which could lead to various nutrition related diseases such as anemia, night blindness, goiter osteoporosis. Promoting healthy diets and life style through adopting good food processing methods can help to reduce global burden of diseases

Leafy vegetables are known to be an important source of protective foods and occupy a major place among the food crops (Nupo *et al.*, 2013). They represent a valuable source of minerals, fibre, and vitamin C, as well as vegetable pigments (carotenoids, chlorophylls) and polyphenolic compounds, with therapeutic and high biological activity (Aamir *et al.*, 2017). The health promoting effects of vegetables is attributed to their natural dietary antioxidants. Dietary antioxidants prevent free radicals relative to aging such as reactive oxygen species in the human body (Idris, 2011). *Telfairia occidentalis* leaves is a tropical vine grown in West Africa as a leaf vegetable and for its edible seeds. It is a perennial plant with great economic importance in Nigeria. It belongs to the family, Cucurbitaceae and originated from tropical West Africa (Kuku *et al.*, 2007).

Drying is one of the most efficient ways to preserve foods. It involves the removal of water from a wet feedstock by inducing phase changes of water from solid or liquid into a vapor phase via the application of heat. This processing greatly influences the quality attributes of biological materials. It is a complex process involving simultaneous heat and mass transfer requiring precise process control. It reduces water activity in the product, which inhibits microbial growth and reduces degradative reactions (Pinki *et al*., 2016). Different drying methods can have effect on the chemical composition of fluted pumpkin leaves.

There is limited scientific information regarding the effect of drying on the chemical composition of fluted pumpkin leaf, therefore, there is need to explore on the effect of the different drying methods on fluted pumpkin leaf. Thus, the study examined the effect of shade, oven and sun drying method on fluted pumpkin leaves.

The broad objective of this study was to determine the effect of different drying methods on the chemical composition of fluted pumpkin leaves (*Telfariria occidentalis)*. Specifically, the study determined the effect of different drying methods on the vitamin (Pro vitamin A, Vitamin C and E) composition of fluted pumpkin leaves and the effect of different drying methods on the mineral composition (riboflavin, thiamine, niacin) of the samples and

2.0 Materials and Methods

2.1 Study design: The study adopted a pure experimental research design.

2.2 Procurement of samples: The raw materials (fluted pumpkin leaves) were obtained from *Ogige* Main Market, Nsukka as they were freshly harvested.

2.3 Preparation of samples for chemical analysis: The method used was as described by Emmanuel *et al.* (2006) with slight modification. The green fluted pumpkin leaves were weighed, sorted and removed from the stalk, trimmed, washed and shredded. They were stored in controlled atmospheric condition for further analysis.

2.4 Chemical Analysis: This involved vitamin and mineral analysis of the three samples.

2.5 Determination of Pro-vitamin A (β-Carotene) Vitamin C and Vitamin E content: The Official Methods of Analysis of Association of Official Analytical Chemists, AOAC (2010) method was used. 5g of the sample was weighed into a flat-bottom flask and 60ml TCA/Acetic acid solution was added. The mixture was left for about an hour before it was filtered. The filtrate was made up to 200ml. 10ml was taken for titration with 0.05% 2, 6-dichlorophenol indophenols. The vitamin C content was calculated. Vitamin E absorbance of the solution was then taken at 520nm against a blank

2.6 Minerals Analysis: The AOAC (2010) method was used for the determination of Iron, Potassium, Calcium and selenium content.

2.7 **Statistical Analysis:** Data obtained in this study were analyzed using statistical product for service solution (SPSS) version 22. Descriptive statistics such as means and standard deviation were used to present results. Analysis of variance was used to test for differences. A p – value of < 0.05 was considered statistically significant.

3.0 Results and Discussion

3.1 Antioxidant Vitamin Composition of Fluted Pumpkin Leaf Samples

Table 1 presents the vitamin composition of the sun dried, shade dried and oven dried samples. The pro vitamin A content of the samples ranged from 775.60 to 1316 IU/100g where shade dried sample had the highest value (1316 IU/100 g) while sun dried had the lowest (775.60IU/100g). All samples differing significantly ($P<0.05$) from each other. The vitamin C content of the samples ranged from 13.61 to 20.64 mg/100g. Shade dried sample had the highest vitamin C content. There was no significant difference ($P>0.05$) between sun dried and oven dried samples, but differed significantly ($P>0.05$) from shade dried sample.

Table 1: Antioxidant Vitamin Composition of Fluted Pumpkin Leaf

Samples	Vitamin E (mg/100g)	Vitamin C (mg/100g)	Pro Vitamin A (IU)
Sun dried	$1.34^{b}\pm0.155$	$13.61^{b}\pm0.014$	$775.60^{d}\pm1.202$
Shade dried	$1.98^{a}\pm0.113$	$20.64^{a}\pm0.000$	$1316.45^{a}\pm2.807$
Oven dried	$1.23^{b}\pm0.311$	$13.66^{b}\pm0.056$	$1188.51^{c}\pm6.222$

Values are mean ± Standard deviation, values with different superscripts across the rows are significantly different ($P<0.05$).

3.2 Mineral Composition of Fluted Pumpkin Leaf

Table 2 present the mineral composition of the samples. The calcium content of the samples ranged from 208.00 to 276.50 mg/100g where sun dried sample had the highest (276.50mg) calcium content. There were significant differences among all samples. The iron content of the samples ranged from 5.40 to 5.71 mg/100g. Shade dried sample had the least iron value. The iron content of samples was significantly similar ($P>0.05$). In potassium constituents, the mean values ranged from 422 to 487.50 mg/100g. Oven dried sample recorded highest in potassium mean value, while sample shade dried had the lowest potassium content. The selenium content of the samples ranged from 0.00 to 1.12 mg/100g. Selenium was detected in sun dried and oven dried samples with 1.12 and 0.98 mg/100g respectively.

Table 2: Mineral Composition of Fluted Pumpkin Leaf Samples

Samples	Iron (mg/100g)	Calcium (mg/100g)	Potassium (mg/100g)	Selenium (mg/100g)
Sun dried	$5.58^{b}\pm0.091$	$276.50^{a}\pm6.363$	$447.50^{b}\pm17.677$	$1.12^{a}\pm0.021$
Shade dried	$5.40^{b}\pm0.311$	$241.00^{b}\pm1.414$	$422.50^{b}\pm3.535$	0.0
Oven dried	$5.71^{b}\pm0.056$	$208.00^{c}\pm0.000$	$487.50^{a}\pm3.535$	$0.98^{b}\pm0.003$

Values are mean ± Standard deviation, values with different superscripts across the rows are significantly different ($P<0.05$).

3.3 Vitamin Composition of Fluted Pumpkin Leaf

Pro Vitamin A content of the vegetable samples ranged from 775.60 to 1316 IU/100g. These values were lower than the finding by Agiang *et al.* (2017) whose report showed a range from 2.77 to 4.04 mg/100g, the difference in pro vitamin A content could be due to the different in processing method used. The presence of vitamin A in the leaves make them good for the maintenance of immune system, good vision and also serves as an antioxidant. Beta carotene is invaluable for the promotion of growth of cells and tissues, resistance to diseases and for delaying the ageing process.

3.3.1 Vitamin E: The vitamin E content of the vegetable also ranged from 1.23 to 1.98 mg/100g. The vitamin E content was lower than the finding of Agiang *et al.* (2017) that had vitamin E range of 3.88 to 6.23mg/100g. The lower vitamin E content compared to the reference sample could be due to the processing method used. Vitamin E in the sample can function as an antioxidant, vitamin involved in immune function and other metabolic processes.

3.3.2 Vitamin C: The vitamin C content of the samples ranged from 13.61 to 20.64 mg/100g. This study revealed that shade drying retained highest vitamin C content due to low heat treatment with dehydration. Vitamin C is known to be unstable under heat. This shows that freshly consumed vegetables are better than processed ones in terms vitamin C retention, however shade drying concentrate the vitamin C in fluted pumpkin leaf due to moisture loss. Heating destroyed ascorbate content of the oven dried leaf and the sun-dried samples.

3.4 Mineral Composition of Fluted Pumpkin Leaf

3.4.1 Calcium: The findings of study on table 2 showed the mineral composition of sun dried, oven dried and shade dried fluted pumpkin leaves. The calcium content of the samples ranged from 144.00 to 276.50 mg/100g. This finding was similar to the findings of Obinaju *et al.* (2011) in fluted pumpkin leaf. Calcium in conjunction with magnesium, phosphorus and protein are involved in bone formation.

3.4.2 Iron: The iron content of the samples ranged from 5.40 to 6.39 mg/100g. Iron is an important component of haemoglobin which is an oxygen carrying pigment in the blood (Moll and Davis, 2017). The iron values obtained in this study were similar to the findings of Muhammad *et al.* (2014) that had 1.84 - 126.88 mg/100g in raw pumpkin leaf and also higher than 1.010 - 1.025 mg/100g reported by Orole *et al.* (2020).

3.4.3 Potassium: In potassium constituents, the mean values ranged from 422 to 482 mg/100g. These values obtained were higher than the findings of Muhammad *et al.* (2014) with mean value ranges of 3.8 - 20 mg/100g in fluted pumpkin leaf. Potassium is an essential mineral that helps in fluid balance and regulation of nerve impulse conduction, regular heart beat and cell metabolism therefore consumption of fluted pumpkin leaf will definitely increase the level of these major elements in the body (Ifeoluwapo, 2018).

3.4.5 Selenium: The selenium content of the samples ranged from 0.00 to 1.12 mg/100g. The most preferable treatment of the sample with highest retention of selenium was shade dried method. Selenium plays an important role in living organisms, mostly through its incorporation in a family of proteins called selenoproteins, which are important antioxidant enzymes. This study showed a significant observation in selenium content of *Telfairia occidentalis* leaf (Omotosho, 2013).

4.0 Conclusion

The results of this study showed that shade-dried fluted pumpkin leaf possess highest nutrient content in terms of pro vitamin A, vitamin C, vitamin E. The findings on mineral composition of the samples revealed that oven dried leaves contain appreciable content of iron and potassium, while sun dried, calcium and selenium. The study suggest that these different drying methods could be recommended for pumpkin leaf processing due to their high nutrient retention abilities. Food nutritionists and dietitians should utilize the information from this research to counsel families, mothers and care-givers on the best way to preserve fluted pumpkin leaves in so as to make it available all year round.

References

Aamir, H. D., Sofi, S. A. and Shafiya, R. (2017). Pumpkin the Functional and therapeutic ingredient: A review. International Journal of Food Science and Nutrition 1(1), 168-173

AOAC (2010). *Official Methods of Analysis of Association of Official Analytical Chemists*. 18th Edition, Washington, DC.

Idris, S. (2011). Compositional Studies of *Telfairia Occidentalis* Leaves. *American Journal of Chemistry* **1**(2): 56-59

Ifeoluwapo, A. (2018). Health benefits of fruits and vegetables: Review from Sub-Saharan Africa. IntechOpen 1(1): 34-53

Kuku, A., Etti, U. J. and Ibironke, I. S. (2007). Processing of fluted pumpkin seeds, *telfairia occidentalis* (hook f) as it affects growth performance and nutrient metabolism in rats. *African Journal of Food, Agriculture, nutrition and development,* 14 (5), 1992-2014

Leroy F., Beal, T., and de Mûelenaere N., De Smet S.,Heinrich, F., Lannotti . L., Johnson, B. Manna, N., Mente, A. and Stanton, A. (2025). A Framework for Adequate Nourishment: Balancing Nutrient Density and Food Processing Levels within the Context of Culturally and Regionally Appropriate Diets. Animal Frontiers, 15(1), 10–

Moll, R. and Davis, B. (2017). Iron, vitamin B12 and folate. *Medicine* 45(4):198–203.

Moyo, H. N. (2024). ***The Impact of Food Processing Techniques on Nutrient Retention and Bioavailability.*** *Iconic Research and Engineering Journals* (Volume 8, Issue 2, Pages 435–460),

Muhammad, G. L., Abubakar, S. A., Abdul'azeez, L. M. and Kabiru, J. U. (2014). Effects of Three Drying Techniques on Mineral Composition of Some Leafy Garden Vegetables. *Journal of Applied Chemistry* 7 (1): 38-42

Nupo, S. S., Onigbogi, I. O., Akinlotan, J. V. and Ilori, O. A. (2013). Effect of different processing methods on the nutrients and antinutrient composition of *Senecio biafrae*, *Crassocephalum crepidiodes* and *Solanum nigrum* consumed in south west Nigeria. *American Journal of Food And Nutrition,* 3(3), 147-154

Obinaju, L. C. and Asa, U. A. (2015). Economic analysis of vegetable (*telfairia occidentalis hook*) Production among farming households in Ibiono Ibom Local Government Area of Akwa Ibom State, Nigeria, European *Journal of Agriculture and Forestry Research,* 3 (4),17-24

Omotosho, E. O. (2013). Nigeria vegetable and nutraceutical. Powerful antioxidants and functional properties in vegetables from West Africa. Pp. 1-104

Orole, R. T., Olugbenga, O. O., Erasmus, A. J., Isyaku, J. and Mohammed, Y. S. (2020). Comparative study of the physicochemical properties of male and female flutted pumpkin (*Telfairia occidentalis*). *The Journal of Medical Research* **6**(2): 55-61

Pinki, S., Shreyasi, D., Priyanka, S., Pragya, S. and Kanchan, S. (2016). Effect of processing methods on nutritional composition and antioxidant activity of green leafy vegetables. *International Journal of Nutrition* **5**(4): 1-11

Traore, K., Parkouda, C., Savadogo, A., Ba-Hama, F., Kamga, R.. and Traore, Y. (2017). Effect of processing methods on the nutritional content of three traditional vegetables leaves: Amaranth, black nightshade and jute mallow. *Food Science and Nutrition,* 5(1), 1139–1144.

Evaluation of The Toxicity and Hepatoprotective Effect of Tea Produced from Ixora Red Flower, using a Rat Model.

*Ezugwu, C. O., Obeta, N. A. and Ezeh, C. I.

Department of Food Science and Technology, University of Nigeria Nsukka, Enugu State, Nigeria

*Corresponding Author's email: tranquiljacy@gmail.com

ABSTRACT

This paper discusses the results of a study carried out on a rat model to determine the antioxidant and hepatoprotective effect of tea produced from Ixora coccinea red flower (IXT). Fresh Ixora flowers (IXF) were harvested, withered, dried mechanically at 60^0C, crushed and bagged in tea bags. Samples were subjected toxicity test using the LD_{50} method and liver function test indicated by ALT, AST and ALP. For toxicity test, the animals were given IXT based on their body weight (kg) and were monitored for 24 hours in both stage 1 and stage 2, all the animals survived after the two stages respectively and there were no signs of toxicity. A sample size of 30 rats were randomly divided into 5 groups administered orally for 21 days per body weight after toxin administration to experimental groups: Group 1 (Control G), Group 2 (0.2ml of 10%CCL_4 alone in olive oil), Group 3 (CCl_4 + 70mg silymarin), Group 4 (CCl_4 + 400g IXT) and Group 5 (CCl_4 + 800g IXT). Results showed that activities of ALT and AST in the groups treated with Silymarin, 400mg IXT and 800mg IXT respectively, decreased significantly after liver injury induced by CCL_4. These results indicate that IXT have potential protective effect against hepatic injury.

Keywords: silymarin, flowering plant, herbal.

1.0 Introduction

The liver is an organ in the human body which is responsible for various functions that support metabolism, immunity, digestion, detoxification, and vitamin storage, among other functions (Arjun, *et al.,* 2023). Hepatotoxicity is defined as an injury to the liver or impairment of the liver functions which happens when there is exposure to xenobiotics such as drugs, food additives, chlorinated solvents, alcohol, peroxidized fatty acids, fungal toxins, environmental toxicants, radioactive isotopes, and even some medicinal plants (Faustin, et al., 2014). The liver has several defensive mechanisms against hepatotoxicity, including antioxidant defenses, detoxification pathways, and immune responses. These mechanisms help to minimize damage from toxic substances and prevent liver cell death (Chiang, 2014) but these mechanisms may fail resulting in hepatotoxicity. While conventional drugs can be used as remedy, most of them come with significant side effects, including metabolic disturbances and organ toxicity. Health teas, rich in vitamins, polyphenols and flavonoids may offer hepatopoctective effects with lesser side effects.

Ixora coccinea Linn., (*Rubiaceae*) also known as red ixora or jungle of geranium is an evergreen flowering shrub indigenous to Southern part of India, Bangladesh and Sri Lanka, (Anisha Devendran and G. Gnanavel, 2020), and spread throughout different countries including Nigeria. This plant has a lot of health benefits and all parts of it are used to cure different ailments in the Indian indigenous medicine. The fruits, when fully ripe, are used as a dietary source, (Anisha Devendran and G. Gnanavel, 2020), and the flower for herbal tea and health drinks. The pharmacological activities of Ixora coccinea was reported to have antioxidant, antitumor, hepatoprotective and chemoprotective properties (Bindu and Roy, 2018). Though some research has been made over the years on the traditional medicinal use of various parts of Ixora coccinea plant, research on Ixora coccinea red flower health tea is limited. The objective of this study was

conducted to evaluate the toxicity and hepatoprotective effects of tea produced from Ixora Coccinea red flowers.

2.0 Materials and methods

2.1 Materials

The Ixora coccinea Linn, (*Rubiaceae*) Red flowers were sourced within premises of University of Nigeria Nsukka. All reagents used were of analytical grade.

2.2 Animal treatment

Toxicity test was carried out using the Lorke's method of determining LD_{50}. The animals were given the extract based on the body weight and monitored for 24 hours in two stages. Healthy male Wistar rats (150-200 g body weight, 4-6 wk old) were used for the experimental study. Animals were provided a standard diet and filtered tap water was given as often as necessary. Animals were maintained under standard 12 h dark-light cycle, 60 humidity and a temperature of 21.5 ^{0}C. Coprophagy was prevented by keeping the animals in cages with gratings on the floors. The distribution of animals in the groups was randomized. This study was carried out with the agreement of the institutional Animal Care and Use Committee, Faculty of veterinary Medicine, University of Nigeria. Rats (30) were randomly distributed (to assure equal distribution of weights) into five following groups containing six animals each. All experimental groups were fed orally with CCl_4 for 3 days to induce toxicity. The groups were divided as follows: Control group fed with commercial feed and adequate water; Groups 2 (Toxin only) given carbon tetrachloride (0.5 ml/ kg in olive oil) orally and held for 21 days; Group 3 (Silymarin Treatment) received Silymarin (standard drug - 70 mg/kg body weight) orally for 21 days after toxicity was induced. Group 4 (Ixora tea) received Ixora tea (400 mg/kg of body weight) orally for 21 days after toxicity was induced. Group 5 (Ixora tea) received Ixora tea (800 mg/kg of body weight) orally for 21 days after toxicity was induced. Blood samples were collected after 24 hours and rats were euthanized. To confirm liver function and injury, serum biochemical analysis was carried out to determine the activities of AST (aspartate transaminase), ALT (alanine transaminase) and ALP (Alkaline Phosphatase).

2.3 Experimental Design and Data Analysis

To compare responses between groups the data obtained were subjected to one way Analysis of Variance (ANOVA) based on completely randomized design (CRD) and mean separation were done using Duncan s multiple range test (DMRT) with statistical significance accepted at $p< 0.05$.

3.0 Results and Discussion

3.1 Biochemical analysis results

Statistical analysis show that the mean difference of ALT, AST and ALP in the studied groups are significant at 0.05 level. The AST and ALT activities increased from 95.67±17.66 (control group) to 100.50±6.76 (group 2 toxin only) and from 21.67±3.61 (control group) to 22.00±4.55 (group 2 toxin only) respectively. This means that the levels of AST and ALT were elevated after administration of CCL_4 in Group 2 in comparison with the control group. This indicates that toxicity in the liver was established by the administration of CCL_4. Carbon tetrachloride (CCL_4) is activated to form trichloromethyl radical CCl_3*. This radical can bind to cellular molecules, impairing key cellular processes such as lipid metabolism, with the potential outcome of fatty degradation. This radical can also react with oxygen to form trichloromethylperoxy radical CCl_3OO*, a highly reactives species which initiates a chain reaction of peroxidation, attacking and destroying poly unsaturated fatty acids in particular those associated with phospholipids leading to hepatic oxidative degeneration and cell death, (Algefare *et al*, 2024). AST and AlT are two enzymes released during hepatocyte injury, therefore an elevation in these two enzymes is a marker for liver injury, which is in agreement with this study results and reports of previous researches (Khovarnagh and Seyedalipour., 2021, Kulkarni *et al.,* 2021 and Algefare *et al.,* 2024).

The administration of Silymarin to group 3; 400 mg of the sample to group 4 and 800 mg of the sample to group 5, decreased the activities of ALT and AST in these groups significantly. Group 5 had the lowest

AST and ALT activity followed by Group 3 and then group 4. This means that the hepatoprotective effect of the sample is more potent at 800mg which has been indicated by the reduced levels of aminotransferases. The present study revealed that the investigated sample (Ixora coccinea red flower tea) has a significant hepatoprotective effect.

Table 1. Effect of IXT on serum enzyme levels of rat induced administered with CCL_4.

Enzymes			
Samples	AST	ALT	ALP
Control G	95.67±17.66	21.67±3.61	124.12±60.19
Group 2	100.50±6.76	22.00±4.55	149.13±27.46
Group 3	79.00±27.67	20.67±3.61	110.35±27.03
Group 4	93.80±9.68	19.17±6.43	102.41±23.88
Group 5	60.00±5.90	17.83±2.48	155.53±46.46

Control G (group 1), Group 2 (0.2ml of 10%CCL_4 alone in olive oil), Group 3 (CCl_4 + 70mg silymarin), Group 4 (CCl_4 + 400g IXT) and Group 5 (CCl_4 + 800g IXT)

Conclusions

The study showed that Ixora coccinea red flower is not toxic as established by Lorke's method of the determination of LD_{50}. Tea produced from Ixora Coccinea red flower has potential of being applied to facilitate recovery after hepatic injury. These results showed hepatoprotective roles of tea produced from Ixora coccinea red flowers.

Reference

Algefare, I.A., Alfwuaires, M., Famurewa, C.A., Elsawy, H. and Sedky, A. (2024). Geraniol Prevents CCl_4-Induced Hepatotoxicity Via Suppression of Hepatic Oxidative Stress, Pro-Inflamation and Apoptosis in Rat. Toxicology Reports. 12, pp 128-138.

Anisha, D., and Gnanavel, G. (2020). A Review on Ixora Coccinea: Traditional use, Phytochemical and Pharmacological Studies. Journal of Chemical and Pharmaceutical Studies, 13, 0974-2115.

Arjun, K., Ekrem, Y., Chase, I. and faiz, T. (2023). Physiology, Liver. National Library of Medicine.

Bindu, G., and Chirenjeev, Roy. (2018). Pharmacognostical Study of Ixora Coccinea Flower. A Multifaceted Journal in the Field of Natural Products and Pharmacognosy, 10(5), 1042-1046.

Chiang, Y.L. (2014). Liver physiology. Metabolism and Detoxification. Pathophysiology of Human Diseases.

Faustin, M., Edouard, N. and Victor, K. (2014). Hepatotoxicity and Hepatoprotective Effects of African Medical Plants, Toxicological survey of African Medicinal plants, pp 323 – 355.

Khovarnagh, N. and Seyedalipour, B. (2021). Antioxidant, Histopathological and Biochemical outcomes of a short-term exposure to Acetamiprid in liver and Brain of Rat: The protective role of N-acetylcysteine and S-methylcysteine, Saudi Pharmaceutical Journal. 29(3), pp 280-289.

Kulkarni, S., Roper, M.S. and Stoll, M.J. (2021). Chapter 8 – Hepatic and Gastrointestinal disorders. Biochemical and Mechanical Basis of pediatric Diseases (Fifth Edition), Academic press, pp 229-226.

Narratives Exploring Food Security through Literary Representations of Agricultural Innovation, Technology, and National Development in African Literature: A Study of Yellow-Yellow and Oil on Water

*Adeleke, K. J. and Adediran, O. B.

Department of English Federal College of Education (Sp) Oyo.

*Corresponding author's email: adelekejames1@gmail.com

ABSTRACT

This study explored how African stories reflect the problems of food security connected to farming changes, environmental harm, and new technologies. It focuses on Kaine Agary's Yellow-Yellow and Helon Habila's Oil on Water. Using ecocriticism. It analyses how these books reveal environmental damage, explore how literature can shape public awareness and provide different ideas for sustainable, people-focused national development and criticize poor development choices in the Niger Delta. It reveals that food security is fundamental to sustainable development, point out how traditional farming systems are breaking down and how effective technological solutions are not being used. By examining the conflict between resource extraction and the hope for better innovations, the study highlights how literature can help us think of more sustainable and fair ways to develop our countries.

Keywords: Food Security, Ecocriticism, Agricultural Innovation, Technological Development, Nigerian Literature.

Introduction

Food security is a big challenge in Africa, especially in places like Nigeria's Niger Delta where environmental damage has hurt farming and the way people usually make a living. Although many talks around the world focus on using new technology to improve food systems, but many African communities still don't get to benefit from these solutions because of political issues, poor infrastructure, or environmental challenges.

Investigation reveals that African literature is a powerful way to understand these struggles. Books like 'Yellow-Yellow' and 'Oil on Water' show how oil extraction harms the environment, cripples farming, and does not bring the promised benefits to the people who need them most. These stories explore the destruction caused by industrial growth and the lost chances for using sustainable technology. By looking at these texts through ecocriticism, one can see how they highlight the environmental and social problems that arise when we ignore traditional farming methods and leave out rural voices from technological progress.

Despite the believe that there is a lot of talk about using technology in farming and finding new ways to secure food, stories in literature show that these ideas often don't help the people who are most hurt by environmental damage. In Nigeria's Niger Delta, where oil activities have caused serious ecological problems, literature highlights the gap between what is promised in development talks and what people actually experience. This shows that there is a lack of effective and fair technological solutions and that traditional farming methods are often overlooked in discussions about food security. This study aims to fill this gap by looking at how African literature criticizes and reimagines development through an ecocritical lens.

The study aims to analyse how the books Yellow-Yellow and Oil on Water show the link between food insecurity, environmental harm, and failed agricultural innovation. Also, to examine how these stories

criticize the lack of proper technological solutions in food and farming development and lastly, explore how literature can shape public awareness and provide different ideas for sustainable, people-focused national development.

Focusing on Yellow-Yellow and Oil on Water as examples of ecocritical thought in Nigerian literature, the study will analyse these texts for how they represent food security, environmental issues, and the exclusion of technology. While the study is centered on the Niger Delta, the findings are relevant to wider discussions in Africa about sustainable farming and development through literature.

This research fills a critical gap between literary analysis, environmental ethics, and development studies. It demonstrates how African literature reflects ecological trauma and food insecurity while critiquing the uneven application of technological solutions. The study contributes to ecocriticism and African literary studies, offering valuable insights for policy makers and development strategists seeking to ground innovation in lived realities.

Methodology

This study adopts a qualitative research design, utilizing textual analysis approach rooted in literary criticism. Through the lens of ecocriticism, it examines how selected Nigerian novels portray food security issues, agriculture innovation, and the impact of technology on national development.

Theoretical Framework: Ecocriticism helps to understand how literature talks about environmental issues. It looks at how stories show our relationships with nature, point out ecological damage, and dream of better, sustainable futures. This study adopts ecocriticism lens to examine how the novels "*Yellow-Yellow*" and "*Oil on Water*" show the effects of the environment degradation, the loss of food-producing ecosystems, and the neglect of local technology solutions. These books criticise the kind of development that puts profit above sustainability and ignores local knowledge.

Ecocritical Portrayals of Food Security and National Development: In the novels, Yellow-Yellow and Oil on Water, Kaine Agary and Helon Habila offer powerful ecocritical portrayals of how environmental degradation, driven by extractive industries, undermines food security and stalls national development in Nigeria's Niger Delta. These works highlight the systemic neglect of food systems and the absence of sustainable technological interventions, emphasizing the need to redefine national development to include environmental justice and agricultural innovation.

In Yellow-Yellow, Agary vividly depicts a village where oil spills have destroyed rivers and farmlands, leading to food scarcity and migration. The protagonist, Zilayefa, reflects a youth population detached from traditional food production, illustrating the long-term socio-economic consequences of ecological disruption. An elder laments, "The oil companies have killed everything… no more fish, no more crabs" (Agary, 2006). This quote underscores the connection between food insecurity and the failure of development models that ignore rural needs.

The Absence of Sustainable Development: Similarly, in Oil on Water, Habila's narrative juxtaposes the technological sophistication of oil extraction with the lack of investment in agricultural restoration. The observation that "They have the machines to drill into the earth, but not the will to clean what they destroy" (Habila, 2010) highlights a critical imbalance: development is measured by revenue and infrastructure, not by food security or ecological health.

The Need for Inclusive Development: These literary narratives support the argument by scholars like Oloruntoba (2019) and Akinyele (2020) that food security is fundamental to sustainable development, especially in regions affected by resource extraction. By highlighting the absence of food technology and innovation, these novels advocate for a more inclusive and environmentally responsible vision of national development.

Food security encompasses more than just providing affordable calories. It's about creating a system that enables people and nations to prosper, now and in the future, by supporting long, happy, and healthy lives.

Unfortunately, food security is often misconstrued as merely ensuring cheap calorie access, neglecting its deeper implications, Callon (2013)

However, recent studies highlight technology's potential to transform African agriculture and enhance food security (Ayim *et al.*, 2020; Gikunda, 2024). Innovations like AI-driven crop monitoring, digital market places, and mobile apps such as SELL HARVEST are proposed as solutions to longstanding agricultural inefficiencies. Nevertheless, critics argue that these solutions often overlook critical issues, including ecological degradation and political exclusion (Salahudeen *et al.*, 2024).

According to Gadzekpo (2023), African literature plays a crucial role in discussions about environmental and food justice. These texts provide valuable insights into the failures of development models and offer alternative perspectives rooted in community and ecological balance. By exploring novels like *Yellow-Yellow* and *Oil on Water*, this study examines how literature critiques the shortcomings of traditional and technological approaches to agriculture, highlighting more inclusive and sustainable possibilities.

Conclusion

It is crystal clear from the discussion that it is paramount to have more environmental education that uses literary texts to raise awareness about sustainable food systems and ecological justice. By bringing literature into environmental education, we can inspire young leaders and citizens to care about sustainability and taking care of our planet.

Recommendations

This review suggests that there is need for inclusion of literary insights in environmental and development policies to better reflect what our communities experience. This way, policymakers can understand local situations more deeply and create solutions that really meet our needs. Also, it encourages research that connects literature, environmental studies, and technology to support sustainable development. It is important to create storytelling platforms that capture local farming knowledge and ecological traditions. We should also invest in technologies that are fair and can be used by rural communities while being mindful of our environment.

References

Agary, K. (2006). *Yellow-Yellow*. A Novel. Dtalkshop. p. 74

Akinyele, S. T. (2020). *Agricultural policy, food security and technology in Nigeria: Pathways to sustainable development*. Nigerian Journal of Development Studies, 18(1), 45–60.

Ayim, C., Kassahun, A., Tekinerdogan, B., & Addison, C. (2020). *Adoption of ICT innovations in the agriculture sector in Africa: A Systematic Literature Review*. arXiv:2006.13831.

Callon M. (2013). *Reclaiming food security*. London, England: Routledge.

Gadzekpo, A. (2023). *Ecojustice in African Literature: Land, Food, and Resistance.* African Studies Quarterly, 24(2), 75–90

Gikunda, K. (2024). *Harnessing Artificial Intelligence for Sustainable Agricultural Development in Africa*. arXiv:2401.06171.

Habila, H. (2010). *Oil on Water*. Penguin UK. p. 143

Oloruntoba, S. O. (2019). *Food insecurity and governance failure in Africa.* African Journal of Governance and Development, 8(1), 1–16.

Salahudeen, M. M., Mukhtar, M. A. and Abubakar, S. S. (2024). *Mobile Technology: A Panacea to Food Insecurity in Nigeria – A Case Study of SELL HARVEST Application*. arXiv:2407.16614.

Effect of Baobab Seed Flour Inclusion on the Mineral and Phytochemical Properties of Wheat and Tigernut Residue Biscuits

*Odo, J.E[1], Ugwu, K.,[2] Lazarus, C. C. [1], Asogwa, I.S. [1] and Chime, A. J[1]

[1]Department of Food Science and Technology, University of Nigeria, Nsukka. [2]Department of Nutrition and Dietetics, David Umahi Federal University of Health Sciences, Uburu, Ebonyi State.

Corresponding author's email: jessica.odo@unn.edu.ng

ABSTRACT

This study investigated the micronutrient and phytochemical contents of biscuits from a blend of wheat, baobab seed, and tigernut flour. Baobab seed flour was obtained by cleaning, milling, and sieving baobab seeds. Tigernut was cleaned, milled, the milk extracted, residue dried and milled into flour. Biscuits were formulated from wheat, tigernut residue and African baobab flours in the ratio of 85:10:5, 80:10:10, 70:10:20, 60:10:30, 50:10:40 for WBsT1, WBsT2, WBsT3, WBsT5 while sample WBsT0 with 100% wheat flour served as the control. The micronutrient and phytochemical properties were determined using standards methods. Results revealed that potassium content ranged from 492.75 to 579.00%, iron (4.58 to 4.80%), magnesium (20.01 to 39.14%), calcium (43.94 to 73.06%) and phosphorus (91.26 to 123.45%) and differed significantly ($p<0.05$). Results for phytochemicals revealed that phenol, flavonoid, tannin and saponin content significantly ($p < 0.05$) increased with an increase in baobab seed flour while a decrease in saponin content was observed. These findings suggest that incorporating 40% of baobab seed flour into wheat-tigernut biscuits can enhance the nutritional properties.

Keywords: Biscuits, baobab seeds, tigernut residue

1.0 Introduction

Biscuit is a flour- based baked and shaped food item which are typically hard flat and unleavened. Traditionally, biscuits are made from wheat flour, which provides the gluten necessary for the desired texture and structure (Methe *et al*., 2024; Ubbor *et al*., 2022). Biscuit is a popular snack due to its convenience, shelf-stability, and variety of textures and flavours. Traditionally, biscuits are produced from wheat flour, sugar, and fat (Mamat and Hill, 2018). However, conventional biscuits often lack essential nutrients, such as vitamins, minerals, and bioactive compounds, vital for addressing malnutrition and promoting overall health.

Tigernut (*Cyperus esculentus L.)* is an underutilized crop usually with a sweet and nutty taste. Tigernut residue also known as tiger nut meal or tiger nut by-product is the leftover material from the processing of tiger nuts (Uzochukwu *et al.,* 2023). It is high in fibre and protein, making it a sustainable ingredient in food formuations. The residues exhibit antioxidant activity, with flavonoid content and FRAP values of 0.91mg GAE/g and 3.43 AAE for yellow residue (Oladele *et al.,* 2023).

African baobab (*Adansonia digitata L.*) is a common, multifunctional tree native to Western Africa's arid and semi-Arid regions. Baobab seeds are rich in essential fatty acids, proteins, vitamins, and minerals (Chadare *et al*., 2009). Baobab seed flour has been studied for its potential to enhance the nutritional and functional properties of various food products (Stadlmayr *et al*., 2013).

There is growing interest in fortifying common food products like biscuits with nutrient-rich, underutilized ingredients to improve their nutritional profile and potentially introduce beneficial phytochemicals. Utilizing tigernut residue, a by-product of tigernut milk production which contains appreciable amounts of

important nutrients will help to reduce food waste. The aim of this study was to evaluate the effect on the inclusion of African baobab seed and tiger nut residue flours in biscuit formulations.

2.0 Materials and Methods

Wheat flour (Crown), milk (Dano), margarine (Simax), egg, and salt (Dangote) were purchased from Ogige market in Enugu state, Nigeria Nsukka while tigernut and baobab seeds were purchased from Jos.

2.1 Method of production

Tigernut residue flour was produced following the method described by (Ayo *et al.,* 2018). Baobab seeds were processed into flour following the method described by Babalola *et al.* (2021). The biscuits were produced by mixing the flour with other ingredients following the method described by Ayo *et al,* (2018). Six samples of biscuits were formulated from wheat, tigernut residue and African baobab flours in the ratio of 85:10:5, 70:20:10, 60:10:30, 50:10:40 for sample WBST1, WBST2, WBST3, WBST5 and WBST0. The flour and other ingredients were mixed properly to form a dough. The dough was kneaded, rolled with a roller, and cut using a locally fabricated biscuit cutter. It was then baked in an oven (KAS3UTUE-18A) at 180◦C for 15 min. The biscuit was removed from the oven, cooled, packaged, and stored in air-tight containers for further analysis.

Potassium, calcium, phosphorus, iron, and magnesium were determined as described by AOAC (2010). Phenol, flavonoid, tannin and saponin contents were determined following the method described by AOAC (2010). Sensory evaluation was conducted using a 9-point Hedonic scale. Biscuits were presented to 20 panelists comprising male and female students of the Department of Food Science and Technology, University of Nigeria Nsukka based on their familiarity with biscuits for assessment of the sensory attributes.

3.0 Results and Discussion

The mineral content of the formulated biscuits is presented in Table 1. The potassium content of the biscuits ranged from WBsT0 (492.75 mg/ 100g) to WBsT5 (579.00 mg/100g) and increased significantly ($p < 0.05$) with increase in baobab seed substitution. The calcium content showed a consistent increase from WBsT0 (43.94 mg/100g) to WBsT5 (73.06 mg/100g), iron content ranged from 4.58 to 4.80 mg/ 100g, with WBsT5 showing the highest value (4.80 mg/100g) and WBsT0 (4.58 mg/100). The phosphorous content of the biscuits ranged from 91.26 to 123.45 mg/100g with sample WBsT0 having the highest phosphorous content (91.26 mg/100g) and sample WBsT5 (123.45 mg/100g) having the lowest phosphorous content.

The significant increase in the calcium, iron, phosphorus contents of the biscuits with increase in the substitution level of baobab seed flour could be due to the higher mineral content of baobab seed flour. Several research has shown that baobab seed contains good amount of minerals (Gadanya *et al*., 2014; Mamman *et al*., 2021; Muthai *et al*., 2017).

Table 1: Mineral content of biscuits produced from flour blends of wheat, tigernut residue and baobab seed.

Values are means ± standard deviation of duplicate determination. Means with the same superscripts in a column are not significantly ($p > 0.05$) different. WBST0: 100% wheat, WBST1: 85% wheat + 10% tiger nut +5% baobab seed, WBST2: 80% wheat + 10% tiger nut+ 10% baobab seed, WBST3: 70% wheat + 10% tiger nut+20% baobab seed, WBST4: 60% wheat + 10% tiger nut + 30% baobab seed, WBST5: 50% wheat + 10% tigernut + 40% baobab seed.

Sample	Potassium (mg/100g)	Iron (mg/100g)	Magnesium (mg/100g)	Calcium (mg/100g)	Phosphorus (mg/100g)
WBsT0	$492.75^{b} \pm 2.45$	$4.58^{c} \pm 0.00$	$20.01^{b} \pm 0.02$	$43.94^{e} \pm 0.00$	$91.26^{e} \pm 0.00$
WBsT1	$489.30^{b} \pm 2.43$	$4.50^{c} \pm 0.11$	$25.03^{b} \pm 0.34$	$45.76^{a} \pm 2.58$	$95.84^{a} \pm 0.89$
WBsT2	$557.72^{ab} \pm 22.77$	$4.42^{b} \pm 0.11$	$30.85^{b} \pm 0.35$	$62.01^{b} \pm 0.18$	$95.43^{b} \pm 3.41$
WBsT3	$584.75^{ab} \pm 7.31$	$4.30^{b} \pm 0.08$	$35.16^{b} \pm 0.08$	$63.44^{d} \pm 0.74$	$96.88^{bc} \pm 0.65$
WBsT4	$604.29^{a} \pm 2.45$	$4.42^{a} \pm 0.23$	$39.26^{a} \pm 0.17$	$68.25^{c} \pm 0.55$	$104.50^{c} \pm 0.76$
WBsT5	$579.00^{a} \pm 8.94$	$4.80^{a} \pm 0.11$	$39.14^{b} \pm 0.00$	$73.06^{e} \pm 1.43$	$123.45^{e} \pm 1.70$

The Phytochemical content of the biscuits produced from flour blends of wheat, African baobab seed and tiger nut residue is shown in Table 2. The control sample (WBsT0, 100% wheat) exhibited the lowest phenolic content (148.85 mg/g), while WBsT5 (50% wheat + 40% baobab + 10% tiger nut) showed the highest (499.27 mg/g). WBsT0 had the least flavonoid content (94.85 mg/g), whereas WBsT5 had the maximum (196.98 mg/g). The control sample (WBsT0) had the lowest tannin content (59.72 mg/g), while WBsT5 had the highest level (123.37 mg/g). WBsT5 had the highest saponin concentration (48.58 mg/g), whereas the comparison sample (WBsT0) had the lowest at 31.87 mg/g. The alkaloid content decreased with increase in the substitution level of baobab seed flour in contrast to other phytochemicals. WBsT5 had the lowest alkaloid concentration (0.090%), while the control sample (WBsT0) had the highest (0.245%). The increase in the phenolic, flavonoid, tannin and saponin content of the biscuits

Table 2: Phytochemical content of biscuits produced from flour blends of wheat, African baobab seed flour and tigernut residue

Sample	Phenol (mg/100g)	Flavonoid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Alkaloids (mg/100g)
WBsT0	$148.85^{a} \pm 0.05$	$94.85^{a} \pm 1.67$	$59.72^{a} \pm 1.15$	$31.87^{ab} \pm 0.34$	$0.245^{d} \pm 0.02$
WBsT1	$169.36^{b} \pm 1.20$	$121.20^{b} \pm 2.51$	$69.01^{b} \pm 0.04$	$30.11^{a} \pm 0.05$	$0.140^{c} \pm 0.00$
WBsT2	$211.07^{c} \pm 11.06$	$133.34^{c} \pm 0.42$	$72.17^{bc} \pm 0.66$	$31.70^{ab} \pm 0.51$	$0.120^{bc} \pm 0.01$
WBsT3	$286.30^{d} \pm 4.06$	$146.00^{d} \pm 0.89$	$74.28^{c} \pm 1.85$	$32.52^{b} \pm 0.43$	$0.105^{ab} \pm 0.01$
WBsT4	$343.32^{e} \pm 5.59$	$181.64^{e} \pm 2.08$	$98.85^{d} \pm 1.22$	$37.20^{c} \pm 1.57$	$0.095^{ab} \pm 0.01$
WBsT5	$499.27^{f} \pm 7.29$	$196.98^{f} \pm 2.56$	$123.37^{e} \pm 3.79$	$48.58^{d} \pm 0.95$	$0.090^{a} \pm 0.00$

Values are means ± standard deviation of duplicate determination. Means with the same superscripts in a column are not significantly ($p>0.05$) different. WBST0: 100% wheat, WBST1: 85% wheat + 10% tiger nut +5% baobab seed, WBST2: 80% wheat + 10% tiger nut+ 10% baobab seed, WBST3: 70% wheat + 10% tiger nut+20% baobab seed, WBST4: 60% wheat + 10% tiger nut + 30% baobab seed, WBST5: 50% wheat + 10% tigernut + 40% baobab seed.

With increase in baobab seed substitution depict higher content of phytochemicals in baobab seed (Babalola *et al.*, 2021). The lower alkaloid content with increasing baobab seed flour may be due to interactions between the components of baobab seed and wheat flour that affect the extractability or detectability of alkaloids. A study by Arowora *et al.* (2019) reported that compounds in baobab flour might interfere with the extraction process of alkaloids, leading to lower measured values.

Conclusion

Biscuit was made from a blend of wheat, African baobab seed and tigernut residue flours and the inclusion of baobab seed flour improved the mineral and phytochemical properties. The inclusion of baobab seed flour resulted in increase in the potassium, iron, phosphorus, and magnesium content of the biscuits. Furthermore, the flavonoid, phenol, saponin, tannin contents of the biscuits increased with baobab seed inclusion although a decrease in alkaloid content was observed. The increase in the phytochemicals suggests improved antioxidant capacity of the biscuits. The incorporation of baobab seed flour up to 40% in biscuit production will result in biscuits with improved nutritional properties.

References

AOAC (2010). Official methods of analysis. Association of official Analytical chemists. 18th Edition, Gaithersburg, Maryland, USA.

Arowora, K. A., Yakubu, O. E., Shaibu, C., Iornenge, T. J., and Ugwuoke, K. C. (2019). Chemical composition of baobab leaves and fractionation of its ethanolic extract using column chromatography. *International Journal of Science and Research*, 8(7): 812–821.

Ayo J.A., Ojo M.O., C.A. Popoola C.A., Ayo V.A., and Okpasu A., (2018). Production and quality evaluation of acha-tigernut composite flour and biscuits, *Asian Food Science Journal* 1(3):1–12

Babalola, J. O., Adesina, D. A., Alabi, O. O., Adepoju, M. R., Bamisaiye, Y. O., and Awotunde, B. R. (2021). Effect of processing method on proximate, minerals, phytochemicals, and antinutrients present in Baobab seeds (*Adansonia digitata*). *GSC Advanced Research and Reviews* 6(3): 1–10.

Braca, A., Sinisgalli, C., De Leo, M., Muscatello, B., Cioni, P. L., Milella, L., Ostuni, A., Giani, , and Sanogo, R. (2018). Phytochemical Profile, Antioxidant and Antidiabetic Activities of *Adansonia digitata L.* (Baobab) from Mali, as a Source of Health-Promoting Compounds. *Molecules* (Basel, Switzerland) *23*(12): 3104.

Chadare, F. J., Linnemann, A. R., Hounhouigan, J. D., Nout, M. J. R., and Van Boekel, M. A. J. S. (2009). Baobab food products: A review on their composition and nutritional value. *Critical Reviews in Food Science and Nutrition* 49(3):254-274.

Gadanya, A. M., Atiku, M. K. and Otaigbe, B. O. (2014). Proximate and elemental analysis of baobab (*Adansonia digitata*) seed. International Journal of Analytical Biochemistry Research 1(1): 1-4.

Mamman, S., Shuaibu, B. S., and Yusuf, J. A. (2021). Exploring the nutritional and mineral compositions of baobab (*Adansonia digitata* l) fruit pulp and seed. *FUDMA Journal of Sciences,* 5(2): 128–132.

Mamat, H., and Hill, S. E. (2018). Structural and functional properties of major ingredients of

biscuit. *International Food Research Journal* 25(2); 462–471.

Methe, P., Kawade, S., and Oak, M. (2024). Study of ancient and modern wheat rrain textures, physiochemical properties, and biscuit quality. *Current Agriculture Research Journal*, 12(2): 803–819.

Muthai, K. U., Karori, M. S., Muchugi, A., Indieka, A. S., Dembele, C., Mng'omba, S., and Jamnadass, R. (2017). Nutritional variation in baobab (*Adansonia digitata L.)* fruit pulp and seeds based on Africa geographical regions. *Food Science and Nutrition*, 5(6): 1116–1129.

Oladele, A. K., Liman, A. A., Abass, M. F., and Ekawu, B. (2023). Chemical, techno-functional, and antioxidant properties of tigernut (Cyperus esculentus L.) residue flour. *FUDMA Journal of Agriculture and Agricultural Technology* 9(1): 179-188.

Stadlmayr, B., Charrondiere, U. R., Eisenwagen, S., Jamnadass, R., and Kehlenbeck, K. (2013). Nutrient composition of selected indigenous fruits from sub-Saharan Africa. *Journal of the Science of Food and Agriculture*, 93(11): 2627-2636.

Ubbor, S. C., Ezeocha, V. C., Okoli, J. N., Agwo, O. E., Olaoye, O. A., and Agbai, I. E. (2022). Evaluation of biscuits produced from wheat (Triticum aestivum), tiger nut (Cyperus esculentus) and orange fleshed sweet potato (Ipomea batatas) flours. *FUDMA Journal of Sciences*, 6(4): 254–261.

Uzochukwu A. O., Nneoma E. O., Patricia U., Chinaza P. U., Martina O., Okereke I., and Chinyere, E. (2023). Comparative Analysis of the Proximate and Sensory Properties of Wheat-whole Tigernut Biscuits replaced with avocado paste. *Nigerian Journal of Nutritional Science* 44(1):13-24.

Storage Stability of Smoked Catfish Treated with *Syzygium Aromaticum* Ethanolic Extract

*Aniagor, E. N.,[1] Eze, C. M.,[1] Amonyeze, A. O.[1] and Nduka, O. C[1].

[1]Department of Food Science and Technology, University of Nigeria, Nsukka

*Corresponding author's e-mail: ebele.aniagor@unn.edu.ng

ABSTRACT

This study was aimed at evaluating the preservative effects of clove extract on the quality and shelf-life of smoked catfish. Catfish (*Clarias gariepinus*) was cut, eviscerated, washed, dipped into 10 % brine for 10 minutes and drained. The fish was then divided into four sample groups and treated with clove extract at different concentrations of 1, 2 and 3 %, v/v (SPC1, SPC2 and SPC3, respectively) leaving the control (SPC0) with no treatment. These were smoked at temperatures of 75 °C for 4 hours, cooled and stored at ambient temperature for 4 weeks. The smoked catfish samples were evaluated for, water activity (aw) and free fatty acid (FFA). During storage, water activity (aw), free fatty acids (FFA), were conducted weekly to evaluate the fish stability. From the results obtained, the aw and FFA increased as storage progressed. Sample SPC3 had the lowest values of water activity (0.75 to 0.81) and FFA (0.03 to 0.15%). The aw and FFA values for sample SPC2 ranged from 0.77- 0.85 and 0.03 - 0.14 % respectively. The aw and FFA values for sample SPC1 ranged from 0.80-0.87 and 0.05 - 0.16 % respectively. Sample SPC0 had the highest values of aw (0.83 - 0.91) and FFA (0.07 to 0.20 %) From the findings of this research it can be concluded that clove extract improved the storage stability of smoked catfish by reduced FFA and aw values in the treated samples.

Keywords: Catfish (*Clarias gariepinus*), Smoking, Storage.

1.0 Introduction

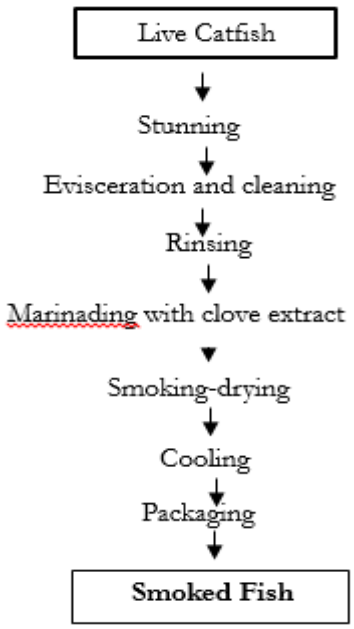
The high perishability of catfish due to its high moisture, protein and polyunsaturated fatty acids contents as well as low acidity remains the major problem in the catfish industry (Olatunde *et al.,* 2022). Fish is subjected to different preservation method in order to extend its shelf-life and reduce postharvest loss. In Africa, fish smoking is the most widely used traditional methods of fish preservation. Smoked catfish is a popular and widely consumed delicacy in many regions especially in Nigeria valued for its unique flavour, extended shelf life, and convenience. However, maintaining the quality of smoked catfish during storage remains a challenge due to microbial spoilage, lipid oxidation, and subsequent organoleptic changes. Herbs and spices have long been used in traditional food and medicinal preparations, and recent studies have shown their potential as antibacterial, antifungal, antiviral and antioxidant due to their bioactive contents especially the phenolic compounds and flavonoids (Yashin *et al.,* 2017). The objective of this work was to produce and evaluate the effect of ethanolic extract of clove on storage stability and acceptability of smoked catfish (*Clarias gariepinus*).

2.0 Materials and Methods

Freshly harvested catfish (*Clarias gariepinus*) were purchased from Ogige market, Nsukka. Common salt and dried cloves were purchased from the same market, while the wood and saw dust for smoking were obtained from timber shed Nsukka, Enugu State.

2.1 Sample Preparation

Smoked catfish treated with clove extract was produce as shown in Fig 1. The catfish (samples) were washed with water and lime to remove dirt and reduce sliminess from the catfish. Prior to smoking, the sample was divided into four groups; the first group served as control while the second, third and fourth groups were treated with clove extract of concentrations 1 %, 2 % and 3 % respectively (v/v).



Source: (Iheanacho *et al.*, 2017)

Fig 1: Smoked catfish treated with clove extract

2.1.1 Preparation of Clove Extract

The dried clove buds were milled into the powder using the method designed by Kumudavally *et al.,* 2011. Ethanolic extract of clove (*Eugenia caryophyllata*) was prepared by soaking clove powder in 95 % ethyl alcohol- overnight (1:4 w/v) followed by filteration after agitation for 10 –15 min in a rotary flash shaker, and then concentrating the filtrate

3 Results and Discussion

The water activity values of the smoked fish is shown in table 1. During the four weeks of storage, a consistent increase in water activity was observed in all the samples. The water activity values ranged from 0.75-0.91 with sample SPC0 having the highest value of 0.91 and sample SPC3 the lowest value of 0.75 at the end of the 4-week storage. Obiero *et al.*, (2019) reported similar water activity values of smoked catfish samples of 0.70 and 0.79 for a 30-day storage period but with a decreasing trend in water activity. The increase in water activity observed in the study could be due to exposure of the samples to atmospheric humidity during storage. However, the water activity of all the samples was above the Codex Standard for smoked fish, smoke-flavoured fish and smoke-dried fish, which is 0.75 aw, as necessary to control bacteria pathogens and spoilage fungi (Fasuan *et al.,* 2022). Therefore, more dehydration during smoke-drying to water activity level of < 0.75 is necessary.

Table 1: Water activity values of the smoked catfish during a 4-week storage period

Samples	Water activity				
	Week 0	Week 1	Week 2	Week 3	Week 4
SPC0	0.83 ^{d} ± 0.00	0.84^{c} ± 0.00	0.86 ^{c} ± 0.00	0.89^{d}±0.00	0.91^{c}±0.00
SPC1	0.80 ^{c} ± 0.00	0.83^{c} ± 0.00	0.85^{c} ± 0.03	0.86^{c}±0.00	0.87^{b}±0.00
SPC2	0.77 ^{b} ± 0.01	0.80 ^{b} ± 0.01	0.81 ^{b} ± 0.01	0.84^{b}±0.00	0.85^{b}±0.00
SPC3	0.75 ^{a} ± 0.00	0.76 ^{a} ± 0.00	0.78 ± 0.00	0.80^{a}±0.00	0.81^{a}±0.00

Values represent mean score ± standard deviation. Mean values with the same superscript within the same column are not significantly (p>0.05). Values are means and standard deviations of duplicate readings.

SPC0 = Control sample with no spice treatment, SPC1= sample with 1% clove extract, SPC2= sample with 2% clove extract, SPC3= sample with 3% clove extract

Free fatty acid gives a measure of hydrolytic breakdown in which short chain triglycerides are split into free fatty acids (FFA). The FFA values of the fish samples ranged from 0.03-0.20% with the control (SPC0) having the highest value (0.20%) and sample SPC3, the lowest (0.03%) at the beginning of the 4-week storage. Higher free fatty acid values of 1-1.23% were reported by Adeyeye *et al.* (2016) in smoked silver catfish after convective Kiln smoking. The result shows the effect of the spice extract in retarding hydrolytic breakdown. A similar trend was reported by Olatunde *et al.* (2022) in which smoked spiced catfish samples treated with garlic, ginger and turmeric extracts had lower FFA values of (0.72 - 9.64%) when compared to the untreated sample (2.24 - 11.88%) during a 20-day storage period.

Table 2: Free fatty acid values of the smoked fish samples over the 4-week storage

Samples	FFA (%)				
	Week 0	Week 1	Week 2	Week 3	Week 4
SPCO	0.07 ^{c} ± 0.00	0.11^{a}± 0.02^{a}	0.15 ^{b} ± 0.00	0.18 ^{c}± 0.00	0.20 ^{c}± 0.01
SPC1	0.05 ^{b} ± 0.01	0.08^{ab}± 0.01	0.13 ^{a} ± 0.00	0.15 ^{b}± 0.00	0.16 ^{b}± 0.00
SPC2	0.03^{a} ± 0.01	0.07^{b}± 0.01^{b}	0.12 ^{a} ± 0.00	0.13 ^{a} ± 0.00	0.14 ^{a} ± 0.00
SPC3	0.03 ^{a} ± 0.00	0.08^{ab}±0.00	0.11 ^{a} ± 0.00	0.13 ^{a} ± 0.00	0.14 ^{a} ± 0.00

Values represent mean score ± standard deviation. Mean values with the same superscript within the same column are not significantly (p>0.05). Values are means and standard deviations of duplicate readings.

SPC0 = Control sample with no spice treatment, SPC1= sample with 1% clove extract, SPC2= sample with 2% clove extract, SPC3= sample with 3% clove extract

Conclusion

Findings from this study have shown that clove extract has antioxidative properties that retarded oxidative rancidity thus extending the shelf stability of the smoked fish. The antioxidant activity of the clove extract was evident from lower water activity and free fatty acid values of treated samples when compared to the untreated sample during the 4-week storage period.

References

Adeyeye, S. A. O. and Oyewole, 0. B. (2016). An Overview of Traditional Fish Smoking in Africa, Journal of Culinary Science and Technology, 14:3, 198-215.

Fasuan, A. A, Akin-Obasola, B. and Abiodun, B. O. (2022). Water activity relations of spoilage fungi associated with smoke-dried catfish (*Clarias gariepinus*) sold in some open markets in Nigeria. Journal of Food Science and Technology, 59(6): 2168-2176

Iheanacho S. C., Nworu S. A., Ogueji E. O., Nnatuanya I., Mbah C. E., Anosike F., Okoye C., Ibrahim U. B., Kogi, E. and Haruna, M. (2017). Comparative assessment of proximate content and organoleptic quality of African catfish (*Clarias gariepinus*) processed by smoking and solar drying methods. African Journal of Agricultural Research. 12(38):2824-2829.

Kumudavally, K. V., Tabassum, A., Radhakrishna, K. and Bawa, A. S. (2011). Effect of ethanolic extract of clove on the keeping quality of fresh mutton during storage at ambient temperature (25 ± 2°C). Journal of Food Science and Technology, 48(4): 66-71.

Obiero, M. O., Odoli, C. O., Odote, P. O., Ruwa, R. K. and Omega, M. O. (2019). Shelf-life assessment of hot smoked African catfish stored under different storage conditions at Lake Kenyatta, north coast, Kenya. Western Indian Ocean Journal of Marine Science, 18(1):1-9

Olatunde, S. J., Akinbisoye, A. F. and Ade-Omowaye, B. I. O. (2022). Storage Stability of Hot Smoked Spiced African Catfish (*Clarias gariepinus*). International Journal of Food Studies, 11, 63-70.

Yashin, A., Yashin, Y., Xia, X. and Nemzer, B. (2017). Antioxidant Activity of Spices and Their Impact on Human Health: A Review. Antioxidants (Basel). 6(3):70.

Proximate and Micro-Nutrients Composition of Pumpkin Seed, Leaf, Pulp, and Peel Powders

*Obeta, N. A., Efobi K. B., Oba, B. N. and Ezugwu, C. O.

Department of Food Science and Technology, University of Nigeria Nsukka, Enugu State, Nigeria

*Corresponding Author nwamaka.obeta@unn.edu.ng

ABSTRACT

This study analysed the proximate and micronutrients composition of pumpkin seed, leaf, pulp, and peel powders. The pumpkin parts were separated after washing and cutting the fruit, the pulp, peel and leaves were cut into pieces blanched at 80°C for 2min. Also the seeds were dried under the sun and deshelled. All the samples were dried at 60℃ grinded and sifted using 3mm mesh sieve and packaged in airtight containers. The samples were coded as follows: seed powder (PSP), leaf powder (PLP), pulp powder (PPUP) and peel powder (PPP). Standard methods were used to analyse for proximate and micronutrients. The results obtained from the evaluation of proximate composition showed these values for moisture, protein, fat, ash, fibre and carbohydrate content 4.79-9.83%, 9.15-26.19%, 0.95-12.10%, 3.07-12.78%, 9.42-25.59%, 34.01-65.67% respectively. Micronutrient analysis demonstrated varying values of vitamins B_1: 0.78mg/100g (PLP) to 0.37mg/100g (PPuP), vitamin A: 1305.55 iu (PLP) to 385.50 iu (PPuP) and mineral content range for zinc: 4.61mg/100g (PLP) to 0.64mg/100g (PPP), iron 2.71mg/100g (PSP) to 0.34mg/100g (PPP)). The study concluded that pumpkin seed, leaf, pulp and peel powder had high protein, ash, vitmin A, zinc and iron which will significantly improve health diets.

Key words: Bioactive, nutrients, powder and Pumpkin

1.0 Introduction

Pumpkin belongs to the family of Cucurbitaceae. It is a plant that has been traditionally used as a medicine in developing countries. Edible parts of the plant include the flowers, fruit, leaves, root and seeds (Caili *et al.*, 2006). Pumpkin fractions are rich sources of nutritional components like oils, proteins, carbohydrates and minerals (Syed *et al.,* 2019). The presence of nutritional and health protective polysaccharides in the fruit, protein and oil in the seeds increased interest in pumpkin and pumpkin-based products, by food processing, agriculture, pharmaceutical and feed industries in the last few years (Sojak and Glowacki, 2010).

Pumpkin seeds are inexpensive but have priceless nutritional value; their bioactive components which possess significant nutraceutical and therapeutic benefits (Rezig *et al.,* 2019). Pumpkin pulp consists of polysaccharides, colors, amino acids, bioactive lipids and proteins (Roongruangrsi *et al.,*2015). Pumpkin peels are waste product which contain pectin, a complex polysaccharide but a great source of bioactive chemicals, which can be reutilized or turned into high value products (Hussain *et al.,* 2021).

The study is aimed at determining the proximate and micronutreint composition of four pumpkin parts.

2.0 Materials and Methods

2.1 Sample Procurement: Pumpkin fruits were purchased from *Ogige* market in Nsukka Local Government Area of Enugu State, Nigeria.

2.2 Sample preparation: The method described by Cerniauskiene *et al.*, (2014) was adopted in the processing of pumpkin (seed, leaf, pulp and peel) into powder. Pumpkin fruits were washed, dried, peeled and slicing with sharp knives. Seeds were removed by extracting from the fluffy portion, manually decorticated, the pulp and peel were cut into pieces of 4.5-5.5mm thick and blanched at 80 °C for 2 min. Leaves were plucked, sorted, washed, sliced blanched at 80 °C for 2 min. Each of the samples was dried at

60 ℃ (using a dehydrator). After seeds were crushed by a mechanical grinder (Atuonwu and Akobundu, 2010) dried at 60 °C for 24 h. The samples were grinded and sifted using 3mm mesh to obtain a fine powder. The samples were coded as PSP (pumpkin seed powder), PLP (pumpkin leaf powder), PPuP (Pumpkin pulp powder), PPP (Pumpkin peel powder) and packaged separately in airtight containers to prevent moisture absorption and spoilage. It is stored in a cool, dry place.

2.3 Proximate Composition:

The moisture content was determined using the method of AOAC, (2010). A clean dish with a lid was dried in an oven at 100 ^{0}C; cooled in a desiccator and weighed. Five grams each of the sample was weighed into the dish. The dish with its content was put in the oven at 105 ^{0}C and dried to a constant weight. The moisture content (%) was calculated as:

$$\%\text{moisture content} = \frac{\text{weight of moisture}}{\text{weight of sample}} \text{x } 100$$

The crude protein content was determined by AOAC (2010), semi-micro kjeldahl flask 3.0g of hydrated cupric sulphate and 0.1 N conc H_2SO4 were added and digested the sample. The clear liquid was then cooled and made up to 100ml with distilled water Then 5ml of the digest and 60% NaOH solution was put into the distillation flask and distilled. The Boric acid indicator absorbed the ammonia which was distilled off and was titrated with 0.1N HCl.

The titre value was recorded.

$$\%\ \text{Nitrogen} = \frac{(\text{titre value} - \text{Blank}) \text{ xdilution factorx } 6.25}{\text{weight of sample}}$$

Percentage fat content was determined using AOAC (2010). A round bottom flask was weighed and 150ml petroleum ether (boiling point of 60-80 ^{0}C) was poured into the flask. The Soxhlet apparatus was assembled and allowed to reflux for 6 h. When the flask was free of ether, it was removed, dried at 100 ^{0}C for two hours in a hot air oven, cooled in a desiccator and weighed. The fat content was calculated:

$$\%\ \text{Fat} = \frac{\text{Weight of extracted fat} \times 100}{\text{Weight of sample taken}}$$

Ash content was determined using the methods described in AOAC (2010). Triplicate samples (each1g moisture free weight) in the crucible were charred on a hot plate in the fume cupboard. The charred samples were then incinerated in the furnace (Muffle, China, SX2-25-10) at 550^{0}C until a whitish grey ash was obtained. It was allowed to cool in a desiccator and then weighed. The percentage ash content was calculated with the expression:

$$\%\ \text{Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Crude fibre was determined using the AOAC (2010) method. Five grams of each sample was weighed (W_3) into a 500 ml Erlenmeyer flask and 100 ml of TCA digestion reagent added. It was then allowed to boil and refluxed for exactly 40 min counting from the start of boiling. The flask was removed from the heater, cooled and filtered through a 15.0 cm number 4 Whatman filter paper. The residue was washed with hot water, stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105^{o}C. After drying, it was transferred to a desiccator and weighed (W_2). It was incinerated in a muffle furnace at 550 ^{o}C for 6 h, allowed to cool, and reweighed as W_1

$$\%\ \text{Crude fibre} = \frac{W_2 - W_1}{W_3}$$

The Carbohydrate content of the sample was determined according to differences as described by AOAC, (2010). This was done by subtracting the sum of percentage weight of crude fat, crude protein, ash and moisture from the weight of the sample.

2.4 Micronutrients determination:

Determination of minerals: magnesium, Zinc and iron were determined by AOAC 2010.

Vitamin A and Vitamin B_1 by AOAC method while Vitamin E- determined using Kirk and Sawyer.

2.5 Experimental Design and Data Analysis

The experiment design used was Completely Randomized Design (CRD) and the data obtained were subjected to one- way analysis of variance (ANOVA). Mean separation was done using Duncan multiple Range test and significance was accepted at $p<0.05$.

3.0 Result and Discussions

The moisture content of pumpkin seed, leaf, pulp, and peel ranged from 4.79 % in (PSP) to 9.83% in (PLP) with significant ($p<0.05$) difference in the values. Sample PSP having the lowest moisture content can be attributed to the high oil content in the seed (Kar et al., 2023). The samples were all found within the range of the FAO recommended moisture level (<10%) for most dried food samples.

The protein content ranged from 9.15% to 26.19%. Sample containing pumpkin seed (PSP) had the highest protein content (26.19%), while pumpkin leaf (PLP) had the lowest protein content (9.15%).

The high protein content shows that pumpkin seeds are rich source of protein, as they store essential nutrients. On the other hand, the low protein content observed in peel (PPP) is because it is mainly composed of carbohydrates especially cellulose. The protein content in the seed is lower than the protein content reported by Das *et al.,* (2021), 39.35 % for pumpkin seed product.

The ash content of pumpkin samples ranged from 3.07% to 12.78%. The formulation that resulted to the lowest and highest amount of ash content was PPP and PLP respectively. There was significant ($p<0.05$) difference among the ash content of the samples. Ash content is an important indicator of mineral content and a quality parameter that determines contamination with foreign matter. The higher ash content in PLP could be attributed to their higher composition of inorganic compounds and minerals which are expected to speed up metabolic processes, improve growth and development (Elinge *et al.,* 2012; Adebayo *et al.*, 2013).

The fat content ranged from 0.95% (PPuP) to 12.10% (PSF). The low-fat content of pumpkin pulp powder is in agreement with the findings of Batool *et al.,* (2022). The high fat content in PSP is well expected as seeds are naturally rich in oils, and fatty acid components. The crude fibre content of the sample ranged from 9.42 % to 25.59%. Sample PLP (25.59%) had the highest fibre content because it is rich in cellulose. The crude fibre values were higher than those reported by Mishra and Sharma, (2019). This infers that pumpkin leaves are significant source of dietary fibre, making it a valuable addition to various food products.

The carbohydrate content of the samples ranged from 3.40 % to 65.67 %. Sample PPP had the highest carbohydrate content (65.67%), while sample PSP (3.40%) had the least carbohydrate content. Sample PPP is mostly high carbohydrate components. Sample PSP having the least carbohydrate content is due to higher protein and fat content. The relatively high carbohydrate content of pumpkin peels is an indicator that it may provide energy required for optimum growth and development.

3.1 Micronutrient composition of pumpkin seed, leaf, pulp, and peel:

The vitamin A content ranged from 385.50 iu (PPuP) to 1305.55 iu. (PLP). There was significant difference ($p<0.05$) in the vitamin A content. Sample PLF is higher in vitamin A because of its active role in photosynthesis. Bhat and Bhat, (2013) reported that pumpkin leaf had high beta-carotene level which will significantly improve the beta-carotene content and subsequently improve vitamin A status of diet which has them.

Table 1: Proximate composition (%) of pumpkin seed, leaf, pulp and peel flour

Values are means ± standard deviation of 2 replicate determination. Means with the same superscripts in a column are not significantly (p> 0.05) different.

Key: PSF= Pumpkin seed flour, PLF= Pumpkin leaf flour, PPuF= Pumpkin pulp flour, PPF= Pumpkin peel flour.

The vitamin B_1 content varied between 0.37mg/100g (PPuP) to 0.78mg/100g (PLP). Sample PLP had the highest value because they are the primary site for the synthesis of thiamine. The values are higher compared to 0.27mg/100g) obtained by Syed et al. (2019). Vitamin E varied between 0.18mg/g to 2.77mg/g. Sample

Sample	Moisture	Protein	Fat	Ash	Crude Fibre	Carbohydrate
PSP	$4.79^{a} \pm 0.84$	$26.19^{d} \pm 0.46$	$12.10^{c} \pm 0.08$	$3.84^{b} \pm 0.04$	$19.09^{c} \pm 0.04$	$34.01^{a} \pm 0.27$
PLP	$9.83^{d} \pm 0.04$	$15.76^{c} \pm 0.03$	$0.96^{a} \pm 0.02$	$12.78^{d} \pm 0.04$	$25.59^{d} \pm 0.12$	$35.09^{b} \pm 0.05$
PPuP	$9.61^{c} \pm 0.02$	$13.45^{b} \pm 0.15$	$0.95^{a} \pm 0.02$	$7.60^{c} \pm 0.03$	$10.30^{b} \pm 0.08$	$58.11^{c} \pm 0.21$
PPP	$7.97^{b} \pm 0.05$	$9.15^{a} \pm 0.05$	$4.75^{b} \pm 0.04$	$3.07^{a} \pm 0.91$	$9.42^{a} \pm 0.11$	$65.67^{d} \pm 0.08$

PLP had the highest value, while sample PPuP had the lowest value. Sample PSP and PPP did not differ (p>0.05), while sample PLP differed significantly from all the samples.

Magnesium content ranged from 227.48 mg/g in PPuP to 1713.67mg/g in PPP.

The iron content ranged from 0.34mg/g in PPF to 2.71mg/g in sample PSF. The zinc content of pumpkin samples ranged from 0.64 mg/100g in PPP to 4.61mg/100g in PLP. The higher iron content in sample PSP could be attributed to the fact that pumpkin seeds are a rich source of iron.

Table 2: Micronutrient composition (mg/100g) of pumpkin seed, leaf, pulp, and peel.

Sample	Mg (mg/100g)	Zn (mg/100g)	Fe (mg/100g)	Vit.A (IU)	Vit. B1 (mg/100g)	Vit. E (mg/100g)
PSP	$358.51^{c} \pm 2.74$	$1.32^{c} \pm 0.01$	$2.71^{c} \pm 0.02$	$953.82^{c} \pm 1.20$	$0.64^{c} \pm 0.01$	$0.00^{a} \pm 0.00$
PLP	$1177.27^{d} \pm 1.12$	$4.61^{d} \pm 0.01$	$0.50^{b} \pm 0.21$	$1305.55^{d} \pm 7.18$	$0.78^{d} \pm 0.00$	$2.77^{c} \pm 0.04$
PPuP	$227.48^{b} \pm 1.54$	$0.76^{b} \pm 0.01$	$0.38^{a} \pm 0.04$	$385.50^{a} \pm 4.12$	$0.37^{a} \pm 0.00$	$0.18^{b} \pm 0.01$
PPP	$1713.67^{a} \pm 1.23$	$0.64^{a} \pm 0.02$	$0.34^{a} \pm 0.02$	$877.48^{b} \pm 1.05$	$0.55^{b} \pm 0.01$	$0.00^{a} \pm 0.00$

Values are means ± standard deviation of 2 replicate determination. Means with the same superscripts in a column are not significantly (p> 0.05) different.

Key: PPP= Pumpkin seed powder, PLP= Pumpkin leaf powder, PPuP= Pumpkin pulp powder, PPP= Pumpkin peel Powder.

Conclusion

The high protein and fat content in the seed, carbohydrate in the peel, vitamin A content of the leaf highlights the potential of pumpkin parts to create value-added products rich in dietary fibre, vitamins and minerals through incorporating underutilized pumpkin components. This research encourages preservation of pumpkin parts (which is a seasonal crop) through dehydration to increase their shelf life so it can be incorporated into food products to improve their nutrient density. The use of pumpkin by-products aligns with circular economy principles, offering economic opportunities for farmers and food processors to repurpose agricultural residues.

References

Adebayo, O. R., Farombi, A. G. and Oyekanmi, A. M. (2013). Proximate, mineral and anti-nutrient evaluation of pumpkin pulp (Cucurbita pepo). Journal of applied chemistry, *4*(4):25-28.

AOAC (2010). Officicial Methods of Analysis (18th edition), Washington DC, USA: Association of official Analytical Chemist.

Atuonwu, A. C. and Akobundu, E. N. T. (2010). Functional and pasting properties of pumpkin (Cucurbita pepo) seed products. Journal of Agricultural and Veterinary Sciences, 2: 36-49.

Batool, M., Ranjha, M. M. A. N., Roobab, U., Manzoor, M. F., Farooq, U., Nadeem, H. R. and Ibrahim, S. A. (2022). Nutritional value, phytochemical potential, and therapeutic benefits of pumpkin (Cucurbita sp.). *Plants*, 11(11): 1394-1400.

Bhat, M.A. and Bhat, A. (2013). Study on PhysicoChemical Characteristics of Pumpkin Blended Cake, Food Processing & Technology 4(9) :1-4.

Caili, F. U., Huan, S, and Quanhong, L. I. (2006). A review on pharmacological activities and utilization technologies of pumpkin. Plant foods for human nutrition, 61: 70-77.

Cerniauskiene, J., Kulaitiene, J., Danilcenko, H., Jariene, E., and Jukneviciene, E. (2014). Pumpkin fruit flour as a source for food enrichment in dietary fibre. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 42(1): 19-23.

Das, S., Ghosh, M. and Chakraborty, P. (2021). Study of the utilization of "Pumpkin seed" for the production of nutritionally enriched biscuits. International Journal of Food Science and Nutrition, 6(1): 63-67.

Elinge, C. M., Muhammad, A., Siaka, A. A., Atiku, F. A., Hannatu, A. S., Peni, I. J., & Yahaya, Y. (2012). Nutritional and Antinutritional Composition of Pumpkin (Cucurbitapepo L.) Pulp. Advances in food and Energy security, 2: 22-28.

Hussain, A., Kausar, T., Din, A., Murtaza, A., Jamil, M. A., Noreen, S., and Iqbal, M. A. (2021). Antioxidant and antimicrobial properties of pumpkin (Cucurbita maxima) peel, flesh and seeds powders. Journal of Biology, Agriculture and Healthcare, 11(6): 42-51.

Kar, S., Dutta, S. and Yasmin, R. (2023). A comparative study on phytochemicals and antioxidant activity of different parts of pumpkin (Cucurbita maxima). Food Chemistry Advances, *3*: 100505-100545

Mishra, S. and Sharma, K. (2019). Development of pumpkin peel cookies and its nutritional composition. Journal of Pharmacognosy and Phytochemistry, 8(4): 370–372

Rezig, L., Chouaibi, M., Meddeb, W., Msaada, K. and Hamdi, S. (2019). Chemical composition and bioactive compounds of Cucurbitaceae seeds: Potential sources for new trends of plant oils. Process Safety and Environmental Protection, 127: 73-81.

Roongruangsri, W. and Bronlund, J. A. (2015). Review of Drying Processes in the Production of Pumpkin Powder. International Journal of Food Engineering, 11: 789–799.

Sojak, M. and Głowacki, S. (2010). Analysis of giant pumpkin (Cucurbita maxima) drying ki- netics in various technologies of convective drying. Journal of Food Engineering, 99(3): 323–329.

Syed, Q. A., Akram, M. and Shukat, R. (2019). Nutritional and therapeutic importance of the pumpkin seeds. *Seed*, 21(2): 15798-15803.

Mineral and Sensory Properties of Breads Produced from the Blends of Wheat Flour and Flaxseed Flour

Obarisagbon, I. and *Okechukwu, N.G

Department of Food Science and Technology, Federal Polytechnic Oko.

Corresponding author's email: gracebasilica2015@gmail.com

ABSTRACT:

This study determined the sensory qualities and mineral composition of breads produced with wheat and flaxseed flour blends. Flaxseed was prepared through washing, sun drying, roasting, milling, and sieving. Varying proportions of wheat flour and flaxseed flour were used to produce bread samples: BR1 (100% wheat flour), BR2 (90% wheat flour-10% flaxseed), BR3 (80% wheat flour-20% flaxseed), BR4 (70% wheat flour-30% flaxseed), and BR5 (60% wheat flour-40% flaxseed). Sensory evaluation revealed BR2 as the most preferred. BR2, BR3, and BR4 were further analyzed for mineral composition. The results showed that these bread samples were rich in potassium (K) and calcium (Ca) but relatively low in manganese (Mn) and iron (Fe). The mineral composition was as follows: BR2 contained 2.01 mg/100g Ca, 4.42 mg/100g K, 0.31 mg/100g Mn, and 0.11 mg/100g Fe; BR3 contained 3.90 mg/100g Ca, 39.89 mg/100g K, 1.00 mg/100g Mn, and 0.12 mg/100g Fe; and BR4 contained 2.04 mg/100g Ca, 46.11 mg/100g K, 0.56 mg/100g Mn, and 0.15 mg/100g Fe.

Keywords: Flaxseed, Bread, Sensory, Mineral, Wheat

1.0 Introduction

Bread can be described as a fermented confectionary product produced mainly by combining basic ingredients such as wheat flour, water, yeast, sugar, salt, shortening and improver which undergoes series of processes involving mixing, kneading, proofing, shaping and baking (Kure *et al.,* 2021; Thakaeng *et al.,* 2021). Being a good source of energy for the human body, bread is considered a staple food worldwide and it plays a vital role in food security (Brites *et al.,* 2022; Malavi *et al.,* 2022). According to the reports in the study of Mudau *et al.* (2021), bread contains useful nutrients including carbohydrates, protein, fiber, vitamins, and minerals and the quality and quantity of these nutrients are solely dependent on the raw materials used (especially flour). The most important ingredients in bread formulation are flour, yeast and water because they primarily affect the crumb texture, bread structure and bite characteristics (Thakaeng *et al.,* 2021). The quality of bread depends on the properties of the raw materials as well as on the baking process. The most frequently quality parameters assessed are the volume, weight, and specific weight (true density) of bread (Różyło and Laskowski, 2011). There are a large variety of bread products with large differences in volume, crumb structure and texture, and crust thickness or crispness. The optimal bread quality depends therefore on the type of bread product. Różyło and Laskowski (2011) suggested that structure, moisture and mechanical properties (e.g. firmness/hardness) are important aspects of crumb quality, whereas the quality of bread crust is often based on colour and thickness/crispness of the crust.

Wheat (*Triticum aestivum*. L) flour according to Masood *et al.* (2020), is the major ingredient for bread production and it can contribute to more than 50% of the total caloric intake worldwide. It has been confirmed that the entire grain is rich in nutrients such as minerals, protein, fat and fiber while the refined grain is generally starch (Senya *et al.,* 2021). Wheat flour has proteins with superior baking properties. The flour contains high amounts of digestible starch with a high glycemic index, making wheat bread unsuitable

for consumption by patients suffering from diabetes and other cardiovascular diseases (Chikpah *et al.,* 2021; Mbogo *et al.,* 2021).

Flaxseed (*Linumusitatissimum*) is the seed from the flax plant, an annual herb, which is a member of the *Linaceae* family. It is an important oil seed crop. It is rich in bioactive components that provide health benefits, including alpha linolenic acid, protein, lignans, dietary fiber and soluble mucilage. In addition, it is a good source of calcium, manganese, vitamins and omega-3 (Man *et al.,* 2021). Flaxseed has medicinal benefits and has been used as a source of health-giving additives in many bakery products. Flaxseed consumption in the diet reduces the risk of serious diseases like coronary diseases, diabetes, obesity, gastrointestinal, renal and bone disorders, cardiovascular risk and certain types of cancers, particularly hormone-dependent cancers (such as breast and prostate cancer) (Kaur *et al.,* 2019). Flaxseed can be supplemented in bread and other goods such as cookies and muffins including gluten free products. The incorporation into bread results in an improved texture and crumb texture. Healthy functional snack foods such as high protein energy bars can also be prepared with flaxseed as ingredient (Chishty and Bissu, 2016)

Flaxseed contains good source of minerals especially, phosphorus, magnesium, calcium and has low amount of sodium. It also contains small amounts of water-soluble and fat-soluble vitamins. Vitamin E is present as γ-tocopherol, amounting to 39.5 mg/100 g. γ-tocopherol acts as an antioxidant preventing fat from oxidation Vitamin C is absent in flaxseed (Morris, 2007).

2.0 Materials and Methods

All-purpose wheat flour, flaxseed and other baking materials such as shortening, sugar, bakers' yeast and salt were purchased from *Eke Awka* market Awka in Anambra State. These materials were packaged in a clean polyethylene bag and taken to the Food Processing Laboratory of Department of Food Technology, Federal Polytechnic Oko for further processing

2.1 Sample Preparation

Flaxseed flour was prepared according to the method describe by Kaur *et al.* (2019) wth slight modification. Flaxseed were thoroughly cleaned by winnowing to remove physical hazards like dust particles, damaged seeds, other crop grains and other extraneous materials. The seed were washed, sundried (6h) and roasted in an open pan for 15minutes.The roasted flaxseed were allowed to cool at room temperature before they were milled and sieved to obtain fine flour.

2.2 Formulation of Composite Flour

The composite flours for the production of bread were formulated by blending wheat flour with flaxseed flour in the ratio shown in the table below.

2.3 Production of Bread

Bread and composite bread were produced using the Straight dough method described in the study of Kure et al. (2021). Ingredients (wheat flour or composite flour, fat, water, instant dry yeast, sugar and salt) were mixed together in various proportions for 15 min. After mixing, the dough was kneaded properly until soft, moulded, and shaped into greased pans for proofing. The dough was proofed in a proofing cabinet for 2 hours at 50°C and thereafter baked in a preheated electric oven at 230°C for 30 min. Bread samples were de-panned, cooled, packed in polyethylene bags and stored at ambient temperature till subsequent analyses.

2.4 Standard Analytical Methods

The analysis for essential mineral element was investigated using the method of AOAC (2012). Nitric and hydrochloric acid (10 ml each) were individually added to the sample of 0.5 g in a digestion flask. The mixture was digested for 10 min. The digested mixture was filtered. The filtrate was made up to 50 ml with distilled water. Calcium, iron, zinc, phosphorus and magnesium were measured by Flame Atomic Absorption Spectrophotometer.

2.5 Sensory Evaluation

The sensory attributes of the breads were evaluated using the method described by Iwe (2014). Ten (10) panelists randomly selected from students of Department of Food Technology, Federal Polytechnic Oko, evaluated the colour, taste, aroma, texture and general acceptability of the breads. Quality attributes of the breads were scored in a 9-point Hedonic scale. The degree of likeness was expressed as follows: like extremely (9), like very much (8), like moderately (7), like slightly (6), neither like nor dislike (5), dislike slightly (4), dislike moderately (3), dislike very much (2), dislike extremely (1).

2.6 Statistical Analysis

Data analysis was carried out using one-way analysis of variance (ANOVA) in a completely randomized design (CRD) using Statistical package for Service Solutions, SPSS; mean separation was by Duncan's New Multiple Range Test (Steel and Torrie, 1980). Significance was accepted at $p<0.05$.

3.0 Result and Discussion

Table 2a: Mean sensory scores of breads produce from blends of wheat and flaxseed flours**.**

Samples	Colour	Taste	Texture	Flavour	Overall Acceptability
BR1	$8.30^{a}\pm0.48$	$8.50^{a}\pm0.70$	$7.90^{ab}\pm1.28$	$8.50^{a}\pm0.70$	$8.30^{a}\pm0.57$
BR2	$8.20^{a}\pm0.78$	$8.60^{a}\pm0.69$	$8.40^{a}\pm0.84$	$7.70^{a}\pm1.49$	$8.25^{b}\pm0.68$
BR3	$7.20^{ab}\pm1.47$	$7.30^{ab}\pm1.49$	$7.30^{ab}\pm1.33$	$7.30^{a}\pm1.33$	$7.27^{ab}\pm1.20$
BR4	$7.30^{ab}\pm1.63$	$6.50^{b}\pm1.43$	$6.60^{ab}\pm1.89$	$7.20^{a}\pm1.92$	$6.90^{ab}\pm1.45$
BR5	$6.50^{b}\pm2.63$	$5.80^{b}\pm2.78$	$5.90^{b}\pm3.63$	$4.90^{b}\pm3.10$	$5.77^{b}\pm2.89$

*Values are means ± standard deviations of sensory evaluation. Means with the same superscript in the same column are not significantly different at $p< 0.05$.

Keys: BR1: 100 % Wheat bread, **BR2**: 90:10% Wheat-Flaxseed bread **BR3**: 80:20% Wheat-Flaxseed bread **BR4**: 70:30% Wheat-Flaxseed bread, **BR5**: 60:40% Wheat-Flaxseed bread

Table 2: Mineral composition of bread produced from blends of wheat and flaxseed flours (mg/100g).

Samples	Calcium	Potassium	Iron	Magnesium
BR2	$2.01^{c}\pm0.14$	$4.42^{c}\pm0.01$	$0.11^{b}\pm0.00$	$0.31^{c}\pm0.01$
BR3	$3.90^{a}\pm0.12$	$39.89^{b}\pm0.01$	$0.12^{ab}\pm0.01$	$1.00^{a}\pm0.01$
BR4	$2.04^{b}\pm0.10$	$46.11^{a}\pm0.10$	$0.15^{a}\pm0.02$	$0.56^{b}\pm0.05$

Values are means ± standard deviations of duplicate determinations. Means with the same superscript in the same column are not significantly different at $p< 0.05$.

4.0 Discussion

The results of the sensory scores of bread produced from wheat and flaxseed flour blends is shown in Table 1.The results obtained from the study showed significant difference ($P<0.05$) between the control samples and the composite flour bread samples in colour assessment which ranged from 6.50 obtained for sample BR5 (60%wheatflour-40%flaxseed) to 8.30 obtained for sample BR1 (100% wheat flour) except sample BR2 (90%wheatflour-10%flaxseed) which is statistically the same with the control sample. The colour of

the samples was influenced by the varying inclusion of the flaxseed flour in the bread formulation, with the acceptability of the colour decreasing with increasing substitution of wheat flour with flaxseed especially sample BR5 containing 40% flaxseed. Flaxseed inclusion significantly reduced the colour acceptability of the bread product which could be attributed to the black spots in the surface of the bread at inclusion of flaxseed flour.

The mean score for the taste of the bread samples ranged from 5.80 to 8.60. The taste of bread containing 40 % flaxseed flour (BR5) was the least accepted while sample (BR6) containing 20% flaxseed flour was the most accepted followed closely with the control sample. There was no significant difference ($p > 0.05$) between sample BR1 and BR2 but their values differed significantly ($p < 0.05$) with other sample while sample BR4 and BR5 was statistically the same. The score recorded shows that the taste of the bread decreased with substitution of flaxseed flour. The addition of flaxseed flour reduced the taste of the bread sample.

The mean scores for the textures of the samples ranged from 5.90 to 8.40 with BR5 having the least score and sample BR2 having the highest score. The results showed that the panelists had high preference for the texture of sample substituted with 20% flaxseed flour more than the control sample. Statistically there were no significant difference ($p < 0.05$) between sample BR1, BR3 and BR3 but their values were significantly different from other sample.

There was no significant difference ($p>0.05$) in the flavour of the bread samples except from sample BR5 which was significantly different from other sample. The value of the flavor ranged from 5.90 in samples BR5 to 8.5 in sample BR1.It was observed that the flavour of the bread sample reduced with increase in substitution of flaxseed flour.

The overall acceptability score showed that the control sample (BR1) was the most preferred with a mean score of 8.30 followed closely by the sample containing 20% flaxseed flour (BR2) with a mean score of 8.25. The result of the sensory evaluation has shown that replacement of wheat flour with up to 30 % flaxseed flour yielded a product whose attributes were more preferred though the control sample was more preferred in all sensory attributes assessed. Hence, production of this bread sample in commercial quantity will help to reduce the burden placed on wheat flour and also conserve huge amount of money spent on wheat importation. The three best samples (BR2, BR3 and BR4) were selected for further analysis of mineral composition.

Table 2 depicts the results of the mineral composition of bread produced from composite flours of wheat and flaxseed. The calcium content of the bread samples ranged from and 2.01 mg/100g to 3.90 mg/100g. Sample BR2 recorded the lowest calcium content while sample BR3 recorded the highest calcium content. The results revealed that significant difference ($p < 0.05$) existed amongst the samples. The calcium content obtained in this study was below the range of 39.30 to 250.00 mg/100g reported by Hussain et al. (2011) for pan bread fortified with flaxseed. El-Soukkary (2012) also reported higher range of calcium 98.30 to 145.30 mg/100g for bread fortified with pumpkin seed. The reason for the variation might be attributed to the difference in processing method and raw material used. Calcium intake in diabetics has been shown to be beneficial and likely to reduce osteoporosis in older diabetics (Ayo et al., 2018). The value obtain in this study shows that the bread is not a good source of calcium and should be consumed together with calcium rich foods.

The potassium content of the bread sample varied significantly ($p < 0.05$) from one another with sample BR4 having the highest value of 46.11 mg/100 and sample BR2 having the lowest value of 4.42 mg/100g. It was observed that the potassium content increased with higher substitution of flaxseed flour in the bread. Similar trend but higher value of 187.30 to 643.43 mg/100g was reported for bread fortified with flaxseed flour in the study of Hussain et al. (2011). The difference in the value may be attributed to the processing method used to process flaxseed into flour.

The manganese content of the bread samples ranged from 0.31 mg/100g to 1.00 mg/100g with sample BR3 having the highest value while BR2 had the lowest value. Significant differences ($p < 0.05$) existed amongst all the samples. El-Soukkary, (2012) reported high manganese content ranging from 0.73 to 2.40

mg/100g for bread fortified with pumpkin seed flour. The varied results could be due to differences in the raw materials used in product formulation. Manganese has been reported to be an activator of many enzyme systems and maintains the electrical potential in the nerves. It has also been reported to assist in muscle contraction, blood clotting and the regulation of blood pressure and lung function (Swaminathan, 2013).

There was significant difference ($p < 0.05$) in the iron content of the bread samples. The iron content ranged from 0.11 to 0.15 mg/100g. The lowest value was recorded for sample BR2 while the highest sample was recorded for sample BR4. The iron contents obtained in this study were lower than 1.90 to 4.10 mg/100g reported for pumpkin seed fortified bread (El-Soukkary 2012). Hussain et al. (2011) also reported higher iron content ranging from 1.23 to 5.60 mg/100g for bread fortified with flaxseed flour. This could be due to different raw materials used in the bread production.

4.0 Conclusion:

This study showed that bread can be produced from blends of wheat flour and flaxseed flour. The bread produced contained significant amount of mineral like potassium and calcium but are low in iron and manganese. The sensory evaluation results revealed that substitution of wheat flour with up to 10 % flaxseed flour yielded a product that was highly accepted even more than the control. This when commercialized will ameliorate the excessive use of wheat and improve the use of our indigenous oilseed crops without significant change in the quality of the product. This will also increase National Gross Profit, income for rural farmers and improve the production of flaxseed.

References

Asumugha, V. U. and Uwalaka, B. C. (2010). Chemical and organoleptic evaluation of snacks developed from cocoyam (Colocasia esculenta, Xanthosoma mafafa) and wheat (Triticum spp) composite flours. Nigerian Agricultural Journal., 31: 78-88.

Brites, L. T., Rebellato, A. P., Meinhart, A. D., Godoy, H. T., Pallone, J. A. L. and Steel, C. J. (2022). Technological, sensory, nutritional and bioactive potential of pan breads produced with refined and whole grain buckwheat flours. Food Chemistry 10(13): 100243.

Chikpah, S. K.; Korese, J. K.; Hensel, O.; Sturm, B. and Pawelzik, E. (2021). Rheological properties of dough and bread quality characteristics as influenced by the proportion of wheat flour substitution with orange-fleshed sweet potato flour and baking conditions. LWT, 147: 111515.

Chishty, S., and Bissu, M. (2016). Health benefits and nutritional value of flaxseed-a review. Indian J Appl Res, 6(1), 243-245.

El-Soukkary, F. (2012). Evaluation of pumpkin seed products for bread fortification. Journal of Food and Dairy Sciences, 25(11), 7021-7038.

Hussain, S., Anjum, F. M., & Alamri, M. S. (2011). Fortification of pan bread with healthy flaxseed.

Iwe, M. O., Onyeukwu, U., and Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea eeds composite flour. Cogent Food

Kaure, P., Sharma, P., Kumar, V., Panghal, A., Kaur, J., & Gat, Y. (2019). Effect of addition of flaxseed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies. Journal of the Saudi Society of Agricultural Sciences, 18(4), 372-377.

Malavi, D.; Mbogo, D.; Moyo,M.;Mwaura, L.; Low, J. and Muzhingi, T. (2022). Effect of Orange-Fleshed Sweet Potato Purée and Wheat Flour Blends on Beta-Carotene, Selected Physicochemical and Microbiological Properties of Bread. Foods, 11(1051): 1-18.

Man, S. M., Stan, L., Păucean, A., Chiș, M. S., Mureşan, V., Socaci, S. A. and Muste, S. (2021).Nutritional, sensory, texture properties and volatile compounds profile of biscuits with roasted flaxseed flour partially substituting for wheat flour. Applied Sciences, 11(11): 1-16, (2021)

Masood, S., Attiq, R., Shahid, B., Muhammad, I., Palwasha, K., Tara, K., Faiza, I., Hafiza, M., Sana, F., Bahisht, R. and Nida, J. (2020). Proximate and Sensory Analysis of Wheat Bread Supplemented with Onion Powder and Onion Peel Extract. Bioscience Research, 17(4): 71-78.

Mbogo, D.; Muzhingi, T. and Janaswamy, S. (2021). Starch digestibility and _-carotene bioaccessibility in the orange-fleshed sweet potato puree-wheat bread. J. Food Sci. 2021, 86, 901–906.

Morris, D. H. (2007). Flax: A health and nutrition primer. Flax Council of Canada.

Mudau, M., Ramashia, S. E., Mashau, M. E., and Silungwe, H. (2021). Physicochemical characteristics of bread partially substituted with finger millet (Eleusine corocana) flour. Brazilian Journal of Food Technology, 24: e2020123.

Orhevaba, B. A. and Ndanaimi, Y. (2021). Proximate and Sensory Properties of Wheat-Cocoyam (Colocasia Esculenta) Composite Bread. European Journal of Agriculture and Food Sciences 3(3): 86-90.

Rózyto, R. and Laskowski, J. (2011). Predicting bread quality (bread volume and crumb texture). Polish Journal of Food and Nutrition Sciences, 61(1), 61-67.

Senya, E. K., Kwaatemaa, F. and Sitsofe, K. R. (2021). Production and Acceptability of Tit-Bits Made From Wheat and Tiger Nut Flour Blends. International Journal of Academic and Applied Research, 5(1): 142-147.

Steel, G. D. and Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach 2nd Edition. McGraw-Hill Book Company Inc. New York.

Swaminathan, R. (2013). Magnesium metabolism and its disorders. Clin Biochem Rev.; 24(2): 47–66.

Thakaeng, P.; Boonloom, T. and Rawdkuen, S. (2021). Physicochemical Properties of Bread Partially Substituted with Unripe Green Banana (Cavendish spp.) Flour. Molecules

Effects Of Fermentation on the Proximate Composition of Chin-Chin Produced from Brown Rice, Wheat and Kidney Beans Flour

Obarisagbon, I. and *Okechukwu, N.G

Department of Food Science and Technology, Federal Polytechnic Oko.

Correspondence: gracebasilica2015@gmail.com

ABSTRACT

The aim of this study was to assess the effects of fermentation on the proximate composition of chin-chin from brown rice, wheat and kidney beans flours. The raw materials (brown rice, wheat and kidney beans flours) were purchased, sorted, washed, steeping, dehulled, drained, oven-dried, milled, sieved, processed into chin-chin and packaged for further analysis. proximate analysis was carried out on the best three samples using standard methods and sensory evaluation was conducted on five samples using semi-trained panelists. The proximate composition showed that CS1, CS3, CS4 scored 6.43%, 2.01% and 4.47% moisture; 15.95%, 18.49% and 13.75% Ash; 8.15%, 9.85% and 5.74% Fibre; 4.39%, 6.38% and 2.00% Protein; 36.49%, 22.96%, 25.01% Fat; 26.60%, 40.32% and 49.04% Carbohydrate respectively. The result for sensory showed that CS1, CS2, CS3, CS4 and CS5 contained 8.70, 5.70, 6.20, 6.90, 6.60 colour; 8.50, 6.80, 6.90, 6.60, 7.10 taste; 8.30, 6.40, 6.30, 6.60, 7.10 flavour, 8.30, 6.00, 6.50, 6.70, 6.70, 6.60 texture; 8.38, 6.58, 6.48, 6.73, 6.85 overall acceptability respectively.

Key words: Chin-chin, Brown rice. Kidney beans, composite flour, proximate.

1.0 Introduction

Snacks have become a major portion of human nutrition in most countries around the world due to its increasing consumption pattern (Abioye *et al.,* 2020). This is because consumers have increasingly and recently been demanding for healthy foods that can provide quick and affordable sources of nutrients. The food industry in a bid to respond to this has resorted to the development and production of "convenient products". This demand has initiated the need to produce foods like snacks (that provide both convenience and nutrition). Most snacks are prepared basically from cereal flours which are nutritionally inadequate. There is the need to complement the nutrient content of these snacks by varying the food sources. Chin-chin (one of these snacks) is a fried snack popular in West Africa. It is a sweet, hard, doughnut-like baked or fried dough of wheat flour and other customary baking items. It is deep-fried until golden brown and crispy (Abu-Salam and Abou-Arab, 2011; Adebayo-Oyetoro *et al.,* 2017; Adegunwa *et al.,* 2014). This golden-brown crunchy food product is eaten amongst several age brackets. It is available in various shapes and sizes and is also widely accepted and promoted for commercial production and marketing by entrepreneurs (Adelekan *et al.,* 2019).

Chin-chin, just like biscuits and cookies, has proven to be an excellent vehicle for providing and/or improving the nutritional quality of foods by the incorporation of less expensive high-quality proteins, vitamins, minerals, dietary fiber, functional ingredients, etc. This had been done by incorporating nutrient sources of protein, fiber, micronutrients and so on (Adeleke *et al.,* 2021). The gap between the protein requirement and supply can be abridged by amino acid fortification, use of protein mixture (protein supplementation and complementation), genetic modification of food crops and identification and evaluation of underexploited sources (Adenike, 2013). The food processing industry can better bridge this gap by supplementation and/or complementation.

Wheat (*Triticum* spp.) is one of the major grains in the diet of a vast proportion of the world's population. It falls among the 'big three' cereal crops (including rice and maize), with over 600 million tons being harvested annually. It is the most important staple food of about 2billion people (36% of world population). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Akhtar *et al.,* 2008). Most snacks are prepared basically from cereal flours which are nutritionally inadequate. There is the need to complement the nutrient content of these snacks by varying the food sources (Akindele *et al.,* 2017). Brown rice is whole grain rice with intact bran layer and the inedible outer hull removed. It is the unmilled rice containing the pericarp, the seed coat and nucellus, the germ or embryo, and the endosperm (Ajimilah and Rosniyana, 1995). The dark colour of brown rice is due to the bran layer and is rich in vitamins like thiamine, niacin, pyridoxine, and minerals like manganese, phosphorus, and iron. Although brown rice contains several vitamins and minerals, it is only consumed by a limited number of health conscious and nutritionally aware people (Roy *et al*., 2008), probably due to its longer cooking time, instability during storage, strong bran flavour, and undesirable texture.

Kidney beans are an excellent source of minerals such as Calcium, Magnesium, copper, iron, manganese, phosphorus, potassium, molybdenum, Vitamin E and Vitamin K_1 and folate, and possessing a low glycemic index (GI). Polyphenol-rich kidney beans have potential effects on human health, and possess anti-oxidant, anti-diabetic, antiobesity, anti-inflammatory and anti-mutagenic and anti-carcinogenic properties Pradeepkumar *et al*., 2014, 2015; Ganesan and Xu, 2017; Celmeli *et al*., 2018; Salma *et al*., 2018; García-Cordero *et al*., 2021; Rodríguez-Madrera *et al*., 2021).

Chin-chin is a traditional Nigerian snack prepared using wheat flour, butter, milk and eggs from which a stiff paste is made. It is deep-fried until golden brown and crispy. It is quite popular across Nigeria and in most of Western Africa countries. Chin-chin is sweet to taste, slightly hard and can be compared to a harder version of a doughnut and sometimes prepared by baking instead of frying (Adegunwa *et al*., 2014).

2.0 Materials and Methods

Brown rice grains, kidney beans, all-purpose wheat flour, butter, egg, baking powder, sugar, milk powder, vanilla essence and packaging materials were obtained from *Eke Awka* Market. All the materials were packaged in a clean bag and taken to the Food Processing Laboratory of Department of Food Technology, Federal Polytechnic Oko, Anambra State; for further processing and analysis.

2.1 Sample Preparation: The Rice flour was processed by modifying the method described by Iwe *et al.* (2016). Parboiled rice grains were cleaned, sorted and washed, then steeped and allowed to ferment in water for 48 hours, drained and dried in a hot air laboratory oven at a temperature of 60 ^{o}C for 30 min. It was finely milled using a milling machine and sieved to obtain fine flour which was packaged in an airtight container prior to further use.

2.2 Processing of Kidney Beans Flour: The kidney beans flour sample was cleaned, sorted and washed, then steeped and dehulled and allowed to ferment in water for 48 hours, drained and dried in a hot air laboratory oven at a temperature of 60 ^{o}C for 30 min. It was finely milled using a milling machine and sieved to obtain fine flour which was packaged in an airtight container prior to further use.

2.3 Production of Composite Chin-Chin: Chin-chin was prepared using the method outlined by Akubor (2004) with slight modifications. Hundred grams (100 g) of the composite flour was weighed and sieved (250-micron particle size). All other ingredients (sugar, salt and baking powder) were also added. Margarine, eggs and milk were turned in and mixed to form dough. The dough was kneaded, rolled out (2 cm thick) and cut into small squares (2 cm by 2 cm). It was deep fried (180 ˚C, 8 min) till it turned golden brown, drained, cooled, packaged and stored at room temperature (28±2 ˚C).

2.4 Standard Analytical Methods

Moisture content was determined by drying 5 g of sample at 105 °C for 3 hours using a moisture extractor. Ash content was determined by burning 10 g of sample in a muffle furnace at 550 °C and calculating the weight of ash obtained. Crude fibre was determined by boiling 2 g of sample in 1.25 % H2SO4 solution, washing, drying, and ashing, then calculating the weight of fibre obtained. Fat content was determined by

extracting 10g of sample with N-hexane using a Soxhlet apparatus for 3 hours. Crude protein was determined by digesting 0.5g of sample with H2SO4 and selenium catalyst, then distilling and titrating against EDTA. Carbohydrate content was calculated by difference using the formula: % carbohydrate = 100 - % (moisture + crude protein + ash + crude fibre + crude fat) Sensory Evaluation was Conducted using a semi-trained panel of 10 judges who evaluated the chin-chin samples for taste, colour, texture, aroma, and overall acceptability using a 9-point Hedonic scale, where 9 was equivalent to like extremely and 1 meant dislike extremely. Presentation of coded samples were done randomly and portable water were provided for rinsing of mouth in between the respective evaluations (Iwe *et al.*, 2014)

Statistical Analysis. All measurements were carried out in triplicate. The data generated were analyzed using statistical package for service solution SPSS (version 25.0) and significant difference were compared by Analysis of Variance test (ANOVA) following Duncan's multiple range tests at the significance level of 5%.

3.0 Results and Discussions

Table 1: Proximate Composition of Chin-Chin

SAMPLES	CS1%	CS3%	CS4%
Moisture	$6.43^{a}\pm0.11$	$2.01^{c}\pm0.01$	$4.47^{b}\pm0.0.05$
Protein	$4.39^{a}\pm3.58.$	$6.38^{a}\pm1.88$	$2.00^{a}\pm1.69$
Fibre	$8.15^{b}\pm0.49$	$9.85^{a}\pm0.49$	$5.74^{c}\pm0.08$
Fat	$36.49^{a}\pm0.01$	$22.96^{c}\pm0.06$	$25.01^{b}\pm0.01$
Ash	$15.95^{b}\pm0.08$	$18.49^{a}\pm0.01$	$13.75^{c}\pm0.35$
Carbohydrate	$28.60^{b}\pm4.27$	$40.32^{a}\pm2.47$	$49.04^{a}\pm2.19$

Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($p<0.05$). **Keys:**

CS1-Wheat 100% **CS3**-Wheat 80%; Brown Rice 10%; Red Kidney Beans 10% **CS4**-Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%

Table 2: Sensory Composition of Chin-Chin

SAMPLES	COLOUR	TASTE	FLAVOUR	TEXTURE	ACCEPTABILITY
CS1	$8.70^{a}\pm0.67$	$8.50^{a}\pm0.53$	$8.30^{a}\pm0.48$	$8.30^{a}\pm0.82$	$8.38^{a}\pm0.58$
CS2	$5.70^{c}\pm1.57$	$6.80^{b}\pm1.99$	$6.40^{b}\pm1.90$	$6.00^{b}\pm1.05$	$6.58^{b}\pm1.66$
CS3	$6.20^{bc}\pm1.03$	$6.90^{b}\pm1.10$	$6.30^{b}\pm1.16$	$6.50^{b}\pm0.97$	6.48 ± 0.63
CS4	$6.90^{b}\pm0.88$	$6.60^{b}\pm0.97$	$6.60^{b}\pm1.07$	$6.70^{b}\pm1.16$	$6.73^{b}\pm0.75$
CS5	$6.60^{bc}\pm1.26$	$7.10^{b}\pm1.10$	$7.10^{b}\pm0.88$	$6.60^{b}\pm0.97$	$6.85^{b}\pm0.77$

Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different (p>0.05)

Keys: CS1-Wheat 100%, **CS2**-Wheat 90%: Brown Rice 5%: Red Kidney Beans 5%. **CS3**-Wheat 80%: Brown Rice 10%: Red Kidney Beans 10%. **CS4**-Wheat 70%: Brown Rice 15%: Red Kidney Beans 15%. **CS5**-Wheat 60%: Brown Rice 20%: Red Kidney Beans 20%.

3.0 Discussion.

3.1 Proximate Composition of Chin-Chin Produced from Blends of Wheat, Brown Rice and Red Kidney Beans

The results of the proximate composition of chin-chin provided from blends of wheat brown rice and kidney beans is shown in Table1, the moisture content ranged from 2.01% to 6.43%, protein content ranged from 2.00 to 6.38%, fibre content ranged from 5.74% to 9.85%, fat content ranged from 22.96% to 36.49%, ash content ranged from 13.75% to 18.49% and carbohydrate content ranged from 28.60% to 49.04%

The moisture content of the samples produced ranged from 2.01 to 6.43% showing significant difference (p>0.05). The sample with the highest value of 6.43% is CS1 (Wheat 100%) compared to the formulated samples are 4.47% for CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) while the least value is 2.01% for CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%). The value falls below the 14% standard recommended for shelf stable storage of flour products (Ukpabi and Ndimele, 1990; Adeleke and Odedeji, 2010). Moisture content indicates the shelf-stability of a product; such that, the lower the moisture content, the better the shelf stability of such products (Oluwamukomi *et al.,* 2021). The result of this study is slightly above the report of (Omoba *et al.,*2015) (4.35–5.34%) who produced a maize-wheat chin-chin enriched with (3.98-5.05%) who produced chin-chin from a millet-wheat composite flour. The trend in results also agree with other studies of (Pelto and Armar-Klemesu, 2011).

The values for the protein content ranged from 2.00 to 6.38% showing no significant difference (p>0.05). The statistical analysis showed that the sample are the same. The sample with the highest value showed that the formulated sample CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) is 6.38% compared to 4.39% for CS1 (Wheat 100%) while the least value was recorded for CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) which is 2.00%. The increases in crude protein could be due to enzyme hydrolysis of the insoluble protein to soluble protein, which increased the protein availability. It could also be attributed to the fact that some amino acids are produced in excess amount of the requirement during protein synthesis and these tend to accumulate in free amino acid pool (Echendu *et al*., 2009). Other researchers have also attributed the increase to the degradation of storage protein and synthesis of new protein and other materials (Khademi, 1990; Ali and Elozeiri, 2017). These results agree with those by (Popova and Mihaylova, 2019) who produced chin-chin from millet and wheat. Ram *et* (2020) reported protein content of 11.1 to 14.9%, while reported protein content of 10.51-14.58%. This shows that the chin-chin herein produced are very rich in protein. The protein content in this study was also slightly lower than those reported by (Ramakrishna *et al.,* 2006) for wheat-soursop flour chin-chin of 5.32-7.94%.

The result for fibre content ranged from 5.74 to 8.15% showing significant difference (p>0.05) among the studied samples. The CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) had the highest value of 9.85% compared to 8.15% for CS1 (Wheat 100%) while the least value was recorded for CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) which is 5.74%. The result showed that there was increase in the crude fibre with the formulated samples compared to CS1 (Wheat 100%). This increase in crude fibre might be due to starch breakdown during procesing. Similar report was recorded by Nkhata *et al.* (2018). Though crude fibre does not contribute nutrients to the body, it adds bulk to food thus facilitating bowel movements (peristalsis) and preventing many gastrointestinal diseases in man (Grundy *et al*., 2016). The significant decrease in the fiber content of the samples slightly disagreed with the report of 11.02% by (USDA, 2019).

The result for fat ranged from 22.96 to 36.49% showing significant difference ($p>0.05$). The sample CS1 (Wheat 100%) had the highest value of 36.49% when compared to sample CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) with value of 25.01% while the least value is 22.96% and it was recorded for CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%). The increase in the fat content could be due to the substitution effect as a result of some residual fat content in the formulated samples. The results in this study are higher than those reported by (Rami *et al.,* 2020; Romelle *et al.,* 2016; Senthil *et al.,* 2002; Settaluri *et al.,* 2012) reported lower fat content values (11.67-17.34%) and (9.93-15.82%) for maize-wheat chin-chin and vegetable enriched chin-chin respectively. The high fat content of the chin-chin samples was expected as was shown by the significant increase in the wheat the flours compared to the formulated samples. This high fat content could arise to absorption of oil by the samples during frying as well as the difference in the recipes.

The ash content ranged from 13.75 to 18.49% showing significant difference ($p>0.05$) among the produced samples. The sample with the highest value of ash is sample CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) with value of 18.49% compared to 15.95% recorded for CS1 (Wheat 100%) while the least sample is 13.75 recorded for CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%). The increase in ash content is an indication of increase in mineral content of the food formulations. This is a welcome development, as consumers will have the opportunity of a balance in their diet due to the increased levels of minerals from the ash (Balogun *et al.,* 2012). The ash content in this study was higher than those reported by several studies on the production of chin-chin (Singh and Arivuchudar, 2019; Spence, 2015; Surkan *et al.,* 2009; Ugwuanyi *et al.,* 2020). However, the trend in results is comparable to those reported by in wheat-germinated finger millet-based chin-chin. The ash content of a product indicates a rough estimate of its mineral content (UNIDO Technology Manual, 2004.). This study therefore indicates that the chin-chin samples would contribute enormous mineral elements to the body.

The carbohydrate content ranged from 28.60% to 49.04% showing significant difference ($p>0.05$). The CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) recorded the highest value of 49.04% compared to 40.32% recorded for CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) while the least sample with 28.60% as value was recorded for sample CS1 (Wheat 100%).

Sensory Composition of Chin-Chin Produced from Blends of Wheat, Brown Rice and Red Kidney Beans

Sensory quality is considered a key factor in food acceptance because consumers look out for food with specific sensory characteristics (Bello *et al.,* 2018). The result for colour ranges from 5.70 to 8.70 showing significant difference ($p>0.05$)

among the studied samples. The sample CS1(Wheat100%) had the highest score of 8.70 compared to other samples while sample CS2 (Wheat 90%; Brown Rice 5%; Red Kidney Beans 5%) had the least score 5.70. The result of the colour of almost all the products is encouraging as colour is an important parameter to consumers as initial quality of products can be assessed through their colour. Colour equally serves as a cue for the doneness of foods and is correlated with changes in aroma and flavour (Lawless and Heymannm, 2010). The acceptability of the colour of almost all the products is encouraging as colour is an important parameter to consumers as initial quality of products can be assessed through their colour.

The taste scores ranged from 6.60 to 8.50 showing significant difference ($p>0.05$)

among the formulated samples. The sample with the highest score 8.50 is CS1(Wheat100%) while CS4 (Wheat 70%; Brown Rice 15%; Red Kidney Beans 15%) is the sample with the least score of 6.60 when compared to other samples. The flavour scores ranged from 6.30 to 8.30 showing significant difference ($p>0.05$). The sample CS1 (Wheat100%) had the highest score of 8.30 compared to other formulated samples while CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) had the least score of 6.30. Flavour is a fundamental sensory attribute which refers to the sensations in the nostrils as a result of rising of food or drink volatile compounds (Okache *et al.,* 2020). It is the flavour of a food that majorly determines whether it will be accepted or rejected, despite the fact that its appearance elicits the initial response (Orhevba and Ndanaimi, 2021).

The texture result ranged from 6.00 to 8.38 showing significant difference ($p>0.05$) among the formulated samples. The sample CS1 (Wheat 100%) had the highest score of 8.30 compared to the formulated samples which looks the same while the least score was recorded for sample CS2 (Wheat 90%; Brown Rice 5%; Red Kidney Beans 5%) with a score of 6.00. The texture of food has a lot to do with the visual, audio, and tactile stimuli which influences the consumers' liking and preference of a food product (Chen and Rosental, 2015).

The acceptability scores ranged from 6.48 to 8.38 showing significant difference ($p>0.05$) among the studied samples. The CS1 (Wheat 100%) had the highest score of 8.38 compared to other samples while CS3 (Wheat 80%; Brown Rice 10%; Red Kidney Beans 10%) had the least score of 6.48. The sensory evaluation revealed that chin-chin made from 100% wheat flour had better acceptability. This could be due to the fact that people are more familiar with it than chin-chin from other composite samples. The chin-chin produced from composite flours were rated closely in almost all the quality attributes evaluated. This result suggests that there are potentials for composite flours (wheat, brown rice and red kidney beans flour) in the snack industry. The overall acceptability shows how much or less a product is globally accepted. Acceptability may not always depend solely on the sensory attributes of the product but also on other determinants such as physiological, behavioral and cognitive factors, related to the consumer.

4.0 Conclusion.

The study showed that chin-chin could be formulated from blends of wheat, brown rice and red kidney beans which are presently underutilized. The results showed that the formulated sample had appreciable levels of moisture, protein, fibre and high amount of fat, ash carbohydrates. The colour, taste, flavour, texture and overall acceptability of the chin-chin samples were not completely affected by the formulations as their significant difference ($p<0.05$) that existed amongst the samples in these attributes. The moderate nutrient density of the samples makes the samples potential raw materials for production of chin-chin so as to enhance dietary diversification. It is recommended that further studies be carried out on the chin-chin to determine their health benefits and storage stability. Also, the production of chin-chin from the blends used in the study should be encouraged as this would help to reduce importation of foreign ones to a reasonable extent and also promote diversification of their utilization.

References.

Abioye VF, Olodude OA and Atiba V., (2020). Quality evaluation of produced from composite flours of wheat and germinated finger millet flour. Agrosearch.;20(1):13–22.

Abu-Salem FM and Abou-Arab AA. (2011). Effect of supplementation of Bambara groundnut (Vigna subterranean L) flour on the quality of biscuits. African Journal of Food Science.;5(7):376–383.

Adebayo-Oyetoro, A.O, Ogundipe, O and Lofinmakin, F.K,.(2017). Production and acceptability of chinchin snack made from wheat and tigernut (Cyperus esculentus) flour. Cogent Food and Agriculture. 2017;3(1):1–

Adegunwa, M, Ganiyu A, Bakare H.,(2014). Quality evaluation of composite millet-wheat chinchin. Agriculture and Biology Journal of America. 5(1):33–39.

Adelekan, EO, Adegunwa MO, Adebowale AA, et al. (2019). Quality evaluation of snack produced from black pepper (Piper nigrum L.), plantain (Musa paradisiaca L.), and tigernut (Cyperus esculentus L.) flour blends. Cogent Food and Agriculture.;5(1):1–14.

Adeleke, SA, Taiwo KA, Gbadamosi SO. (2021). Studies on the chemical composition and storage properties of chinchin enriched with polyphenol extracted from amaranthus viridis l. Food Science and Nutrition Technology. 6(1):1–17.

Adenike, O.M. (2013). Studies on the Nutritional quality anti-nutritional factors amino acid profile and functional properties of co-fermented wheat / cowpea. Elixir Food Science.;54(1):12360–12364.

Ajimilah, N.H. and Rosniyana, A. (1995). Brown rice consumption in Malaysia: A new trend? Proceeding of 5th

Akindele O, Gbadamosi O, Taiwo K, (2017). Proximate, mineral, sensory evaluations and shelf stability of chinchin enriched with ugu and indian spinach vegetables. International Journal of Biochemistry Research & Review.;18(4):1–14.

Akubor, P.I. (2004). Protein contents, physical and sensory properties of Nigerian snack foods (cake, chin-chin and puff-puff) prepared from cowpea-wheat flour blends. International Journal of Food Science and Technology, 39 (4), 419-424.

Ali, A.S., and Elozeiri, A.A. (2017). Metabolic processes during seed germination In: J.C. Jimenez-Lopez (Ed.) Advances in Seed Biology.

Balogun, M.A., Karim, O.R., Kolawole, F.L. and Solarin, A.O. (2012). Quality attributes of tapioca meal fortified with fortified with defatted soyflour. *Agrosearch,* 12(1), 61-67.

Celmeli, T., Sari H., Canci H, Sari D, Adak A, Eker T, (2018).The nutritional content of common Bean (Phaseolus vulgaris L.) landraces in comparison to modern varieties. Agronomy 8:166. doi: 10.3390 / agronomy 8090166.

Chen, J and Rosental, A (2015). Food texture and structure. Volume 1: Novel Ingredients and Processing Techniques Woodhead Publishing Series in Food Science, Technology and Nutrition, Pages 3-24

Echendu, C.A., Obizoba, I.C and Anyika, J.U (2009). Effects of germination on chemical composition of groundbean (*Kerstingiella geocarpa harm*) Seeds. *Pakistan Journal of Nutrition,* 8, 1849-1854.

Ganesan K, Xu B. (2017). Polyphenol-rich dry common beans (Phaseolus vulgaris L.) and their health benefits. International Journal of Molecular Sciences;18(11):2331. doi: 10.3390/ijms18112331

García-Cordero JM, Martínez-Palma NY, MadrigalBujaidar E, Jiménez-Martínez C, Madrigal-Santillán E, Morales-

Iwe, M. O., Onyeukwu, U., and Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea eeds composite flour. Cogent Food

Khademi, M. (1990). Storage protein degradation and proteolytic enzyme activities during germination of water stressed impatiens seeds. Retrospective Theses and Dissertations. Available online at https://lib.dr.iastate.edu/rtd/9378. Accessed January 25, 2025

Lawless, H.T and Heymann, H (2010). Sensory Evaluation of Food. Food Science Text Series, DOI 10.1007/978-1-4419-6488-5_12, © Springer Science+Business Media, LLC 201/j.foodchem.2007.08.038.

Nkhata., S.G., Ayua, E., Kamau E.H. and Shingiro, J. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. Food Science and Nutrition, 6(2), 2446–2458.

Okache, T. A., Agomuo, J. K and Kaida, I. Z. (2020). Production and Evaluation of Breakfast Cereal Produced from Finger Millet, Wheat, Soybean, and Peanut Flour Blend. Research Journal of Food Science and Quality Control 6(2): 9-19.

Oluwamukomi MO, Awolu OO, Olapade KT. Nutritional composition, antioxidant and sensory properties of a maize-based snack (kokoro) enriched with defatted sesame and moringa seed flour. Asian Food Science Journal. 2021;20(10):100–113.

Omoba OS, Obafaye RO, Salawu SO, et al. HPLC-DAD phenolic characterization and antioxidant activities of ripe and unripe sweet orange peels. Antioxidants. 2015;4(3):498–512.

Orhevba, B. A. and Ndanaimi, Y. (2021). Proximate and Sensory Properties of Wheat-Cocoyam (Colocasia Esculenta) Composite Bread. European Journal of Agriculture and Food Sciences, 13(3): 86-90.

Pelto GH, Armar-Klemesu M. (2011). Balancing nurturance cost and time: complementary feeding in Accra, Ghana. Maternal and Child Nutrition, *Suppl* 3:66–81.

Popova A, Mihaylova D. Antinutrients in plant-based foods: a review. The Open Biotechnology Journal. 2019;13(1):68–76.

Pradeepkumar MR, Joshi SD, Kulkarni VH, Savant C. (2014). Phytochemical screening and evaluation of analgesic an anti-inflammatory activity of Phaseolus vulgaris Linn., seeds in rodents. Journal of Applied PharmaceuticalScience

Ram S, Narwal S, Gupta OP, et al. Anti-nutritional factors and bioavailability: approaches, challenges, and opportunities. Wheat and Barley Grain Biofortification. 2020.p.101–128.

Ramakrishna V, Jhansi Rani P, Ramakrishna Rao P. Anti - nutritional factors during germination in indian bean (Dolichos lablab L .) seeds. World Journal of Dairy & Food Sciences. 2006;1(1):6–11.

Rodríguez Madrera R, Negrillo AC, Valles BS, Ferreira Fernández JJ. (2021). Phenolic content and antioxidant activity in seeds of common bean (Phaseolus vulgaris L.). Foods;10(4):864. doi: 10.3390/foods10040864

Romelle FD, Ashwini RP, Manohar RS. Chemical composition of some selected fruit peels. European Journal of Food Science and Technology. 2016;4(4):12–21.

Roy, P., Ijiri, T., Okadome, H., Nei, D., Orikasa, T., Nakamura, N., & Shiina, T. (2008). Effect of processing conditions on overall energy consumption and quality of rice (Oryza sativa L.). Journal of Food Engineering, 89(3), 343– 348.

Salma, Baig SG, Hasan MM, Ahmed S, Fatima SA. (2018). Analgesic and anti-inflammatory effects of Phaseolus vulgaris L. fixed oil in rodents. Journal of Basic and Applied Sciences;14:174-179.

Senthil A, Ravi R, Bhat KK, et al. Studies on the quality of fried snacks based on blends of wheat flour and soya flour. Food Quality and Preference. 2002;13(5):267–273.

Settaluri VS, Kandala CVK, Puppala N, et al. Peanuts and their nutritional aspects—a review. Food and Nutrition Sciences. 2012;3(12):1644– 1650.

Singh R, Arivuchudar R. Formulation and evaluation of peanut flour incorporated cookies. International Journal of Food Science and Nutrition 2018;3(5):56–59.

Spence C. Eating with our ears: assessing the importance of the sounds of consumption on our perception and enjoyment of multisensory flavour experiences. Flavour. 2015;4(1):1–14.

Surkan S, Albani O, Ramallo L. Influence of storage conditions on sensory shelf life of yerba mate. Journal of Food Quality. 2009;32(1):58– 72.

Ugwuanyi RG, Eze JI, Okoye EC. Effect of soybean, sorghum and african breadfruit flours on the proximate composition and sensory properties of chin-chin. properties of chin-chin. European Journal Of Nutrition & Food Safety. 2020;12(1):85–98.

Ukpabi, U.J and Ndimele, C. (1990). Evaluation of garri production in Imo State Nigeria. Nigerian Food Journal, 8, 105-110.

Structural Insights into Novel Metal-Peptide Complexes Via DFT-Based Geometrical Optimization and Experimental X-Ray Diffraction

Igbokwe, C. J[ab], Nwadi,, O.M.M.[b], Duan, Y.[a], Zhang, H.[a]

[a] School of Food and Biological Engineering, Jiangsu University, Zhenjiang, China

[b] Department of Food Science and Technology, Faculty of Agriculture, University of Nigeria Nsukka, Nigeria

*Corresponding author: chidinma.igbokwe@unn.edu.ng

ABSTRACT

This study investigates the structural properties of metal–peptide complexes (MPCs) formed between the antioxidant tetrapeptide FFDR (Phe–Phe–Asp–Arg), identified from coix seed, and Ca^{2+}, Mg^{2+}, and Cu^{2+} ions. Density Functional Theory (DFT) using the ωB97XD/def2svp level was employed to optimize complex geometries and calculate molecular descriptors. DFT optimization revealed that calcium peptide complex exhibited the longest bond lengths of 2.095 Å among the MPCs. X-ray diffraction (XRD) analysis of synthesized MPCs confirmed high structural similarity, with peak matching accuracy exceeding 90% across key 2θ ranges. These findings demonstrate the synergy of DFT and XRD for accurate MPC characterization and support their application in designing metal-coordinated antioxidant peptides for functional food development.

Keywords Metal-peptide complexes, Quantum chemical calculations, X-ray diffraction

1.0 Introduction

Metal ions can significantly modulate the structural configuration of peptides and proteins by binding to specific coordination sites, often inducing conformational rearrangements, and altering secondary structure motifs. These interactions commonly involve peptide backbone and polar side chains, leading to changes in folding dynamics bonding patterns and overall geometric stability (Leone et al., 2024). For instance, calcium and magnesium ions typically coordinate with carbonyl oxygen atoms in peptide loops and turns, disrupting local hydrogen bonds and reshaping amide planarity, which affects the mechanical and biochemical stability of peptides. (Pal and Roy, 2022).

Understanding these perturbations is critical for the rational design of bioactive compounds. In this context, DFT has emerged as a powerful tool for predicting the energetically favourable geometries and electronic configuration of MPCs. DFT enables the computation of key molecular descriptors-including bond lengths, bond angles, charge distributions etc, thereby allowing detailed insight into structure-function relationships (Orio et al., 2009). However, theoretical findings require experimental corroboration. X-ray diffraction (XRD), particularly powder XRD (PXRD), remains one the most robust techniques for validating molecular models by providing high resolution information on crystal packing, interatomic distances and symmetry. The agreement between DFT optimized geometry and empirical XRD data is widely regarded as a reliable benchmark for model accuracy (Orio et al., 2009).

This study investigates the structural features of MPCs formed between the antioxidant tetrapeptide FFDR (Phe–Phe–Asp–Arg), reported in previous study (Igbokwe et al., 2024) and divalent metal ions Ca^{2+}, Mg^{2+}, and Cu^{2+}. DFT geometry optimization was used to determine the lowest-energy conformations and electronic properties of the complexes, while XRD analysis served to validate the predicted structural models. This integrated approach aims to elucidate coordination behavior and electronic stability of MPCs, with implications for their functional performance in therapeutics and nutraceutical development.

2.0 Materials and Methods

2.1 DFT protocol

Computational calculations were carried out using density functional theory (DFT). Gaussian 16 collection of programs were used for the optimization of the chemical structures. The molecular structures under investigation were initially sketched using GaussView 6.0.16 and optimized using the ωB97XD/def2svp method to be able to account for minute interactions within the molecules. To make available graphical depictions of both geometric and molecular orbital optimized structure, Chemcraft 3.0 was utilized.

2.2 X-ray diffraction analysis (XRD)

Peptide FFDR was synthesized and used to prepare MPCs following the method outlined by Ke et al. (2022). Peptides were complexed with Cu^{2+}, Mg^{2+}, Ca^{2+} in a ratio of 2:1. XRD patterns of free peptide and its complexes were obtained using a Bruker D8 Avance diffractometer (Germany) equipped with Cu Kα radiation (λ = 1.540598 Å). The instrument operated at 40 kV and 40 mA, with data collected over a 2θ range of 4^0 - 80^0 at a scanning rate of 0.5-1^0/min**.**

3.0 Results and Discussion

3.1 Geometry optimization of MPCs (Ca-FFDR, Mg-FFDR, Cu-FFDR)

Geometry optimization is a critical step in DFT calculations, as it enables the prediction and comprehension of a variety of molecular properties, including bond dissociation energies, charge distributions, and electronic structures, which are essential components of dependable quantum chemical calculations (Bühl and Kabrede, 2006). In an effort to strike a balance between computational efficiency and accuracy, the ωB97XD functional and the def2-SVP basis set were implemented. The bond length values of key atoms within the MPCs are presented in Fig 1(A), and the geometric structures of Ca-FFDR, Cu-FFDR, and Mg-FFDR are illustrated in Figure 1(B). The bond length between the atoms was used to analyze the structural properties of the ligands (MPCs - Ca-FFDR, Mg-FFDR, Cu-FFDR). From the table, seven bond lengths for the three ligands were observed where M = Ca, Cu and Mg. The bond lengths include: metal- oxygen (M-O), metal-hydrogen (M-H), carbon-carbon (C-C), carbon-oxygen (C-O), nitrogen-hydrogen (N-H), carbon-hydrogen (C-H) and oxygen-hydrogen (O-H). The molecular stability of the complex is typically improved by shorter bond lengths, which are indicative of stronger metal-ligand interactions Conversely, longer bond lengths may indicate weaker interactions, which could potentially impact the complex's biological activity and reactivity. The bond lengths presented in Fig A indicate variations in M-O bond lengths, with Ca-FFDR (2.095 Å) exhibiting the longest bond in comparison to Cu-FFDR (1.902 Å) and Mg-FFDR (1.873 Å). This variation may be due to the distinct coordination inclinations and ionic radii of Ca^{2+}, Cu^{2+}, and Mg^{2+} ions with respect to the peptide ligand. The shorter M-O bonds in Cu-FFDR and Mg-FFDR suggest stronger metal-oxygen interactions compared to Ca-FFDR and potentially contribute to their complex stability. Calcium-amino acid complexes were reported to display shorter bond length indicating stronger bonds with oxygen atom (Tang and Skibsted, 2016). The presence of M-H bonds in Ca-FFDR (2.110 Å) indicates additional coordination complexity in comparison to Cu-FFDR and Mg-FFDR, which do not exhibit such bonds. In general, the stability and reactivity of complexes may be affected by variations in bond lengths that result from differences in metal ion size, charge, and coordination preferences.

A

Ligands	Bond length (Å)						
	M-O	M-H	C-C	C-O	N-H	C-H	O-H
Ca-FFDR	2.095	2.110	1.569	1.270	1.040	1.090	1.535
Cu-FFDR	1.902	--	1.393	1.275	1.042	1.088	1.427
Mg-FDDR	1.873	--	1.393	1.248	1.037	1.090	1.500

B

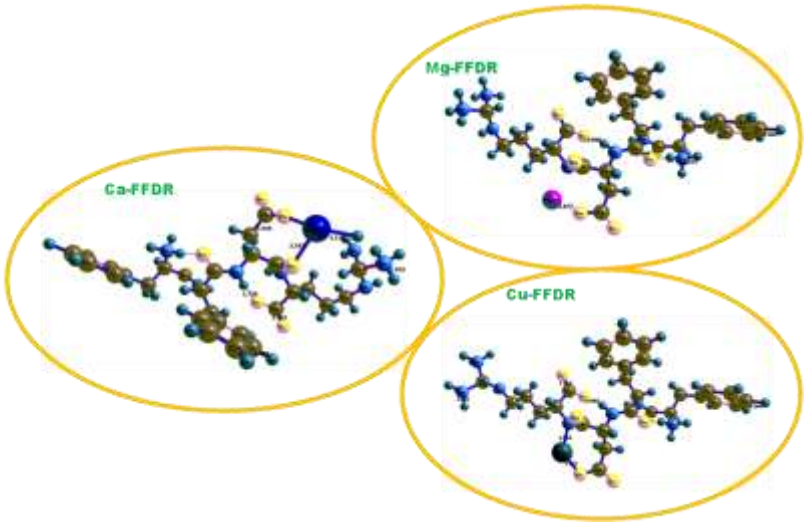


Fig 1 (A) Bond length (Å) of Ca-FFDR, Cu-FFDR and Mg-FFDR complexes calculated at ωB97XD/def2svp theory level. **(B)** Geometric structures of Ca-FFDR, Cu-FFDR and Mg-FFDR complexes optimized at ωB97XD/def2svp level of theory. The yellow ball represents the O atom, the navy green ball represents the C atom, light green represents the H atom, the blue ball represents the Ca atom, the magenta ball represents Mg atom, the dark green ball represents Cu atom.

3.2 XRD pattern of MPCs

The crystal structures of the metal-peptide complexes (MPCs) were analyzed using XRD, and the resulting patterns are presented in Fig. 2. The interaction between peptides and metal ions can induce structural rearrangements, leading to changes in XRD patterns, such as the appearance of new peaks, shifts in peak positions, or the disappearance of existing peaks (Wang *et al.*, 2018). The XRD pattern of the free peptide (FFDR) displayed a broad peak at $2\theta = 20^0$, indicating an amorphous structure. However, upon complexation with metal ions, distinct diffraction peaks emerged, suggesting increased crystallinity. The Cu-FFDR complex exhibited sharp reflections at $2\theta = 18°$, 23°, and 35°, indicating a highly ordered structure. Similarly, the Ca-FFDR complex showed moderate crystallinity with peaks at $2\theta = 21°$, 35°, and 54°, while Mg-FFDR retained broad features with distinct reflections at $2\theta = 16°$ and 20°, suggesting a partially ordered structure. These observations align with previous reports where metal complexation led to enhanced molecular organization and increased crystallinity (Wang *et al.*, 2018).

The observed differences in crystallinity correlate with the DFT-optimized geometries of the complexes, where variations in coordination structure and molecular packing influence the XRD patterns. The Cu-FFDR complex exhibited shorter Cu–O bond lengths (1.902 Å), suggesting stronger metal-ligand coordination, which may promote tighter molecular packing and higher crystallinity, as evidenced by sharp XRD peaks. In contrast, Ca-FFDR exhibited longer Ca–O bond lengths (2.095 Å), which suggest a more extended coordination geometry. This may contribute to differences in molecular packing, as reflected in the increased intensity of XRD peaks. Boshaala *et al.* (2021) reported that DFT-calculated bond lengths of copper (II) complex showed strong agreement with XRD data, whereas bond angles exhibited slight deviations due to coordination-induced distortions in the solid phase. These findings suggest that metal coordination plays a key role in determining molecular packing and crystallinity, which can have significant

implications for the solubility, stability, and functional performance of MPCs in food and pharmaceutical applications.

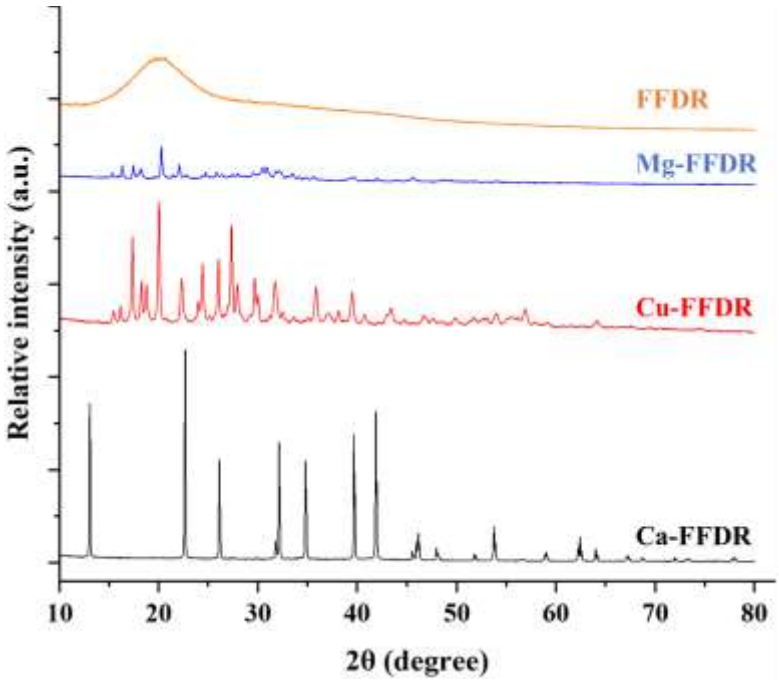


Fig 2 XRD patterns of FFDR and its complexes over a range of 4^0 - 80^0

4.0 Conclusion

This study demonstrates that DFT-predicted structures of MPCs particularly Cu^{2+} complexes with bond lengths of 1.902 Å showed high agreement with experimental XRD patterns (>90% peak match). These findings confirm the synergistic utility of DFT and XRD in elucidating the coordination chemistry of MPCs and provide a foundation for rational design of bioactive compounds in functional food systems.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (32072354), National Key R and D Project of China (2016YFD0400303), and the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD).

References

Booshala, A., Abrahem, A. F., Almughery, A. A., Al-Zaqri, N., Zarrouk, A., Lgaz, H., and Warad, I. (2021). Spectroscopic Insight into Tetrahedrally Distorted Square Planar Copper (II) Complex: XRD/HSA, Physicochemical, DFT, and Thermal Investigations. *Crystals*, *11*(10), 1179.

Bühl, M., and Kabrede, H. (2006). Geometries of Transition-Metal Complexes from Density-Functional Theory. *Journal of Chemical Theory and Computation*, *2*(5), 1282–1290.

Igbokwe, C. J., Feng, Y., Louis, H., Benjamin, I., Quaisie, J., Duan, Y., Tuly, J. A., Cai, M., and Zhang, H. (2024). Novel antioxidant peptides identified from coix seed by molecular docking, quantum chemical calculations and invitro study in HepG2 cells. *Food Chemistry*, *440*, 138234.

Kaupp, M., Danovich, D., and Shaik, S. (2017). Chemistry is about energy and its changes: A critique of bond-length/bond-strength correlations. *Coordination Chemistry Reviews*, *344*, 355–362.

Ke, H., Ma, R., Liu, X., Xie, Y., and Chen, J. (2022). Highly effective peptide-calcium chelate prepared from aquatic products processing wastes: Stickwater and oyster shells. *LWT*, *168*, 113947.

Leone, L., De Fenza, M., Esposito, A., Maglio, O., Nastri, F., and Lombardi, A. (2024). Peptides and metal ions: A successful marriage for developing artificial metalloproteins. *Journal of Peptide Science*, *30*(10).

Orio, M., Pantazis, D. A., and Neese, F. (2009). Density functional theory. *Photosynthesis Research*, *102*(2–3), 443–453.

Pal, V. K., and Roy, S. (2022). Cooperative Metal Ion Coordination to the Short Self-Assembling Peptide Promotes Hydrogelation and Cellular Proliferation. *Macromolecular Bioscience*, *22*(5).

Tang, N., and Skibsted, L. H. (2016). Calcium Binding to Amino Acids and Small Glycine Peptides in Aqueous Solution: Toward Peptide Design for Better Calcium Bioavailability. *Journal of Agricultural and Food Chemistry*, *64*(21), 4376–4389.

Wang, L., Ding, Y., Zhang, X., Li, Y., Wang, R., Luo, X., Li, Y., Li, J., and Chen, Z. (2018). Isolation of a novel calcium-binding peptide from wheat germ protein hydrolysates and the prediction for its mechanism of combination. *Food Chemistry*, *239*, 416–426.

Physico-Chemical Properties of Aerial Yam, Finger Millet and Pro Vitamin A Cassava Flour Blends.

*Mbam, N.J[1]., Ekwu, F.C[2] and Odo, M.O[2]

[1]Department of Chemical Engineering, Faculty of Engineering and Environmental Science, Ebonyi State University, Abakaliki. [2]Department of Food Science and Technology, Faculty of Agriculture and Environmental Science, Ebonyi State University, Abakaliki.

*Corresponding Author's email: donjoe042004@gmail.com

ABSTRACT

This study investigated the Physico-chemical properties of blends of Aerial Yam (*Dioscorea bulbifera*), Finger millet (*Eleusine coracana*) and Pro Vitamin A Cassava *(Manihot esculanta 'Yellow Cassava'*) flours blends. The flour blends were evaluated for proximate, and functional properties respectively using standard procedures (AOAC, 2010). Results of the flour blends revealed moisture, ash, fat, protein, fibre and carbohydrates contents of 11.86-12.71%, 1.09-1.47%, 0.29-3.75%, 2.79-9.79%, 1.34-3.04%, and 70.75-80.48 % respectively. The functional properties showed that oil absorption capacity, water absorption capacity, bulk density, dispersibility and wettability content of the flour blend samples ranged between 156.75 - 203.36 %; 161.63 – 232.08%; 0.73 -0.98g/ml; 18.14- 26.11%; and 5.65 – 34.48 sec respectively. The study showed that flour blends from aerial yam flour (AYF), finger millet flour (FMF) and pro-vitamin A cassava flour (PVACF) have great potentials in the production of confectionary production

Keywords: Fufu, Proximate, Functional, Flour blends, Aerial yam

1.0 Introduction

Aerial yam (*D. bulbifera)* is a species of yam in the family of *Dioscoreacea* (Nwosu, 2013). It is cultivated in Africa, Asia, and Northern Australia where it is used for food and it provides substantial amount of calories and minerals such as iron, calcium, potassium, magnesium and phosphorous (Abara *et al.,* 2000). Some varieties are eaten raw while others are by boiling or soaking. The bulbils are easy to harvest and cook (Nwosu, 2013).

Finger millet (*E. coracana L.*) is a cereal grown in Africa where the climatic conditions are adverse (Syeunda *et al*., 2020). Finger millet is rich in minerals like calcium, iron, Potassium and Zinc. It is reported that finger millets have 18.6% of fibre concentrated in the wall of endosperm and pericarp.

Cassava (*M.esculenta C*rantz) is a staple food for over 500 million people in the developing world where it is a major source of low-cost carbohydrate (O'Hair, 1990). Cassava is valued for its outstanding ecological adaptation, low labour requirement, ease of cultivation, high yield and under optimal conditions, it produces more calories per hectare than most tropical crops (Nweke *et al.,* 1999). Flours from different sources/plants can be blended to yield products with excellent nutritional properties. There is therefore the need to investigate the proximate and the functional properties of the aerial yam, finger millets and pro vitamin A cassava blends. The objective of this study was to investigate the proximate and functional properties of aerial yam, finger millet and pro vitamin A cassava flour blends.

2.0 Materials and Method

Aerial yam (*Dioscorea bulbifera*) and finger millets (*Eleusine coracana L.*) were purchased from *kpirikpiri* market, Ebonyi L.G.A of Ebonyi State, Nigeria. Vitamin A cassava (*Manihot esculenta "Yellow Cassava"*) was purchased from Biotechnology Research Centre, Ebonyi State University, Ebonyi State, Nigeria.

2.1 Sample Preparation

The method described by Prince-will Ogbonna and Ezembaukwu (2015) was adopted for the production of aerial yam flour. The four was stored in an airtight container (laminated nylon) prior to analysis.

2.2 Production of Germinated Finger Millet Flour

The malting of the finger millet was carried out as described by Mbithi-Mwikya *et al.* (2000). The germinated grains were dried in an oven at 48 ± 2 °C for 24 h. The grains were milled using a locally fabricated hammer mill. The flour was stored in an airtight container (laminated nylon) prior to analysis.

2.3 Production of Pro-Vitamin A Cassava flour

The Pro-vitamin A cassava flour was processed as described by Adeshina and Bolaji (2013). The flour was stored at room temperature prior to analysis.

The proportions for each flour were expressed in a ratio, with each treatment combination amounting to the sum of 100%. Ten experimental combinations were produced with four runs replicated to generate a total of fourteen (14) runs. The four runs to be replicated gave an internal estimate of error. The experiments were run in random order to minimize the effects of unexplained variability (Capanzana and Buckle, 1997).

The Proximate composition: moisture, ash, protein, fat and crude fibre were determined using AOAC (2010). The carbohydrate was determined by difference between 100 and other compositions. The method described by Onwuka (2005) was used to determine the bulk density and wettability of the sample. Swelling power was determined by the method described by Takashi and Sieb (1988). Dispersibility was determined using the method described by Kulkarni *et al.* (1991). Water absorption capacity and oil absorption capacity were determined using a method described by Philips *et al.*, (1988).

3.0 Results and Discussion

Proximate composition of the flour blend (Table 1) revealed that the moisture content (MC) ranged from 11.86 to 12.71 %, with 50AYF:50FMF:0 PVACF (50% Aerial Yam Flour, 50% Finger Millet and 0% Pro-Vitamin A Cassava Flour) having the highest moisture, while sample 0AYF: 0FMF:100PVACF had the least. There were significant differences ($P<0.05$) amongst the flour blends. The MC range 11.86 to12.71 %, obtained in this study is slightly lower than the MC of composite flour (13.28 %) reported by Kaushal *et al.* (2012) and higher than the values of 9.14-10.21% obtained by Olaniran *et al.* (2020) for cassava, cowpea and potato blends. This variance could be due to nutritive compositions of the other blends and climatic factors (Ojinnaka, *et al.,* 2017). The MC of the flour blends were lower than the recommended safe moisture (14 %) for storage (Tharise *et al.,* 2014).

The ash content ranged from 1.09 to 1.47%. Flour blends 50AYF: 0FMF:50PVACF, and 50AYF: 50FMF:0PVACF had the highest value and sample 100PVACF had the least value. There was no significant differences ($P>0.05$) in the ash content of most samples. The ash content of the blends is below the value 1.7 % (FAO, 1968).

The fat content of the blends showed sample 0AYF:100 FMF: 0PVACF having the highest 3.75 % and sample 16.66 AYF: 16.66FMF: 66.66PVACF had the least. There were significant differences ($P<0.05$) in the fat content of some samples. Some researchers recorded higher range of fat content 4.00-4.36 % (Awolu and Osigwe, 2017) and 6.58-9.52 % (Meka *et al.,* 2019) respectively for composite flours. Fat is vital in diet as it promotes absorption of fat-soluble vitamin. Generally, the low-fat content of the flour blends would enhance their storability.

The protein content ranged from 2.79 to 9.79 % which was lower than the range (22-31 %) reported by Olaniran *et al.* (2020) for cassava, cowpea, and potato blends.

The fibre ranged from 1.34 to 3.04%. Flour blends 16.66AYF:16.66FMF:66.66PVACF had the highest value while flour blend 50AYF:50FMF:0PVACF had the least value. Significant differences ($P<0.05$) existed in the fibre content of some of the flour blends. The fibre obtained were close to the range of 2.52-

3.78% reported by Awolu and Osigwe (2019) for rice, kerstine groundnut and lemon pomace flour blends. When fibre absorbs large amount of water, it gives a sensation of fullness.

The carbohydrate content (CHO) ranged from 70.75 to 80.48%. Flour samples 0AYF:50FMF:50PVACF, 50AYF:50FMF:0PVACF, and 33.33AYF:33.33FMF:33.33PVACF showed no

significant difference (P>0.05) among each other. The CHO of 100 AYF recorded the highest value 80.48 % in this study which was close to the values (81.93-82.22 %) reported by Ojinnaka *et al.* (2017) for aerial yam cultivars. Roots and tuber crops are generally high in CHO and as such serve as energy staple foods.

Table 1: Proximate Composition of Aerial Yam, Finger Millets and Pro-vitamin A Cassava Flour Blends.

AYF (%)	FMF (%)	PVACF (%)	Moisture content (%)	Ash content (%)	Fat content (%)	Protein content (%)	Fiber content (%)	Carbohydrate content (%)
100	0	0	$12.37^{b}\pm0.06$	$1.32^{ab}\pm0.05$	$1.59^{b}\pm0.36$	$2.88^{g}\pm0.03$	$1.94^{c}\pm0.11$	$80.48^{a}\pm0.26$
0	100	0	$12.02^{b}\pm0.03$	$1.36^{ab}\pm0.11$	$3.75^{a}\pm0.64$	$9.79^{a}\pm0.21$	$1.78^{c}\pm0.03$	$70.75^{e}\pm0.64$
0	0	100	$11.86^{c}\pm0.21$	$1.09^{c}\pm0.06$	$0.86^{c}\pm0.01$	$7.23^{c}\pm0.19$	$2.39^{b}\pm0.01$	$76.58^{c}\pm0.05$
50	0	50	$12.43^{c}\pm0.24$	$1.47^{a}\pm0.05$	$1.48^{b}\pm1.17$	$8.41^{b}\pm0.01$	1.64 ± 0.02	$73.59^{d}\pm0.47$
0	50	50	$12.65^{b}\pm0.33$	$1.24^{ab}\pm0.06$	$0.91^{c}\pm0.21$	$4.64^{f}\pm0.07$	$2.32^{b}\pm0.03$	$78.25^{b}\pm0.55$
50	50	0	$12.71^{a}\pm0.08$	$1.47^{a}\pm0.16$	$0.46^{e}\pm0.02$	$5.58^{c}\pm0.04$	$1.34^{d}\pm0.01$	$78.46^{b}\pm0.21$
33.33	33.33	33.33	$12.33^{b}\pm0.13$	$1.39^{ab}\pm0.06$	$0.65^{d}\pm0.21$	$5.98^{d}\pm0.05$	$2.50^{a}\pm0.08$	$77.17^{b}\pm0.54$
66.66	16.66	16.66	$12.61^{b}\pm0.20$	$1.13^{c}\pm0.11$	$0.31^{f}\pm0.26$	$7.76^{c}\pm0.16$	$1.85^{c}\pm0.01$	$76.36^{c}\pm0.01$
16.66	16.66	66.66	$12.30^{b}\pm0.30$	$1.17^{c}\pm0.05$	$0.29^{f}\pm0.21$	$6.53^{d}\pm0.48$	$3.04^{a}\pm0.08$	$76.68^{c}\pm0.46$
16.66	66.66	16.66	$12.70^{a}\pm0.08$	$1.43^{ab}\pm0.11$	$1.59^{b}\pm0.40$	$8.68^{b}\pm0.29$	$2.08^{c}0.03$	$73.58^{d}\pm0.16$
50	50	0	$12.71^{a}\pm0.08$	$1.47^{a}\pm0.16$	$0.46^{e}\pm0.02$	$5.58^{c}\pm0.04$	$1.34^{d}\pm0.01$	$78.48^{b}\pm0.23$
0	0	100	$11.86^{c}\pm0.21$	$1.09^{c}\pm0.06$	$0.86^{c}\pm0.01$	$7.23^{c}\pm0.19$	$2.39^{b}\pm0.01$	$76.58^{c}\pm0.05$
100	0	0	$12.37^{b}\pm0.06$	$1.32^{ab}\pm0.05$	$1.59^{b}\pm0.36$	$2.88^{g}\pm0.03$	$2.04^{c}\pm0.08$	$80.48^{a}\pm0.26$
0	100	0	$12.02^{b}\pm0.03$	$1.36^{ab}\pm0.25$	$3.75^{a}\pm0.64$	$9.79^{a}\pm0.21$	$1.78^{c}\pm0.03$	$70.75^{e}\pm0.64$

Values are means of triplicate ± standard deviation. Values with the same superscript within the same column are not significantly different (P>0.05).

3.1 The Functional Properties

The functional properties of the flour blends Table 2, showed the oil absorption capacity (OAC) range 156.75 to 203.36% with flour blend 66.66AYF:16.66FMF:16.66 PVACF having the highest OAC. Significant differences (P<0.05) exist amongst some of the flour blends. The OAC value obtained in this study was higher than the values (155-164%) reported by Eke-Eiofor and Oparandu, (2019) for pearl millet, finger millet, and fonio millet blends. OAC is an important characteristic that enhances the mouth feel of flavour when used in food preparation (Adebowale *et al.,* 2004).

The water absorption capacity (WAC) of the blends ranged from 161.63 to 232.08%. Significant difference (P<0.05) exists in the WAC of the blends. The WAC of the blends in this study was higher than the value (160-171%) reported by Eke-Ejiofor *et al.* (2019) for pearl millet, finger millet and fonio millet flour blends. Flour blends, 16.66AYF:16.66FMF:66.66 PVACF had the highest WAC content which can lead to stronger more stable dough, making it easier to shape during consumption. The results imply that at room temperature, flour blends with higher WAC is capable of holding more water than the one with less WAC (Tortoe *et al.,* 2017).

The range of values 0.73 to 0.98g/ml for bulk density (BD) showed sample 50AYF:0FMF:50PVACF and 50AYF:50FMF:0PVACF having the highest value. The BD in this study was higher when compared to the value of 0.54-0.72 g/ml reported by Eke-Ejiofor *et al.,* (2018) for Acha, defatted soybean, and groundnut flour blends. High bulk density is a good physical attribute when determining mixing quality of particulate

matter, it is a measure of heaviness of a flour sample. Significant difference exists ($P<0.05$) amongst some of the flour blend. Low bulk density flour blends are preferred because they contribute to lower dietary bulk, as well as convenience of packaging and transportation.

The dispersibility of the blends ranged from 18.14 to 26.11%. The value obtained in this study was lower than the value of 73.00 – 75.50 % reported by Eke –Ejiofor and Mbaka (2018) for acha, soybean, and groundnut flour blends respectively. There were significant differences ($P<0.05$) in the dispersibility flour blends.

Swelling index (SI) ranged from 5.73 to 8.31 v/v with sample 100AYF having the highest SI, while sample 100PVACF had the least. Protein and starch contents as well as the amylase / amylopectin ratio of the starch, affect SI and the differences in SI could be due to molecular organisation changes inside the starch granules (Ikpeme-Emmanuel *et al.,* 2010).

The range of values 5.65-34.48 seconds for wettability showed sample 0AYF:50FMF:50PVACF had the highest wettability content. Meaning it took more time to wet. This could be due to hydrophobic nature of certain components in cassava flour making it slow to absorb water. The wettability value recorded for the blends is below the value of 27-35 secs reported by Udensi *et al.* (2008) for different flour varieties of *D.alata*. It has been reported that the porosity, particle size, densities and morphology influence wettability (Fitzpatrick *et al.,* 2017). There were significant differences ($P<0.05$) in the wettability of the flour blends

Table 2: Functional Properties of the flour samples.

AYF (%)	FMF (%)	PVACF (%)	OAC (%)	WAC (%)	Bulk (g/ml)	Dispersibility (%)	Swelling Index (v/v)	Wetability (sec)
100	0	0	$156.75^{g}\pm3.68$	$193.89^{d}\pm6.69$	$0.88^{d}\pm0.04$	$23.43^{c}\pm0.95$	$8.31^{a}\pm0.04$	$7.39^{h}\pm0.01$
0	100	0	$187.27^{c}\pm3.10$	$161.63^{f}\pm0.44$	$0.90^{b}\pm0.07$	$24.10^{b}\pm1.89$	6.77 ± 0.01	$8.43^{g}\pm0.01$
0	0	100	$192.13^{b}\pm2.92$	$223.44^{b}\pm2.56$	$0.73^{g}\pm0.04$	19.42 ± 0.95	5.73 ± 0.06	$5.65^{j}\pm0.01$
50	0	50	$173.12^{f}\pm2.45$	$201.62^{c}\pm0.78$	$0.98^{a}\pm0.35$	$26.11^{a}\pm0.95$	$7.14^{d}\pm0.01$	$9.98^{f}\pm0.16$
0	50	50	$203.12^{a}\pm2.84$	$192.89^{d}\pm4.04$	$0.83^{d}\pm0.04$	$19.31^{g}\pm0.83$	$5.08^{j}\pm0.01$	$34.48^{a}\pm0.01$
50	50	0	$179.40^{e}\pm0.85$	$204.86^{c}\pm1.55$	$0.98^{a}\pm0.11$	$22.82^{d}\pm2.48$	$8.05^{b}\pm0.01$	$7.92^{h}\pm0.04$
33.33	33.33	33.33	$182.39^{d}\pm1.84$	$187.18^{d}\pm0.45$	$0.93^{b}\pm0.04$	$21.65^{f}\pm0.83$	$7.61^{c}\pm0.04$	$20.07^{c}\pm0.53$
66.66	16.66	16.66	$203.36^{a}\pm0.52$	$188.49^{d}\pm0.47$	$0.75^{f}\pm0.07$	$17.55^{i}\pm1.65$	$6.96^{e}\pm0.02$	$10.82^{e}\pm0.06$
16.66	16.66	66.66	$194.04^{b}\pm1.22$	$232.08^{a}\pm0.51$	$0.78^{e}\pm0.04$	$18.14^{h}\pm0.83$	$6.41^{h}\pm0.02$	$17.08^{d}\pm0.01$
16.66	66.66	16.66	$180.56^{e}\pm1.80$	$177.84^{e}\pm0.71$	$0.95^{b}\pm0.07$	$22.23^{e}\pm1.65$	$6.67^{g}\pm0.01$	$23.67^{b}\pm0.07$
50	50	0	$179.40^{e}\pm0.84$	$204.38^{c}\pm2.56$	$0.98^{a}\pm0.10$	$22.82^{d}\pm2.48$	$8.05^{b}\pm0.01$	$7.93^{h}\pm0.06$
0	0	100	$192.18^{b}\pm2.85$	$223.44^{b}\pm2.56$	$0.73^{g}\pm0.04$	$19.42^{g}\pm0.95$	$5.73^{i}\pm0.06$	$5.65^{i}\pm0.01$
100	0	0	$156.75^{g}\pm3.68$	$193.89^{d}\pm6.68$	$0.88^{c}\pm0.35$	$23.43^{c}\pm0.95$	$8.31^{a}\pm0.04$	$7.39^{h}\pm0.01$
0	100	0	$187.27^{c}\pm3.10$	$161.63^{f}\pm0.44$	$0.90^{b}\pm0.07$	$24.10^{b}\pm1.89$	$6.77^{f}\pm0.01$	$8.42^{g}\pm0.00$

Values are means of triplicate ± standard deviation. Values with the same superscript within the same column are not significantly different ($P>0.05$).

4.0 Conclusion

The fufu products had acceptable sensory attributes and potentials in alleviating the problem of diabetes. Also good for various food applications, such as food processing and product development.

References

AACC International. 2000. Approved Methods of the *American Association of Cereal Chemists,* 11th ed. Methods 44-15a and 46-10.01. St. Paul: The Association.

Abara, S.E., Okezie, C.E.A., Nwosu, K. (2000). Effects of storage methods on the quality of aerial yam (*Dioscorea bulbifera*) tubers. *Journal of Food Technology in Africa,* 5(2): 54-56.

Abbey, B.W., and Ibeh, G.O. (1988). Functional properties of raw and heat processed cowpea (*vigna unguiculata*, walp) flour. *J. Of food science*. 53; 1775-1777.

Adebowale, A.A., Sanusi, S.A., and Oladapo, F.O. (2004). Chemical, Functional and Sensory Properties of instant yam-bread fruit flour. *Nigerian Food Journal*, 26(1): 2-12.

Adeshina, B.S., and Bolaji, O.T. (2013). Effect of milling machines and sizes of cooked cassava flour quality, *Nigerian Food Journal.* 31(1): 115-119.

AOAC (2010). Official Methods of Analysis, 18th ed. Association of Official Analytical Washington D.C., USA.

Awolu, O.O. and Osigwe, M.A. (2019). Nutritional and Antioxidant Potential of rice flour enriched with Kersting groundnut (*Kerstingiella geocarpa*) and Lemon Pomace. *International Journal of Food Studies*. 8: 30-40.

Capanzana, M.V and Buckle, K.A. (1997). Optimization of germination conditions by response surface methodology of a high amylase rice (*Oryza sativa*) cultivar. *LWT*. 30:155-163.

Eke-Ejiofor, J. and Mbaka, V. (2018). Physico-chemical, pasting and sensory properties of food blends of maize, yellow cassava and sweet potato starch, defatted soybean and groundnut flour. *American Journal of Food Science and Technology*, 6(1): 42-49.

Eke-Ejiofor, J. and Oparandu, F.O. (2019). Chemical, functional and pasting properties of flour from three millet varieties. *Research Journal of Food and Nutrition,* 3(3): 15-21.

Eke-Ejiofor, J., Wordu, G.O., Bivan, S.K. (2018). Functional and pasting properties of acha, defatted soybean, and groundnut flour blends, *American Journal of Food Science and Technology*. 6 (5): 215-218.

Fitzpatrick, J., Salmon, J., Ji, J., and Miao, S. (2017). Characterization of the wetting behaviour of poor wetting food powders and the influence of temperature and film formation. *KONA Powder and Particle Journal* 34: 282-289.

Ikpeme-Emmanuel, C.A., Osuchukwu, N.C., Osheile, L. (2010). Functional and sensory properties of wheat (*Asetium triticum*) and taro flour (*Colocasia esulanta*) composite bread. *African Journal of Food Science*. 4: 248-253.

Kaushal, P., Kumar, V., and Sharma, H.K. (2012). Comparative study of Physico-Chemical, Functional, Antinutritional and Pasting Properties of Taro (*Colocasia Esculenta)*, rice (*Oryza sativa*), pigeon pea (*cajanus Cajan*) flour and their blends. *LWT Food Science and Technology,* 48(1): 59-68.

Kulkarni K.D, Kulkarni D.N, Ingle U.M (1991). Sorghum malt bases weaning food formulation. Functional properties and Nutritive value. *Food Nutr. Bull.* 13(4): 322-327.

Mbithi-Mwikya, S., Van Camp, J., Yiru, Y., and Huyghebaert, A. 2000. "Nutrient and Antinutrient Changes in Finger Millet (Eleusine coracan) during Sprouting." LWT-*Food Science and Technology* 33 (1): 9-14.

Nweke, F.I., Ukwu, B.O., Dixon, A.G.O., Asadu, C.L.A. and Ajodo, O. (1999). Cassava production in Nigeria: A function of farmers' access of markets and to improve production and processing technologies COSCA working paper, 20. IITA Ibadan.

Nwosu, J.N. (2013). Evaluation of the functional and sensory properties of biscuit produced from aerial yam (*Dioscorea bulbifera*). *Interational science and investigation Journal.* 2(5): 1-17.

O'Hair, S.K. (1990). Tropical root and tuber crops. Timber press, Portland, Pp: 424-428.

Ojinaka, M.C., Odimegwu, E.N., Iiechukwu, R. (2017). The functional properties and nutrients composition of flour and starch from two cultivars of aerial yam (*Dioscorea bulbifera*) from south Eastern Nigeria. *Pakistan Journal of Nutrition.* 8(5): 558-567

Olaniran, A.F., Okonkwo, C.E., Owolabi, A.O., Osemweige, O.O., and Badejo, T.E. (2020). Proximate composition and physico-chemical properties of fermented cassava, cowpea and potato flour blends. *IOP Conf. Ser. Earth Environ. Sci. 445.*

Onwuka G. I. (2005). Food Analysis and Instrumentation: Theory and Practice. Naphtali prints, Lagos, 156-161.

Onwuka, G.I. (2018). Food Analysis and Instrumentation theory and practice. Naphtali prints, Lagos-Nigeria Pp 179-228.

Philips R.D., Chinnan M.S., Branch A.L., Miller J. And Mcwatters R.H. (1988). Effects of pre-treatment on functional and nutritional properties of cowpea meal. *Journal of food Sciences* 3:805-809.

Princewill- Ogbonna, I.L., and Ezembaukwu (2015). Effects of various processing methods on the pasting and functional properties of aerial yam (*Dioscorea bulbefera*) flour. *British Journal of Applied Sciences and Technology* 9(5): 517-526.

Sengev, I.A., Akpapunam, M.A., and Ingbian, E.K. (2012). Physicochemical and sensory properties of instant kunun-zaki flour blends from sorghum and mango mesocarp flours. *Nigerian Food Journal*, 30 (2), 8-16.

Syeunda, C. O., Anyango, J. O., Faraj, A. K., and Kimurto, P. K. 2020. "In Vitro Protein Digestibility of Finger Millet Complementary Porridge as Affected by Compositing Precooked Cowpea with Improved Malted Finger Millet." *Journal of Food Science and Technology* 1-10.

Takashi, S. and Sieb, P.A. (1988). Paste and gel properties of prime corn and wheat starches with and without native lipids. *Cereals chemistry* 65; 47.

Tharise, N., Julianti, E. and Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *IFRJ I* 21: 1641-1649.

Tortoe, C., Dowuona, S., Akonor, P.T., and Dziedzoave, N.T. (2017). Examining the physicochemical, functional and rheological properties in ours of farmers 7 key yam (*dioscorea spp)* varieties in Ghana to enhance yam production. *Cogent Food and Agriculture* 3:13715

The Role of Agrovoltaic Technology in Food Security and Safety in Nigeria: A Review

*Ani, C.P[1]., Oyarebu, A. O.[2], Mapamile, A.D[1] and Agu, R. I[3]

[1]Department of Food Technology, Federal Polytechnic Oko, Anambra State, Nigeria. [2]Technical Division, National Board for Technology Incubation, Technology Incubation Centre, Nnewi, [3]Department of Home and Rural Economics, Federal Polytechnic Oko, Anambra State.

*Corresponding author's email: promisechale_ani@yahoo.com

ABSTRACT

Nigeria faces significant challenges in ensuring food security and safety, exacerbated by climate change, land degradation, and inadequate energy access. Agrovoltaic technology, which integrates agricultural activities with photovoltaic energy production, offers a promising solution to these challenges. In Nigeria, a country where agriculture plays a crucial role in the economy and food security, agrovoltaics could revolutionize farming by enabling simultaneous generation of renewable energy and food production. Despite the promising opportunities of agrovoltaic technology such as increased food production, sustainable energy, efficient water use among others, its implementation in Nigeria is anticipated to face some shocking challenges and barriers. Hence, public-private partnerships, research and development, policy support and the likes will help harness the full potentials of agrovoltaic technology. This review explores the potential impact of agrovoltaic technology in addressing food security and safety challenges in Nigeria. It evaluates existing literature, identifies key challenges and benefits, and provides recommendations for the successful integration of agrovoltaics into Nigeria's agricultural landscape.

Keywords: Agrovoltaic, Food Safety, Food Security, Nigeria, Renewable Energy.

Introduction

Nigeria, with a population exceeding 200 million and estimated annual growth rate of 3.2%, faces pressing challenges related to food security and safety (National Bureau of Statistics, 2020). The Nigeria agricultural sector contributes substantially to the country's GDP and employment. Nigeria, though blessed with plentiful natural resources such as 70.8 million hectares of agricultural land area that can support a wide range of food products in agro-ecological zones is burdened by factors such as land degradation, erratic weather patterns, insecurity, animal and plant pests and diseases, flood and energy shortages (FAO, 2021; Nigeria Hydrological Services Agency, 2020; World Bank Group, 2020; United Nations High Commissioner for Refugees, 2020). At the same time, the global shift towards renewable energy solutions offers new opportunities to address these challenges.

Agrovoltaic technology, a dual-use system that combines agriculture with solar power generation, provides a promising solution to these issues. By installing photovoltaic panels over agricultural fields, agrovoltaics can optimize land use, increase energy access, and enhance food security. This technology has the potential to mitigate the impacts of climate change on crop yields, improve water use efficiency, and provide farmers with a reliable energy source, all while contributing to the sustainable development of rural communities. Rising temperatures consequently leads to reduction in crop yields, expands farm weeds and pests hence, the need for effective use of agricultural lands (Smith & Gregory, 2013). Agrovoltaic system has shown to be very effective in growing leafy green vegetables including, lettuce, cabbage, and spinach, root crops such as potatoes, carrots, radishes, and beets have also been implicated (Al Mamun *et al.,* 2022; Weselek *et al.,* 2019; Cho, *et al.*, 2020). However, there is paucity of information regarding its application in livestock grazing

This review aims to assess the role of agrovoltaic technology in promoting food security and safety in Nigeria. The objectives include; exploring its current status, challenges, and opportunities and highlighting the potential socio-economic and environmental benefits of integrating agrovoltaic systems into the Nigerian agricultural framework.

Literature Review

Food Security and Safety in Nigeria

Food security, a critical element for hunger, malnutrition, related social and health challenge reduction encompasses food availability, quality, accessibility, and sustainability (Semeraro *et al*., 2024; Mirzabev *et al*., 2023; FAO:IFAD, 2018). Food security in Nigeria remains a significant issue, with millions of people facing inadequate access to safe and nutritious food. Depletion of natural resources, greenhouse gas emission, soil and biodiversity degradation, water scarcity, climate change and pollution are the consequences of current agricultural practices and exacerbate food production challenges (Toniolo, Russo & Bravo, 2024). Food safety concerns also arise due to poor post-harvest practices, contamination, and lack of proper food storage facilities.

Introduction to Agrovoltaic Technology

In 1982, two German scientists, Goetzberger and Zastrow introduced the dual use of farmlands for PV energy generation and plant growth (Goetzberger and Zastrow, 1982) however, the development and realization of the various advantages of agrovoltaic technology took several years (Kumpanalaisatit *et al.,* 2022; Goetzberger and Zastrow, 2021). Agrovoltaic technology involves the simultaneous use of land for both solar power generation and agricultural activities. This dual-use system can improve land efficiency by combining food production with renewable energy generation. Fixed support systems are used to raise the solar modules roughly a few meters above the ground so as to allow farm equipment access to the crops below (Coşgun, 2021). Agrovoltaics can help mitigate the land-use trade-offs often faced by farmers when deciding between food production and the need for energy sources.

Global Application of Agrovoltaic Systems

Globally, agrovoltaic systems have been successfully implemented in countries such as Germany, Japan, Turkey, India etc. In these countries, the integration of photovoltaics with agriculture has improved energy access, reduced water use, and helped mitigate global temperature anomaly trends that affect food production. Additionally, Aurelia *et al*. (2025) showed that agrovoltaic systems also improved photosynthetic pigment and carotenoid concentrations, and enhanced biomass production. These examples provide a framework for potential implementation in Nigeria.

Agrovoltaic Technology in Sub-saharan Africa

In Africa, several initiatives are underway to explore the potential of agrovoltaics. Countries like Kenya and South Africa have begun trials in integrating photovoltaics into agricultural systems, with positive results in improving crop yields and providing reliable energy to rural communities. The success of these projects highlights the promise of agrovoltaics in enhancing food security and safety in Nigeria.

Potential Challenges in Implementing Agrovoltaic Technology in Nigeria

Implementing agrovoltaic technology in Nigeria faces several barriers, including:

- **High initial costs** for photovoltaic systems.
- **Lack of technical expertise** in agrovoltaics.
- **Limited awareness** of the potential benefits.
- **Regulatory and policy gaps** in integrating renewable energy technologies into the agricultural sector.

Despite these challenges, opportunities such as government support, foreign investment, and the growing interest in renewable energy offer potential pathways for overcoming these barriers.

Materials and Methods

This review was conducted through a comprehensive analysis of existing literature on agrovoltaic technology, food security, and renewable energy integration. Sources were drawn from peer-reviewed journals, government reports, and case studies from countries that have implemented agrovoltaic systems. The key methods involved:

- **Database search** for articles and publications on agrovoltaics, renewable energy, and food security.
- **Comparative analysis** of agrovoltaic applications in countries with similar agricultural challenges to Nigeria.
- **Evaluation of existing policies** and reports on food security in Nigeria and Sub-Saharan Africa.

Results and Discussions

Impact on Crop Yield and Land Efficiency

Agrovoltaic systems have been shown to increase land use efficiency by enabling dual land use, thus allowing for increased food production without requiring additional land. This is particularly significant in Nigeria, where arable land is limited due to urbanization and land degradation (Gorjian *et al.,* 2022).

Energy Access for Farmers

One of the key benefits of agrovoltaics is the provision of reliable energy for rural farmers. Solar power can be used for irrigation, food processing, and storage, which are critical components for enhancing food safety. In regions like northern Nigeria, where the grid is unreliable, agrovoltaics can provide a decentralized and sustainable energy source (Gorjian *et al.,* 2022)

Water Use Efficiency

Agrovoltaic systems help optimize water use by providing shade to crops, reducing water evaporation, and thus lowering irrigation needs (Scarano *et al*., 2024; Paschalis, Bonetti &Fatichi, 2025). This is particularly crucial in areas where water scarcity is a significant challenge, such as in the arid and semi-arid regions of Nigeria (Gorjian *et al.,* 2022).

Source: Aurelia *et al*., 2025.

Figure 1. Schematic representation of the interaction between photovoltaic panels and crop growth in an agrivoltaic system, showing how shading influences light availability, temperature regulation, and water retention. Under full sunlight influence, higher temperatures and increased evapotranspiration occur in plants resulting to greater water loss. Contrastingly, plants under shade experience lower temperatures, reduced light exposure, and enhanced water retention, mitigating water stress and potentially improving biomass production.

Climate Resilience

Agrovoltaic technology can mitigate the effects of climate change by providing a buffer against extreme weather events, such as heatwaves and droughts. The shaded environment under photovoltaic panels creates microclimates that protect crops from extreme heat and excessive rainfall, improving food security (Gorjian *et al.,* 2022; De Francesco *et al.*, 2025).

Socio-Economic Benefits

The integration of agrovoltaic systems can generate income for farmers through the sale of surplus solar energy, which can be fed back into the grid. This additional revenue stream can improve the economic resilience of farmers and rural communities (Gorjian *et al.,* 2022).

Challenges and Barriers

Despite the promising potential, several challenges exist in adopting agrovoltaics in Nigeria. These include:

- **High initial costs:** the initial investment required for agrovoltaic systems can be prohibitively expensive for smallholder farmers.
- **Limited Awareness:** many farmers and policy makers are unaware of the benefits and potential of agrovoltaic technology.
- **Regulatory Gaps:** existing policies and regulations may not support the development and implementation of agrovoltaic systems.

Opportunities for Sustainable Development

1. Increased Food Production: agrovoltaic technology can increase food production, improving food security and safety in Nigeria (Aurelia *et al.*, 2025))
2. Job creation: agrovoltaic systems can create new job opportunities in rural areas, contributing to economic development (Kumpanalaisatit *et al.*, 2022).
3. Sustainable Energy: agrovoltaics provide a sustainable source of energy, reducing reliance on fossil fuels and mitigating climate change effects (Kumpanalaisatit *et al.*, 2022).

Case Studies and Examples

- **Kenya**: agrovoltaic systems have been successfully implemented in Kenya, improving crop yields and providing reliable energy for rural communities (Kenya Ministry of Agriculture, Livestock, Fisheries and Cooperatives, 2020).
- **India**: agrovoltaic systems have been used in India to promote sustainable agriculture and enhance energy access (Government of India, Ministry of New and Renewable Energy, 2020).

Conclusion

Agrovoltaic technology offers a promising solution to food security and safety challenges in Nigeria. By optimizing land use, improving energy access, increasing water-use efficiency and enhancing food production, agrovoltaic systems can contribute to sustainable development and improved livelihoods in rural communiteies. However, successful implementation requires addressing challenges related to initial costs, technical capacity, and regulatory frameworks.

Recommendations

1. **Policy support**: The Nigerian government should introduce policies and incentives to promote agrovoltaic technology, such as tax breaks or subsidies for solar panel installation (Nigerian Government, Ministry of Agriculture and Rural Development, 2020).
2. **Capacity building**: Training programs for farmers and technicians in the operation and maintenance of agrovoltaic systems should be implemented.
3. **Research and development**: Investment in R&D to tailor agrovoltaic systems to Nigeria's specific climatic and agricultural conditions is essential.

4. **Public-private partnerships**: Collaborative efforts between the government, private sector, and international organizations could help overcome financial and technical barriers.

References

Al Mamun, M.A., Dargusch, P., Wadley, D., Zulkarnain, N.A. and Aziz, A.A. (2022). *A review of research on agrivoltaic systems*. Renewable and Sustainable Energy Review, **161**: 112351.

Aurelia, S., Lorenzo, M.C., Teodoro, S., Antonio, C., Marcello S.L., Angelo, S., Alberto, B. and Monica D. C. (2025). *Agrivoltaics as a Sustainable Strategy to Enhance Food Security under Water Scarcity*. *Horticulturae*, ***11***(4): 401. Doi: https://doi.org/10.3390/horticulturae11040401

Cho, J., Park, S.M., Park, A.R., Lee, O.C., Nam, G and Ra, I.H. (2020). *Application of photovoltaic systems for agriculture: a study on the relationship between power generation and farming for the improvement of photovoltaic applications in agriculture*. Energies, **13** (18): 4815

Coşgun, A. E. (2021). *The potential of Agrivoltaic systems in TURKEY*. Energy Reports **7**: 105-111.

De Francesco, C.; Centorame, L.; Toscano, G. and Duca, D. (2025). *Opportunities, TechnologicalChallenges and Monitoring Approaches in Agrivoltaic Systems for Sustainable Management*. Sustainability, **17**, 634.

FAO (2021). *The Federal Republic of Nigeria Resilience Strategy 2021–2023. Increasing the resilience of agriculture-based livelihood*. The pathway to humanitarian–development–peace nexus. Abuja. Doi: https://doi.org/10.4060/cb5856en

FAO; IFAD (2018). *The State of Food Security and Nutrition in the World: Building Climate Resilience for Food Security and Nutrition. Food and Agriculture Organization of the United Nations*. Rome, FAO. Available online:

https://openknowledge.fao.org/server/api/core/bitstreams/f5019ab4-0f6a-47e8-85b9-15473c012d6a/content (accessed on 4 May 2025).

National Bureau of Statistics (2020). *Consumption expenditure pattern in Nigeria 2019*. Available online: https://www.nigerianstat.gov.ng/pdfuploads/Consumption%20Expenditure%20Pattern%20in%2 Nigeria%202019.pdf (accessed on 29 May 2025)

Nigeria Hydrological Services Agency (2020). *Annual flood outlook* (AFO).

Goetzberger, A. and Zastrow, A. (1982). *On the coexistence of solar-energy conversion and plant cultivation*. International Journal of Solar Energy, **1** (1): 55–69.

Gorjian, S., Bousi, E., Özdemir, Ö. E., Trommsdorff, M., Kumar, N. M., Anand, A., … and Chopra, S. S. (2022). *Progress and challenges of crop production and electricity generation in agrivoltaic systems using semi-transparent photovoltaic technology*. Renewable and Sustainable Energy Reviews, **158**: 112-126.

Government of India, Ministry of New and Renewable Energy (2020). National Solar Mission.

Kenya Ministry of Agriculture, Livestock, Fisheries and Cooperatives (2020). Agricultural Sector Development Strategy.

Kumpanalaisatit, M., Setthapun, W., Sintuya, H., Pattiya, A., and Jansri, S. N. (2022). *Current status of agrivoltaic systems and their benefits to energy, food, environment, economy, and society*. Sustainable Production and Consumption, **33**: 952-963.

Mirzabev, A., Kerr, R.B., Hasegawa, T., Pradhan, P., Wreford, A., von der Pahlen, M.C.T. and Gurney-Smith, H. (2023). *Severe climate change risks to food security and nutrition*. ClimateRisk Management, **39**: 100473.

Nigerian Government, Ministry of Agriculture and Rural Development (2020). Agricultural Promotion Policy

Pascaris, A.S., Schelly, C., Burnham, L. and Pearce, J.M. (2021). *Integrating solar energy with agriculture: industry perspectives on the market, community, and socio-political dimensions of agrivoltaics*. Energy Research and Social Science, **75**: 102023.

Paschalis, A., Bonetti, S. and Fatichi, S. (2025). *Controls of ecohydrological grassland dynamics in agrivoltaic systems*. Earth's Future, **13**: e2024EF005183.

Scarano, A., Semeraro, T., Calisi, A., Aretano, R., Rotolo, C., Lenucci, M.S., Santino, A., Piro, G. and De Caroli, M. (2024). *Effects of the Agrivoltaic System on Crop Production: The Case of Tomato (Solanum lycopersicum* L.). Applied Sciences, **14:** 3095.

Semeraro, T., Scarano, A., Curci, L.M., Leggieri, A., Lenucci, M., Basset, A., Santino, A., Piro, G. and De Caroli, M. (2024). *Shading effects in agrivoltaic systems can make the difference in boosting food security in climate change*. Applied Energy, **358**: 122565

Smith, P. and Gregory, P.J. (2013). *Climate change and sustainable food production*. Proceedings of the Nutrition Society, **72** (1): 21–28.

Toniolo, S.; Russo, I. & Bravo, I. (2024). *Integrating product-focused life cycle perspectives in the fresh food supply chain: Revealing intra- and inter-organizational views*. Sustainable Production and Consumption, **48**: 46–61.

United Nations High Commissioner for Refugees (UNHCR) (2020). *Nigerian refugees in Maradi region*. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/74373.pdf (Accessed on 29/5/2025)

Weselek, A., Ehmann, A., Zikeli, S., Lewandowski, I., Schindele, S and Högy, P. (2019). *Agrophotovoltaic systems: applications, challenges, and opportunities: A review*. Agronomy for Sustainable Development, **39:** 1–20.

World Bank Group (2020). *Country Overview Report*. Available online: https://www.worldbank.org/en/country/nigeria/overview (Accessed on 29/5/2025)

Sensory and Proximate Evaluation of Dry-Milled *Pap* Produced from Maize, Sorghum, Millet and Tiger Nut Flours

*Ani, C.P.,[1] Mapamile, A.D.,[1] Oyarebu, A. O.,[2] and Khoza, M[3]

[1]Department of Food Technology, Federal Polytechnic, Oko, Anambra State, Nigeria. [2]Technical Division, National Board for Technology Incubation, Technology Incubation Centre, Nnewi, [3]University of Johannesburg

*Corresponding author's email: promisechale_ani@yahoo.com

ABSTRACT

This study comprehensively evaluates the sensory attributes and proximate composition of dry-milled *pap* produced from maize, sorghum, millet, and tiger nut flours. The flours were formulated into three samples coded as ABC (40% Corn 20% Millet 20% Sorghum and 20% Tiger nut), BCD (20% Corn 35% Millet 35% Sorghum and 10% Tiger nut) and CDE (33.3% Corn 33.3% Millet and 33.3%). Sensory properties, including color, taste, texture, mouthfeel, and overall acceptability, were assessed using a 9-point hedonic scale. Proximate composition was analyzed following standard. Significant differences ($p < 0.05$) were observed in moisture content, with sample CDE exhibiting the highest moisture level (12.23%) and BCD (9.40%) having the least moisture content. Protein content varied notably, with sample BCD showing the highest protein content (10.70%) while sample ABC had the lowest (8.60%). The crude ash content was also significantly higher in sample BCD (8.10%) compared to the other samples. Sample ABC recorded the highest value (5.33%) for fibre whereas sample CDE had the lowest (4.30%). Lipid content was highest in sample BCD (7.00%) and lowest (4.13%) in sample CDE, and carbohydrate content was highest in Sample ABC (65.87%) and lowest (60.03%) in sample BCD. The results indicated that the inclusion of tiger nut significantly improved sensory attributes, particularly taste and texture, while influencing the nutritional composition of the dry-milled *pap*

Keywords: Millet, Proximate, Sensory, Sorghum, Tiger nut.

1.0 Introduction

The increasing demand for nutritious, functional, and shelf-stable foods in West Africa necessitates the development of innovative food products that address both dietary and economic concerns. *Pap,* a staple fermented cereal product, is widely consumed due to its affordability and digestibility, particularly as a weaning food (Odunfa and Adeleye, 2005). However, traditional *pap* formulations often lack essential nutrients, particularly protein, fibre, and bioactive compounds, making reformulation with alternative ingredients an urgent necessity (Akajiaku *et al.*, 2018). Having been implicated with some infant-related illnesses such as kwashiorkor (Akanbi *et al.*, 2003), researchers have made efforts to fortify *pap* with plant-based protein sources to enhance their protein and other nutritional value. For instance, Omah, *et al.*, (2021) reported a 21.5% protein increase with 50% soybean inclusion in *pap* powder while Egounlety *et al.*, (2002) reported an increase of more than 50% in lysine with cowpea-fortified *pap.*

Pap is popularly known as *akamu* in eastern Nigeria, *ogi* in western Nigeria and *koko* in northern Nigeria (Akinsola *et al.*, 2017). Being a staple food, it is commonly used as weaning food for babies, complimentary food for young children and breakfast cereals for adults (Nago *et al.*, 2002). *Pap* also serves as an essential stimulator of lactation in nursing mothers, providing energy required for breast milk production; supporting the production of hormone as well as serving as phytoestrogens (Oguntoyinbo *et al.*, 2016; Afolayan, Afolayan and Abuah, 2010).

Existing studies have explored various ingredient modifications to enhance the nutritional and functional properties of *pap*. Millet and sorghum improve protein and fibre content, while tiger nut contributes essential fatty acids, antioxidants, and bioactive compounds that can enhance the product's overall nutritional profile (Ade-Omowaye *et al*., 2008; Iwe, Uwakwe and Okoli, 2010). Despite these advancements, limited research has systematically evaluated the impact of dry milling and tiger nut powder inclusion on sensory characteristics, proximate composition, microbial load and shelf-life stability of *pap* powder. Thus, this study seeks to bridge this gap by assessing the potential of tiger nut-enhanced formulations in improving dry-milled *pap*'s quality and stability.

The key research question of this study is: How does the incorporation of dry-milled millet, sorghum, and tiger nut flour into dry-milled maize-based *pap* flour influence its sensory properties and nutritional value

Hypothesis: the dry-milling method adopted as well as the inclusion of tiger nut flour will significantly enhance sensory acceptability, improve gut health and prolong shelf stability while improving the overall nutritional composition of the product. By addressing these aspects, this study aims to contribute to the growing body of knowledge on cereal-based product development and commercial food innovations.

The aim of this study is to evaluate the sensory and proximate composition of dry-milled *pap* produced from millet, sorghum, corn and tiger nut flour.

2.0 Materials and Methods

2.1 Sources of Materials

Millet (pearl), sorghum (red), maize (yellow), and tiger nut (yellow) were sourced from *Eke Oko* Market, Orumba North Local Government Area, Anambra State, Nigeria.

2.2 Processing of Sorghum, Maize and Millet flour

A modified method of Odunfa and Adeleye (2005) was employed. One kilogram of each cereal was washed, steeped for 72 hours, dried, milled, and sieved to obtain fine flour.

2.3 Production of Tiger Nut Flour

Tiger nuts were cleaned and processed following the method described by Akajiaku *et al.* (2018). The resulting flour was packaged in an airtight container.

2.4 Formulation of Dry *Pap* Samples

Three *pap* formulations were prepared with varying proportions of maize, millet, sorghum, and tiger nut flours:

Table 1: Formulation of Dried *pap* flour

SAMPLE	Corn	Millet	Sorghum	Tigernut
ABC	**40g**	**20g**	**20g**	**20g**
BCD	**20g**	**35g**	**35g**	**10g**
CDE	**33.333g**	**33.333g**	**33.333g**	**0**

2.5 Sensory Evaluation

The sensory attributes were evaluated on the *pap* for colour, flavour, appearance, mouth feel, taste and overall acceptability using 9-point hedonic scale, where 1 implied 'dislike extremely' and 9 implied 'like extremely'. All the formulated blends were made separately into gruels (20% w/v) by making a smooth cold paste and gradually pouring boiled water into same. This was stirred vigorously until the entire mass became viscous. It was served to 10 panelists drawn from the polytechnic community, who were basically students and non-smokers and are very familiar with *pap*. The 10 panelists were selected based on interest, gender, availability, familiarity with *pap* and health stability and were instructed to rinse their mouth with water after each tasting (Iwe *et al*., 2010). Seven female and three male students with average age of 24 years were selected.

2.6 Proximate Evaluation

Proximate evaluation of the *pap* samples was carried out using the Official Method of Analysis of AOAC International, 18th Edition, 2010.

2.7 Statistical analysis

The data generated was subjected to Analysis of Variance (ANOVA) using version 21.0 of SPSS while the means were be separated using Duncan Multiple Range test at 95% confidence test. Statistical significance was accepted at $p< 0.05$

3.0 Results and Discussions

Sensory analysis showed that *pap* samples containing tiger nut (ABC and BCD) had improved taste and mouthfeel compared to the control (CDE). The highest overall acceptability score was recorded for sample CDE in the first week, while ABC and BCD gained higher scores in subsequent weeks, indicating a preference shift. Similar trends were observed in previous studies. For example, Iwe, Uwakwe and Okoli (2010) reported that the inclusion of tiger nut in composite flour improved sensory properties, particularly taste and texture, which aligns with the findings of this study. Additionally, research by Akajiaku *et al.* (2018) demonstrated that tiger nut-enriched cereal products had higher consumer acceptability over time due to enhanced sweetness and mouthfeel. The study by Ade-Omowaye *et al.* (2008) also highlighted that the integration of tiger nut flour into complementary foods improved flavor perception and increased consumer preference, further reinforcing the findings of this research. This suggests that the integration of tiger nut in *pap* formulation contributes to a gradual increase in consumer preference, reinforcing its potential for commercial application.

Table 2: Sensory evaluation of dry-milled *pap* produced from millet, sorghum, corn and tiger nut.

SAMPLES	COLOUR	TASTE	TEXTURE	MOUTHFEEL	AROMA	OVERALL ACCEPTABILITY
ABC	$8.10^{b}\pm0.10$	$7.40^{a}\pm0.10$	$7.60^{b}\pm0.10$	$7.10^{a}\pm0.10$	$7.70^{b}\pm0.82$	$7.58^{a}\pm0.01$
BCD	$7.50^{a}\pm0.10$	$7.90^{b}\pm0.10$	$7.40^{a}\pm0.10$	$7.40^{b}\pm0.10$	$7.80^{b}\pm0.63$	$7.62^{a}\pm0.01$
CDE	$8.20^{b}\pm0.10$	$7.80^{b}\pm0.10$	$8.10^{c}\pm0.10$	$7.90^{c}\pm0.10$	$7.50^{a}\pm1.08$	$7.90^{b}\pm0.01$

*Value are means ± standard deviations of triplicate determinations. Means with the same superscript in the same column are not significantly different at $p>0.05$

The proximate composition analysis of the formulated dried *pap* samples revealed variations in moisture, protein, fat, and carbohydrate content, influenced by the inclusion of millet, sorghum, and tiger nut. The moisture content (9.40% –12.23%) observed in this study aligns with findings by Odunfa and Adeleye

(2005) and Adedokun *et al*., (2024), who reported that fermented cereal-based products typically have moisture levels ranging from 8.5% to 13.0% and moisture value range of 10.684 – 13.071% from Sorghum-pigeon pea based *pap*. On the contrary Omah *et al*., 2021 reported a value range of 5.39% - 7.72% from maize, sorghum and soybean *pap* blends. The moisture values from this study will contribute to product stability and shelf life of the *pap*. Since moisture is a suitable medium for microbial growth, the relatively higher moisture content in sample CDE suggests its potential susceptibility to microbial spoilage compared to formulations incorporating tiger nut. The range of the moisture content observed in *pap* samples with tiger nut inclusion were within the 5 – 10 % moisture content of complementary foods for infants up to one year of age according to RDA values (24).

Crude protein content varied across the samples, with BCD recording the highest value (10.70%), which is consistent with Akajiaku *et al.* (2018), who demonstrated that tiger nut inclusion enhances protein content in composite flour products. Comparatively, Adedokun *et al*., (2024) reported protein range of 9.893-15.408% from co-fermented sorghum and pigeon pea *pap* while *Omah et al*., (2021) reported protein values of 6.22 % – 21.46 % from maize, sorghum and soybean *pap* flour. This supports the claim that fortification of *pap* contributes significantly to the protein value of cereal formulations.

The ash content across the samples varied significantly with sample BCD having the highest value of 8.10%. These values are considerably higher than those reported by Omah *et al*., (2021) (2.66 % – 3.64 % and Adedokun *et al.* (2024) (2.012 – 2.842) suggesting that tiger nut inclusion significantly improved the ash content of the *pap*. Ash content is a measure of the mineral contents of food and are essential for proper growth and development. The ash contents from this study is higher than the RDA values of not less than 2% and not more than 5% for infants up to one year of age (National Research Council, 1989).

The fat content (7.00% in BCD) is notably higher than the control sample (CDE), a result that mirrors Akajiaku *et al.* (2018), where tiger nut-enriched formulations had significantly increased lipid content due to the high-fat nature of tiger nut. These values are within the range of 4.22 % - 13.22 % reported by Omah *et al*., (2021) but higher than (0.874% – 1.601%) reported by Adedokun *et al.* (2024). It could be deduced that tiger nut inclusion increased the fat content since dehulling can significantly reduce the fat contents of grains which are usually located in the scutellum (Omah *et al.,* 2021).

The fibre content obtained in this study varied significantly across the samples with sample ABC having the highest value (5.33%). These values are comparably higher than those reported by Omah *et al.* (2021) and Adedokun *et al.* (2024) who reported fibre content of 2.22% – 2.65 % and 0.533% – 1.327% respectively. The high fibre content from this study could be attributed to tiger nut inclusion. Fibre has been implicated in gut health, risk reduction in diabetics, cardiovascular diseases and obesity reduction, proper regular bowel movement, weight management and cholesterol reduction, (Duyff, 2017). The recommended daily dose is 25 to 30 grams of which 6-8 grams daily dose is recommended from soluble fibre (Fuller *et al.,* 2016)

Carbohydrate content ranged from 60.03% to 65.87%, showing significant formulation-dependent variation. This is in agreement with Odunfa and Adeleye (2005), who reported carbohydrate values of 58%–67% in fermented cereal products. The slightly reduced carbohydrate content in BCD is likely due to the higher protein and fat contribution from tiger nut and sorghum. These values are lower than 68.751% - 73.160% and 51.32 % - 79.14 % reported by Adedokun *et al.* (2024) and Omah *et al.* (2021) respectively.

Overall, these findings indicate that the incorporation of millet, sorghum, and tiger nut positively influenced the proximate composition of dried *pap*, enhancing its protein and fat content while maintaining an acceptable carbohydrate range. This aligns with previous studies and reinforces the nutritional benefits of multi-grain formulations for improved dietary quality.

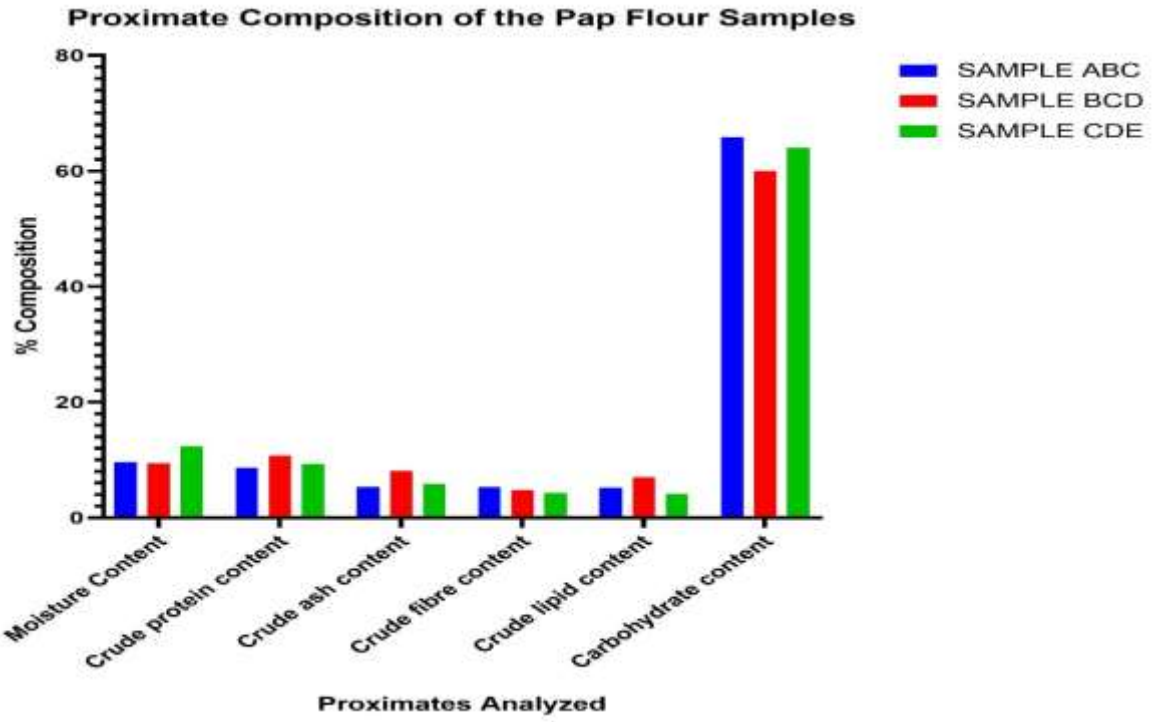


Fig 1: Proximate Composition of dry-milled *pap* produced from millet, sorghum, corn and tiger nut.

4.0 Conclusion and Recommendation

This study demonstrated that incorporating millet, sorghum, and tiger nut into maize-based *pap* enhanced its sensory properties and nutritional value. The tiger nut-enhanced formulation (BCD) exhibited superior sensory and proximate attributes, making it a promising alternative to traditional *pap*. Further research is recommended to explore microbial stability and extended shelf life of these formulations.

References

Ade-Omowaye, B.I.O. (2008). *The Use of Tiger Nut in Food Formulation*. African Journal of Food Science and Technology **9**(4): 255–263.

Afolayan, M.O., Afolayan, M. and Abuah, J.N. (2010). *An Investigation into Sorghum Based Ogi (Ogi-Baba) Storage Characteristics*. Advanced Journal of Food Science and Technology **2**(1): 72-78.

Akajiaku, L.O., Kabuo, N.O., Alagbaoso, S.O., Orji, I.G., and Nwogu, A.S. (2018). *Processing and NutritionalQuality of Tiger Nut Flour*. Journal of Nutrition and Dietetic Practice **2**(1): 1–5

Akanbi, C.T., Ade-Omowaye, B.I., Ojo, A. and Adeyemi, I. A. (2003). *Effect of Processing Factors on Rheological Properties of Ogi*. International Journal of Food Properties **6**(3): 405-418.

Akinsola A.O., Onabanjo, O.O., Idowu, M.A. and Ade-Omowaye, B.I.O. (2017). *Traditional Complementary Foods: A Critical Review*. Greener Journal of Agricultural Science **7**(9): 226-242.

AOAC (2010). Official Methods of Analysis Association of Official Analytical Chemists, (18th Ed). Washington, D. C., USA.

Duyff, R.L. (2017). *Carbs, Sugars, Starches and Fibre In: Academy of Nutrition and Dietetics Complete food and Nutritional Guide* 5th Ed New York, N.Y. Houghton Miffin, Harcourt.

Egounlety, M.O., Aworh, C., Akingbala, J.O., Houben, J.H. and Nago, C.M. (2002). *Nutritional and Sensory Evaluation of Maize – Based Tempered – Fortified Weaning Foods*. International Journal of Food Science and Nutrition **53**(4): 15 – 27.

Fuller, S., Bedk, E., Saiman, H. and Topsell, L. (2016). *New Horizon for the Study of Dietary Fibre and Health: A review*. Plant Foods Human Nutrition **71** (1): 1-12.

Iwe, M.O., Uwakwe, A.A., and Okoli, I.C**.** (2010). *Sensory Evaluation Techniques for Food Products*. Nigerian Journal of Food Science **8**(2): 150–160.

Nago, M.C., Hounhouigan, J.D., Akissoe, N., Zanou, E. and Mestres, C. (2002). *Characterization of the Beninese Traditional Ogi, a Fermented Maize Slurry: physicochemical and microbiological aspects*. International Journal of Food Science and Technology **33**(3): 307–315.

National Research Council (1989). Subcommittee on the Tenth Edition of the Recommended Dietary Allowances. Washington (DC), National Academies Press (US).

Odunfa, S.A., and Adeleye, O.E. (2005). *Microbiological and Nutritional Aspects of Fermented Foods*. African Journal of Biotechnology **4**(3): 298-304.

Oguntoyinbo, A., Akinmoladun, O. and Akinmoladun, F**.** (2016). *Nutritional and medicinal benefits of ogi (akamu): A fermented corn porridge*. Journal of Food and Nutrition Research 4(2): 1–9

Omah, E.C., Nwaudah, E.I., Asogwa, I.S and Eze, C.R. (2021). *Quality evaluation of powdered ogi produced from maize, sorghum and soybean flour blends in Nigeria*. African Journal of Food, Agriculture Nutrition and Development 21: 10

Omololami, T.A., Emmanuel, O.A., Bolanle, O.O., Abebe, M. and Busie, M.D. (2021). *Nutritional properties of ogi powder and sensory perception of ogi porridge made from synthetic provitamin: A maize genotype*. Fronteirs in Nutrition 8:685004

De-Emphasizing Unwholesome-refinement of Traditional Foods, towards Improving National Health

Undie, J. B.,[1] Omang, C. E[2] John, E. G[1]

[1]Department of Social Studies and Civic Education, Faculty of Arts and Humanities, University of Calabar.
[2] Department of Political and Economics Education, Faculty of Arts and Humanities, University of Calabar, Calabar

Corresponding author's email: josephbekeh49@gmail.com

ABSTRACT

In a bid to improve national health, this paper attempts to emphasise the risks of ill-refining of certain traditional foods, which has been practiced as modern lifestyle. The influence of these refinement of traditional foods has occasioned an avalanche of health issues that have terribly affected Nigerians at all levels, and ages. The refining of many natural food products to look like synthetic or chemically produced foods has led to ever-increasing rate of health complications among Nigerians, and this has, affected national health in a disastrous scale that should raise concern. This paper therefore explores some selected traditional foods/dishes in Nigeria, risks of consuming industrially refined foods, multidimensional benefits of consuming traditional foods, and the way forward towards reversing the trend of unwholesome refining of traditional foods.

Key words: De-emphasising, refinement, wholesome, traditional foods, national health

Introduction

Our present-day eating habit, which is now taken to be modern can no longer guarantee a sound national health when considered in terms of the risks it has introduced. Our health is deteriorating everyday due to this.

Life span of people has become increasingly short in Nigeria. According to Macrotrends (2025), Nigerians life expectancy for 2025 is age 56.36, that is, a 0.54% increase from 2024. This is the consequence of over consumption of refined foods such that it has become common seeing people with diseases and food allergies. No doubt, this is due to much consumption of industrially-refined foods which are mostly imported (Undie and Onnoghen, 2017). Nigerians are quick to copying various habits, lifestyles and practices from the western world through the internet, films, and television, paying less attention to the negative impact on us. This instance could be seen in the abandoning of locally produced rice to consume more of the industrially polished rice. We are rather eating malignantly rather than eating to guarantee healthiness (Undie, Aboh, and Omang, 2025; Undie and Onnoghen, 2017; Undie, 2016)

Consumption of our traditional foods without chemical additives does not mean that one is unmodern as some hold (Enu, Undie and Odey, 2016). Evidences abound that our fore fathers outlived us owing to their dependence on traditional foods. They often had different diets that were whole, unprocessed, locally sourced and seasoned, that accounted for their longevity, yet without enjoying modern health facilities, but enjoyed a relatively healthy life that is evident in their living to old ages.

Traditional foods therefore are cultural, natural and homemade foods with so many varieties that ensure the body has all required minerals and vitamins needed for vitality and good health. These foods have long standing history among a people. While industrially-made foods are processed or refined foods to either

modify the taste or flavour. These foods are more of western foods as well as fast foods which come with adverse effects on our health (Undie and Onnoghen, 2017).

Selected traditional foods/dishes in Nigeria

As diverse as Nigeria is, so also is her foods/delicacies. These are known to be naturally rich in dietary fibre, organic constituents, unprocessed and unrefined. A list of these foods commonly consumed in Nigeria are below: *Akpu/fufu, tuwo, amala, alibo*/cassava flour, *eba*, pounded yam, pounded cocoyam, pounded potato. Sweeteners: *dawadawa* (fermented locust beans), mushroom, *eyakyak/ikpa*, Spices; ginger, garlic, hot leaf seeds, peppers, etc. Aquatic foods: crayfish, lobsters, periwinkles, oysters, etc. Soup from wild vegetables: *Edikaikong/Afang, atama, Oha*, hot leaf, bitter leaf, *kuwhel, kudiong, ukem, ugbamu,* etc. Soup from nuts/seeds: groundnut, melon, beneseed, *banga* soup, etc. Varieties of nuts: kolanut, cashew nut, walnut, bitter kola, etc.; varieties of fruits: pear, soursop, mango, carrot, water melon, banana, pawpaw, orange, etc, Cassava, maize, Guinea corn (sorghum), Potato, beans, rice, cocoyam, millet, roasted groundnut., roasted beneseed, coconut. game meat (Bush meat), palm oil, *Akamu/Ogi* (Maize pap), *kunu* (food drink), *akara* (bean cake of beans, cassava or water yam ground and fried), boiled/roasted yam and plantain served with roasted fresh fish with vegetables, cooked beans, groundnut paste, moimoi, kuli-kuli, fura da nono, brurukutu (food drink), palm wine, zobo, soya bean milk, yam porridge, boiled/roasted corn, fried potato, *dodo*, melon cake, palm oiled rice/stew rice, fried/roasted grasshopper and termites.

The risks of consuming industrially refined foods

The increasing complexity of food production, processing/refinement has stirred up much worry concerning food processing contaminants that pose grave health challenge to the public (Ahmadullah, Zhiwe and Iftikha, 2024). Industrially refined foods are also extended to include genetically modified organisms (GMOs) which include crops, vegetables and fruits as such to bring about desired qualities of plants that can enhance our nutrition among other target benefits. This technology is known not to be full proof as it does not have checks and balances that are put in place by nature in traditional or natural breeding, thereby occasioning genetic fluidity that sometimes bring about unintended genetic outcomes. These unintended genetic outcomes are suspected to be causes of the so strange diseases that are prevalent in our contemporary times (Panse, 2014).

No doubt that the much consumed industrially-processed foods have injurious effects on our heAlth. These chemicals could be constituents of the basic ingredients that make up the food or functioning as preservatives. They are responsible for the incidence of diseases in our society, especially cancer to mention among others as heart diseases, etc. which are closely linked with the type of foods we eat (Undie and Onnoghen, 2017).

It is common place to see children with diseases that only adult should have had. Grace Communication Foundation (2016) maintained that these are not real foods because they are over chemicalised and denatured such that they contribute to diseases that reduce the longevity of humans unprecedentedly.

Multidimensional benefits of consuming traditional foods

In the light of Cultures for Health (2015), below are the following benefits of consuming traditional foods. Control of ingredients**:** In preparing your traditional foods you will have knowledge of what goes into them. It saves money**:** Preparing your traditonal food seems to be cheaper. Flavour control through fermentation control: Flavour from traditional foods of peoples differs from place to place, and can as well be hated or offensive to others outside that culture owing to the aroma. An example is "dawadawa" (fermented locust beans). Tamang (2016) asserted that fermented foods are healthy, functional, therapeutic, nutraceutical, or bio-foods. That, these foods contain microorganisms that transform the nutrients, the taste, texture, and odour of the foods which makes them to become traditional delicacies. The fermentation of cassava tubers for garri, fufu and abacha is being detoxified by lactic acid bacteria. In summary, fermented foods according to Mercola (2004) are good for metabolic types, strengthen digestion systems, reduces carbohydrates, build

up immunity and helps us fight diseases. Consuming traditional foods gives you the opportunity to eat what you grew up with. Eating what is compatible with you turns up one's emotions positively which therefore impacts on one's health (Undie and Onnoghen, 2017). Passing it on to the next generation**:** Consuming traditional foods helps to preserve and transmit cultural heritage of a people from one generation to another. Careful watch over allergens**:** Some foods contain so much allergens because they are industrially-made, chemicalized, and biogenically modified. McGill (2016) reported that a study in 43 Artic communities confirmed the benefits of traditional foods. Thus, these foods contain: less calories which helps in weight control; less saturated fat which helps in the heart; more lean meats and fish; more iron that is good for muscles and blood; more zink which helps in wound healing and fighting infections; more vitamin A and is good for vision and fighting diseases; more calcium better for strong bones and teeth; they strengthen cultural capacity and well-being. Most of these traditional foods have the potency of managing chronic diseases like diabetes, hypertension, prostates cancer, erectile dysfunction, HIV, etc. Chipo (2010) identified the benefits of African diets that, they have high fibre which plays a role in the prevention of some forms of colon cancer, and reduces the risk of developing type 2 Diabetes. They have low sodium as African foods rely on the natural flavours of the foods used. Salt is only used in moderate amounts. With the foods being minimally processed, the tendency of the foods to take in sodium is almost low. This tends to prevent the risk of cancer. Chipo (2010) also stated that traditional African foods are grown from manure soil and the seeds are almost not genetically engineered. That the benefit of eating food in this natural/organic state means less pesticides and chemicals entering the human body which improves the general health of the population. More so, Chipo went further to state that the cooking methods employed in preparing African diet is so beneficial to our health as our foods are cooked in leaf wrappers, boil grill, roasted or baked with ashes. Also, African diets are varied such that they provide adequate nutrients for health.

The way forward towards reversing the trend of unwholesome refining of traditional foods

Having explored the negative effects associated with the consumption of industrially refined foods one recommends therefore that:

- The government should include in the curriculum a discrete core subject that carters for our various cultural foods or its content diffused into compatible subjects like social studies, citizenship education and home economics.
- Government agencies, non-governmental agencies and concerned individuals with the mandate of preserving, transmitting, and transforming our cultural heritage should aggressively intensify their activities or bring up activities that will orientate, promote and encourage the shifting from industrially processed foods which have become a modern trend to various cultural foods in Nigeria.
- Government agencies like Standard Organization of Nigeria (SON); National Agency for Food and Drug Administration and Control (NAFDAC); and National Drug Law Enforcement Agency (NDLEA) with their respective responsibilities should be made to be more equipped, and committed to their responsibilities. Also, made to regularly organize campaigns, workshops, and seminars that can help to promote the consumption of traditional foods.
- Heritage centers be established in all the cultural entities in Nigeria where cultural foods are exhibited, and if possible, prepared for sales.
- The government should be concerned by stepping up their involvement in promoting agricultural festivals and shows in Nigeria.

Economic policies that will help to strengthen and diversify the economy from import oriented to export-oriented should be expedited so that our markets would not be saturated with so much imported foods which mostly are industrially processed.

Conclusion

With the ever-increasing **i**ncidence of poor health experienced by Nigerians, which makes life expectancy to be low**,** it has become necessary that we all should be traditional nutrition-conscious and literate, given that researchers have proven and have advocated for a resort to these traditional foods. These undoubtedly made our ancestors to be healthier, and their lives elongated. Though, socioeconomic complexities, it is

understood that, the resort to industrially-processed food is unavoidable, but caution and regulation should be emphasized and applied.

References

Ahmadullah, Z. Zhiwe, G. and Iftikha, A. K. (2024). Public health risks associated with food process contaminants- a review. Accessed, February 25, 2025

Batalion, N. (2009). Fifty harmful effects of genetically modified food. https://www.researchgate .net/publication/23 on Accessed, February 25, 2025

Cultures for Health (2015). Many benefits of preparing cultured food. https://health.com/learn/general/many-benefits-preparing-cultured-foods/?email+andev Accessed, February 25, 2025.

Enu, D.B., Undie, J.B., Odey, C. O. (2019). *The role of social studies in promoting ethics and moral values for nation-building and leadership development among youth in a multi-ethnic Nigerian society*. Nigeria Journal of Social Studies and Civic Education. 10(2),10-22

Grace Communication Foundation (2016). How industrial foods impact your health. www. Sustainable table.org/941/ how-in… Accessed, February 25, 2025.

IFAD (2015). Nigeria spent n1trn on food import in one year. the union.com.ng>Home>Agriculture on Accessed, February 25, 2025.

Index Mundi (2014). Nigeria-food imports. www.indexmundi.com>Home>countries>Nigeria>private sector and trade Accessed, February 25, 2025

Macrotrends (2025). Nigeria life expectancy 1950-12015. Macrotrend.net/glo Accessed, February 25, 2025

McGill (2016). Benefits of traditional foods. https://www.mcgill.ca/cine/research/canada/food/benefits Accessed, February 25, 2025

Mercola, J. (2004). The incredible health benefits to you of traditionally fermented food. articles.mercola.com/sites/articles Accessed, February 25, 2025

Panse, S. (2014). Disadvantages and advantages of genetically modified food. Both sides of the debate. www.brightub.com/science /genetics/articles/23358. Aspx on Accessed, February 25, 2025.

Tamang, J. P. (2015). Benefits of traditionally fermented foods. https://ourworld.unu.edu/en/benefits-of-traditonal-fermented-foods on 7/8/016. Accessed, February 25, 2025

Undie, J.B. (2016). *Vocational and technical occupational choice as a panacea for the incidence of unemployment in Nigeria: An imperative for guidance counsellors.* African Journal of Vocational Education.5(1), 164-170.

Undie, J.B. and Onnoghen, N. U. (2017). *Promoting cultural food to reduce the risk of industrially made food: A necessity towards ensuring healthy lives in Nigeria.* Education for Today.13(1), 225-231.

Undie, J.B. (2016). *Role of social studies as imperative for socioeconomic problem in Nigeria.* Education for Today.12(1), 171-176

Undie, J.B. Aboh, F.I. and Omang, C.E. (2025). *Globalisation: Its effects on sociocultural practices in Nigeria.* Global Journal of Pure and Applied Sciences. 31(2),445-449

BOOK OF PROCEEDINGS FOR THE 11TH REGIONAL FOOD SCIENCE AND TECHNOLOGY SUMMIT -East Central Chapter

Advances in Sustainable Food Packaging Technology: A Review

*Salaudeen, O. H., and Atoo, T. S.

Joseph Sarwuan Tarka University Makurdi, Benue State

Corresponding author: hammed.salaudeen@uam.edu.ng

ABSTRACT

Food packaging industry involves a number of actors which include producers, retailers, consumers and researchers. Each of the actors in the cycle has the primary aim to protect the food from degradation by environmental and human factors and also ensure delivery of food items to ultimate consumers in safe and sound condition. In addition to protection, food package also serves as means of communication between producer and consumer by carrying vital information about the content specification, producer's information, product handling tips and storage requirements. It requires that during containment the package should behave inert and prevent chemical migration between the package and the food. The materials that are commonly used in food packaging are glass, metals papers and plastics. Numerous laminates and coatings with different physical, chemical and barrier properties were developed from these traditional packaging materials. This paper reviews recent innovations in food packaging technology with emphases on principles and applications of active and intelligent packaging, nanotechnology, antimicrobial packaging, edible coatings and films for sustainable packaging.

Keywords: Sustainable packaging, Active packaging, Nanotechnology, Antimicrobial packaging, Food safety

Introduction

Packaging surrounds and protects food after manufacturing, defend its integrity through transportation, handling, storage and retailing, and ensure its wholesomeness during consumption. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely from point of origin to the point of consumption (Prasad and Kochhar, 2014). Food packaging has evolved from simply a container to hold food to something today that can play an active role in food quality. Many packages are still simply containers, but they have properties that have been developed to protect the food (Risch, 2009). Packaging today plays an important role in the quality of food products by providing protection from environmental, chemical and physical challenges. This protection can be as simple as preventing breakage of the product to providing barriers to moisture, oxygen, carbon dioxide, and other gases as well as flavors and aromas. Packaging can block light to protect nutrients and colors in a product from deteriorating. In addition to providing passive protection, many packages today play an active role in the quality of a product by helping to maintain a desired atmosphere around the product (Risch, 2009; Pawar and Aachal, 2013). New trends in food packaging industry aimed at reducing food waste by improved preservation of food through prolonging it shelf-life (Tanja *et al*., 2016).

Changes in consumer preferences have led to innovations and developments in new packaging technologies (Dobrucka *et al.,* 2015). Demand for quality food has driven packaging innovation (Risch, 2009), demand for convenience foods will also continue to be fueled by the aging of our population, the diminished cooking skills of the typical consumer and the reduced time available for home preparation of meals (Eilert, 2005). Increase in incomes in traditionally less economically developed countries has led to a rise in standards of living that includes a significantly higher consumption of packaged foods (Nitaigour, 2014). These developments led to improvement in food processing and packaging technologies.

Packaging has allowed us to have a wide variety of food year-round that would not be possible without the protection of the package. Foods now have a longer shelf life, resulting in less loss due to spoilage. Packaging also provides for convenience with products that can be heated in the package and products that

can be purchased as single-serve items (Dobrucka and Cierpiszewski, 2014). The dynamic nature of food packaging technology will be a continuous process with development of new packaging materials to reflect development in food technology, material and environmental sciences and consumers' preference (Dele, 2012; Dari *et al.,* 2018).

In recent years packaging has developed well beyond its original function as merely a means of product protection and now plays a key marketing role in developing on shelf appeal, providing product information, and establishing brand image and awareness (Kour *et al.,* 2013). Modified atmosphere, control atmosphere and intelligent packaging can extend shelf life and smart packaging can communicate quality indices of it is content (Marina *et al.,* 2015). These development is a response to increase in consumer's demand on mildly preserved, fresh, testy and convenient food products with prolonged shelf-life and controlled quality (Dobrucka *et al.,* 2015). Packaging of the future is likely to be more than just a physical container that provides food with protection from the surrounding environment (Cushen *et al.,* 2012).

Food Packaging Technology

Food Packaging Technology refers to the creation, formulation of the technology that is suitable for protecting products from external impacts such as sunshine, insects, rodents, hazards that are inherent in transportation, humidity, extreme temperatures, wetness and contaminations.

Table 1: Examples of packaged foods and packaged type

Packaging type	Type of container	Examples of foods packaged
Aseptic packages	Primary	Liquid whole eggs
Plastic trays	Primary	Portion of fish
Bags	Primary	Potato chips, salt
Bottles	Primary	Bottle of a soft drink
Boxes	Secondary	Box of a soft drink bottles
Cans	Primary	Can of tomato soup
Cartons	Primary	Carton of eggs, cooking cube
Flexible packaging	Primary	Bagged salad
Pallets	Tertiary	A series of boxes on a single pellet, to transport packaged food from the manufacturing plant to a distribution centre.
Wrappers	Tertiary	Used to wrap the boxes on the pallet for transport.

Source: (Floros, 1993)

The Role of Packaging Technology in Food Product

Food packaging is a life necessity that has evolved and is still evolving to suit the requirements of the consumer and modern society. Commercially manufactured food cannot be processed without packaging and packaging materials, as the world packaging organization estimates and distributes that more than 25% of the food is lost due to poor packaging, which in turn places the burden on packaging to reduce the great loss of food through the continuous development of packaging materials. And methods in proportion to the food product. The use of renewable edible agricultural materials which major role in the food industry has increased because the development in technologies to improve the properties of edible polymers is the main issue in future research. Most of the studies today are focused on extending the shelf life of food in

the application of biological or biological membranes and covering food with the most important advantages of edible films that have aroused consumer interest, which are made of natural edible materials, non-toxic and non-polluting to the environment compared to plastic films and increase the nutritional value when present as a film over the food and controlling the water content in the food wrapped in it, whether in not absorbing or losing moisture, as well as protecting it from the absorption or loss of flavors and does not require expensive techniques and thus reduce the production cost and the cost of treating environmental pollution implicitly without the presence of residues for packaging when used, in light of the wide range of food products such as meat (fish, poultry, beef) and other foods that are very sensitive to fat oxidation and microbial contamination, these products are considered to have edible, antioxidant and microbial membranes very important in their protection targeting innovative trends. In the field of food packaging research in introducing improvements in food quality and safety and increasing the shelf life or period validity as well as quality control based on equipment and international quality standards, where strategies in packaging represent the development of multi-functional packaging materials based on the use of renewable biodegradable materials and natural additives as well as their traditional packaging functions (containment, protection, marketing, provision and consumer).

The Expanded Roles of Food and Beverage Packaging

The principal function of packaging is protection and preservation from external ontamination (Robertson., 2006). This function involves retardation of deterioration, extension of shelf life, and maintenance of quality and safety of packaged food. Packaging protects food from environmental influences such as heat, light, the presence or absence of moisture, oxygen, pressure, enzymes, spurious odors, microorganisms, insects, dirt and dust particles, gaseous emissions, and so on. All of this cause deterioration of foods and beverages (Marsh and Bugusu, 2007). Prolonging shelf life involves retardation of enzymatic, microbial, and biochemical reactions through various strategies such as temperature control; moisture control; addition of chemicals such as salt, sugar, carbon dioxide, or natural acids; removal of oxygen; or a combination of these with effective packaging (Robertson, 2006).

Precise integration of the product, process, package, and distribution is critical to avoid recontamination. The ideal packaging material should be inert and resistant to hazards and should not allow molecular transfer from or to packaging materials (Robertson, 2006).

2.0 TECHNOLOGICAL ADVANCES IN FOOD PACKAGING

Traditional Packaging technology

Food packaging goes back to prehistoric times. It started with the use of natural materials such as leaves, twigs, shells, animal skins, gourds, hollowed logs, etc. to hold edibles. But as man's lifestyle evolved so did the packaging techniques. With the development of cities and trade concepts, the need for storage and distance transportation arose. This in turn, led to the creation of wooden crates, boxes, pottery, clay, pots, stem, baskets and barrels for transportation and stashing away of surplus liquids and dry goods.

Active and Intelligent/Smart Packaging

Active Packaging of Food Products

Active packaging is accurately defined as 'packaging in which subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system.

Developments in active packaging have led to advances in many areas, including delayed oxidation and controlled respiration rate, microbial growth and moisture migration. Other active packaging technologies include carbon dioxide absorbers/emitters, odour absorbers, ethylene removers, and aroma emitters. Active packaging technologies include some physical. chemical, or biological action which changes interactions between a package, product, and/or headspace of the package. The most common active systems scavenge oxygen from the package or the product and may even be activated by an outside source such as UV light. However, allows packages to interact with food and the environment and play a dynamic role in food preservation. The packaging systems are developed with the goal of extending shelf life for foods and increasing the period of time that the food is high quality. Active packaging is typically found in two types

of systems: sachets and pads which are placed inside of packages and active ingredients that are incorporated directly into packaging materials.

Common Active Packaging Materials: Sachets and Pads

In order to absorb or emit gases to a package or headspace, sachets and pads are very commonly used. Sachets were developed in the late 1970s in Japan. For oxygen scavenging, the sachets essentially utilize the process of rusting, or the oxidation of iron compounds in the presence of oxygen and water. Oxygen scavengers can also be made based on enzyme technology. Oxygen absorbers are usually made of powdered iron or ascorbic acid. Iron based scavengers typically do not pass the metal detector inspections on most packaging lines, and in these incidences ascorbic acid is advantageous. These pads prevent the growth of molds or bacteria by absorbing water into superabsorbent polymer granules placed between two layers of micro porous nonwoven polymer. Although sachets work well in many applications, they are not appropriate for every situation. Sachets cannot be used in liquid foods.

foods.

Application of Active Packaging

The following are commercial applications of active packaging system

- Oxygen scavenging
- Carbon dioxide emitters and scavengers
- Moisture control
- Ethylene absorbers
- Antimicrobials

Intelligent Packaging

Intelligent packaging systems exist to monitor certain aspects of a food product and report information to the consumer. The purpose of the intelligent system could be to improve the quality, or value of a product, to provide more convenience, or to provide tamper or theft resistance. Intelligent packaging can report the conditions on the outside of the package, or directly measure the quality of the food product inside the package. In order to measure product quality within the package, there must be direct contact between the food product or headspace and the quality marker. In the end, an intelligent system should help the consumer in the decision-making process to extend shelf life, enhance safety, improve quality, provide information, and warn of possible problems. Intelligent packaging is a great tool for monitoring possible abuse that has taken place during the food supply chain. Perhaps intelligent packaging will be able to inform a consumer of an event that occurred such as package tampering that may save their life. Examples include time-temperature indicators (TTIs), ripeness indicators, biosensors, and radio frequency identification. These smart devices may be incorporated in package materials or attached to the inside or outside of a package. However, the U.S. Food and Drug Administration (FDA) recognizes TTIs in the 3rd edition of the Fish and Fisheries Products Hazards and Control Guidance, so their importance may increase in the seafood industry.

Application of Intelligent Packaging

- Time Temperature Indicators (TTIs)
- Gas Indicators
- Thermo chromic Inks
- Radio Frequency Identification (RFID)
- Leak indicators (CO_2, 0_2)
- Pathogen indicators

Smart Packaging is an amplified packaging systems (Active And intelligent) that permits transparency through an instantaneous ability to track and trace the exact location of a product in the supply chain using

unique barcodes, QR codes, or RFID technology. These features enable predictive planning and more efficient inventory management.

Developing smart packaging to optimize product shelf life using nanotechnologies has been the goal of many companies. Such packaging systems would be able to repair small holes/tears, respond to environmental conditions such as temperature and moisture changes and alert the customer if the food is contaminated (Alfadul and lneshwy, 2010). Unlike traditional packaging, which must be totally inert, active packaging is designed to interact with the contents and/or the surrounding environment (Prasad and Kochhar, 2014). The packaging material interacts with the food to confer longer shelf-life, also improve hygiene safety and organoleptic properties, minimise food losses and increase regularity of the food (Nitaigour, 2014; Dobrucka et al*.,* 2015; Amra et al*.,* 2015).

The advancement in novel food packaging technologies involves retardation in oxidation, hindered respiratory process, prevention of microbial attack, prevention of moisture infusion, use of CO_2 scavengers/emitters, ethylene scavengers, aroma emitters, time-temperature sensors, ripeness indicators, biosensors and sustained release of antioxidants during storage (Ishrat et al., 2016).

Active and Intelligent Packaging – The Future

These packaging technologies anticipated to grow significantly over the next 10 years, due principally to

- Consumer demands for meat and other food products which are premium qualities and which provide adequate shelf-life, safety, conveniences and information.
- Reduction in packaging material costs as formats grow in popular/sales volume, and as newer and cheaper formats emerge through research and development.

Benefit of Smart Packaging

Smart packaging has become increasingly popular in the food and beverage, healthcare, and personal care industries-but the technology can be beneficial for nearly and field where quality control and real-time information is critical.

Depending on your food product and objectives, smart packaging can be designed to achieve a range of benefits, including:

a. Access to supply chain and consumer data.
b. Improved freshness and quality of food and pharmaceuticals
c. Improved compliance, authentication and traceability
d. Extended shelf life
e. Anti-counterfeiting and brand security
f. Reduce waste and costs
g. Optimized logistics

Nano Technology in Food Packaging

Nanotechnologies involve the manipulation of matter at a very small scale generally between 1 and 100 nanometres. Many large international food companies are exploring the potential of nanotechnologies for applications in the food sector. Recent research has highlighted the potential for nanotechnologies use in wide ranging food applications, including novel food packaging (Cushen et al*.,* 2012). Application of nano-science and technology in food packaging is predicted to be increasing in the next two decades (Peelman et al., 2013). Potential benefits were reported particularly in food-package interaction and monitoring of quality and freshness (Amal, 2015).

Nanosensor are extremely small device than can bind to whatever is wanted to be detected and send back a signal. These tiny sensors are capable of detecting and responding to physicochemical (sensors) and biological signal (biosensors), transferring that response into a signal or output that can be used by humans. Various nanosensors were developed for detection of internal and external conditions in food packaging

(Omanović-Mikličanin and Maksimović, 2016). Nanosensors can be used to determine microbes, contaminants, pollutants, and ultimately the freshness of the food (Joyner and Kumar, 2015).

Food contact materials have been developed with improved flexibility, gas barrier properties, temperature control and moisture stability due to the inclusion of nanoscale fillers. The effect a nanopackaging has on a food depends on the composition of the nanomaterial that involved. (Cushen et al*.,* 2012). In addition to protection, nanofillers reduces the use of plastics as packaging materials, and also required less energy for their production and biodegradation, these make them more friendly to environment (Sozer and Kokini, 2009). Nanomaterials and nanoparticles may include any of the following nano forms: nanoparticles, nanotubes, fullerenes, nanofibres, nanowhiskers, nanosheets (Cushen et al*.,* 2012).

Application of nanosensors in food packaging will assist consumers in purchasing fresh and tasty products and also improve food safety (Omanović-Mikličanin and Maksimović, 2016). Consumers rely on expiry date in food package provided by producers which is based on the assumption of the required storage and processing conditions. When either of these requirements is abused the product may likely deteriorate and this may not be known to consumer unless the food package is open. Nanosensors can offer solutions to this problem when apply to food package because they can detect presence of gasses, aromas, chemical contaminants, pathogens, and even changes in environmental conditions (Cushen et al*.,* 2012; Joyner and Kumar 2015). Advancement in food packaging requires development of toxic free and degradable or edible packaging materials that are safe for human and environment (Kour et al. 2013).

Despite the tremendous benefits of nanoparticles in food industry, there is great public concern regarding toxicity in human and the environment (Mahmoud, 2005). Lack of knowledge about the effectiveness and impact of nanoparticles on the environment and on human health is of great concern due to potential risk resulted from migration of nanoparticles into the food (Amra et al*.,* 2015). The migrants may likely react with oxygen and produce toxic substance (Abeer and Choudhary, 2013). There is a growing scientific evidence, which indicates that some free nanoparticles may cause harm to biological systems because of their ability to penetrate cellular barriers, and induce oxyradical generation that may cause oxidative damage to the cell (Chaudhry et al. 2008). There is an urgent need for regulation of nanomaterials before their incorporation into food processing, packaging, and food contact (Alfadul and lneshwy, 2010). Before releasing any new product with the nanotechnology in food system, manufacturers must thoroughly assess its risk on human, animal and environmental health (Abeer and Choudhary, 2013).

Antimicrobial Packaging

Antimicrobial packaging involves combination of food-packaging materials with antimicrobial substances such as the incorporation of antibacterial nanoparticles into polymer films to control microbial surface contamination of foods (Dele, 2012). Antimicrobial food packaging systems have received considerable attention since they help control the growth of pathogenic and spoilage microorganisms on food surfaces (Amra et al*.,* 2015). Development of antimicrobial packaging requires multidisciplinary approach in the fields of food and material sciences. There are different studies on different nanoparticles incorporated into various polymeric matrices, and results are indicating a great potential of antimicrobial nanocomposite system for prolonging the shelf-life and preservation of different food stuff. However, it is clear that this part of active packaging solution is still in the developing phase, because there are not so many studies on the real food systems (Tanja et al*.,* 2016). Nano-silver antimicrobial food packaging application is a novel approach toward the preservation of foods and the extension of their shelf-life (Amal, 2015). Intensive contact between the food product and packaging material is required in antimicrobial packaging, therefore, potential food applications include vacuum or skin-packaged products, e.g. vacuum-packaged meat, fish, poultry or cheese (Dele, 2012).

Basic categories of antimicrobial packaging systems include;

4. incorporation of antimicrobial substances into a sachet connected to the package from which the volatile bioactive substance is released during further storage;
5. direct incorporation of antimicrobial agent into the packaging film;
6. coating of packaging with a matrix that acts as a carrier for the antimicrobial agent (Sunil, 2012). Tinja et al. (2016) summarized in Table 2 showing antimicrobial effects of different nanoparticles used in different antimicrobial packaging system.

Edible Coatings and Films

Edible films and coatings are thin layer of material which can be consumed and provides a barrier to moisture, oxygen and solute movement for the food (Bourtoom, 2008). Edible films coatings form an integral part of the food product, and hence should not interfere with ensory characteristics (Guilbert, 1997). Traditionally, edible wax coatings have been applied to the fresh produce surface in order to improve appearance, reduce bruising during handling and shipping, reduce weight loss, and to provide a carrier for active compounds. Commodities commonly coated include apples, avocados, bell peppers, cantaloupes, cucumbers, eggplants, grapefruits, lemons, limes, melons, oranges, parsnips, passion fruit, peaches, pineapples, pumpkins, rutabagas, squash, sweet potatoes, tomatoes, turnips and yucca. The edible macromolecules used as the coating can be classified into polysaccharides, proteins, and lipids. Comprehensive information on the use of edible coatings on fresh produce can be found in Baldwin (1994). The physical properties of the coating and its permeability to moisture, oxygen, and carbon dioxide are important in realizing its beneficial effects. One recent trend is the development and use of edible coatings that can improve the safety and quality of fresh-cut produce.

Table 2. Summary of antimicrobial packaging systems with different nanoparticles

Nanoparticles	Polymer matrix	Tested microorganisms	Reference
Ag/Chitosan	PLA1	*Staphylococcus aureus* (ATCC6538) *Escherichia coli* (DSMZ 30083)	Turalija et al. (2016)
Ag	Agar banana powder	*Escherichia coli* *Lysteria monocytogenes*	Orsuwan et al. (2016)
TiO2/Ag/Cu	PVC[2]	Mixed microorganism culture media	Krehula et al. (2016)
ZnO/Ag/Cu	PLA1/PEG3	*Lysteria monocytogenes* *Salmonella typhimurium*	Ahmed et al. (2016)
Ag	PE[4]	*Escherichia coli*	Eslami et al. (2016)
Ag/Cu	Guar Gum	*Lysteria monocytogenes* *Salmonella typhimurium*	Arfat et al. (2017a)
Ag/TiO2	PE	*Aspergillus flavus*	Li et al. (2017)
Ag/Cu	Fish skin Gelatin	*Lysteria monocytogenes* *Salmonella enterica* sv Typhimurium	Arfat et al. (2017b)
Ag	Starch/PVA[5]	*Lysteria inocua; Escherichia coli Aspergillus niger; Penicillium, expansum*	Cano et al. (2016)
Ag/SiO2/TiO2	LDPE[6]	*Escherichia coli*	Becaro et al. (2016)
Ag	PHBV3[7]	*Salmonella enterica* *Lysteria monocytogenes*	Castro-Mayorga et al. (2017)
SiO2	PBAT[8]	*Escherichia coli;* *Staphylococcus aureus*	Venkatesan and Rajeswari (2016)
ZnO	LDPE	*Bacillus subtilis; Enterobacter aerogenes*	Esmailzadeh et al. (2016)
ZnO	MC[9]	*Staphylococcus aureus; Lysteria monocytogenes*	Espitia et al. (2012)
Nanoclay (NaMMT, OrgMMT)	PVOH/chitosan	*Escherichia coli*	Giannakas et al. (2016)

1 Polylactic acid; 2 Polyvinylchloride; 3Polyethylene glycol; 4 Polyethylene; 5 Polyvinyl alcohol; 6 Low density polyethylene; 7 poly(3-hdroxybutyrate-co-3mol%-3-hydroxyvalerate); 8 poly(butylene adipate co-terephatalate; 9 Methyl cellulose

Source: Tinja et al. (2016)

Edible coatings may contribute to extending the shelf life of fresh-cut produce by reducing moisture and solute migration, gas exchange, respiration and oxidative reaction rates, and by reducing or even suppressing physiological disorders (Rojas-Graü *et al.,* 2009).

Sustainable Packaging

Sustainable and green protocols recommend the use of biodegradable and environmentally friendly materials for food packaging as many packaging materials generates waste. There is renewed focus on creating sustainable packaging and some of the examples of those materials are polylactide acid (PLA) plastics, sugar cane pulp, fiber composite, starch-based films, and so on (Nitaigour, 2014). Biopolymers have been around for billions of years longer than synthetic polymers like plastics. They are generated from renewable natural sources, are often biodegradable, and not toxic to produce. They can be produced by biological systems (i.e. micro-organisms, plants and animals), or chemically synthesized from biological starting materials (e.g. sugars, starch, natural fats or oils, etc.) (Pawar and Aachal, 2013). Sustainable packaging is a complex idea which must be applied with a systematic approach and critical thinking.

Factors to be considered in evaluation of packaging sustainability

- The entire lifecycle of the package from raw materials through to ultimate disposal to avoid problems being transferred from one part of the lifecycle to another
- The interactions between the package and the product it contains so that the environmental impacts of the product-packaging system as a whole are minimized.
- There is need to consider 'triple bottom line' impacts of packaging: on the business, people and the environment.
- Four principles of sustainable packaging were originally identified by Sustainable Packaging Alliance under the headings of 'effective', 'efficient', 'cyclic' and 'clean' (Helen et al*.,* 2007).

Conclusion

Changes in consumer's preferences, demand for convenience and quality, diminish in cooking skill, limited time available for home preparation of meal, needs to develop an environmental friendly packages and competition between producers in developing shelf appealing packages led to technological advancement in food packaging technology. These forces will be driving the dynamic nature of packaging industry and result in further innovations in food packaging. Number of techniques were developed to tackle these challenges, these include active and smart packaging technology, application of nanotechnology in food packaging, antimicrobial packaging, food packaging using edible films and coating and sustainable packaging and more innovations are expected in near future. It is always important to assess and quantify the potential risk of new technologies in order to avoid damage to food, consumers and the environment.

References

Abeer A. and Choudhary R. 2013. Current practices in bread packaging and possibility of improving bread shelf life by nanotechnology. International Journal of Food Science and Nutrition Engineering, 3(4): 55-60.

Alfadul S. M. and lneshwy A. A. 2010. Use of nanotechnology in food processing, packaging and safety – Review. African Journal of Food, Agriculture, Nutrition and Development, 10(6):2719-2739.

Amal M. M. 2015. Effects of nanocomposite based nano-silver and nano-titanium dioxideon food packaging materials. International Journal of Applied Science and Technology, 5(2):26-35.

Amra B., Amra O. S. and Ćatić, I. Š. 2015. Application of polymer nanocomposite materials in food packaging. Croat. J. Food Sci. Technol, 7(2):86-94.

Bourtoom T. 2008. Edible films and coatings: characteristics and properties. International Food Research Journal, 15(3): 237-248.

Cushen M., Kerry J., Morris M., Cruz-Romero M. and Cummins E. 2012.Nanotechnologiesin the food industry- Recent developments, risks and regulation. Trends in Food Science & Technology, 24:30-46.

Dari, L., Nenguwo, N. and Afari-Sefa, V. 2018. Evaluation of packaging liners in wooden and plastic crates for handling tomatoes. Journal of Postharvest Technology, 6(1): 36-40.

Dele R. 2012. Application of plastics and paper as food packaging materials – An overview. Emir. J. Food Agric. 25(3):177-188.

Dobrucka R. and Cierpiszewski R. 2014. Active and intelligent packaging food – research and development – A Review. Pol. J. Food Nutr. Sci., 64(1):7-15

Dobrucka R., Cierpiszewski R. And Korzeniowski A. 2015. Intelligent food packaging - research and development. LogForum 11(1):7-14.

Guilbert S., Cuq, B. and Gontard, N. 1997. Recent innovations in edible and/or biodegradable packaging materials. Food Additives and Contaminants 14:741-751.

Ishrat M., Gulzar A. N., Shuaib M. D. and Vikas N. 2016. Novel food packaging technologies: Innovations and future prospective. Journal of the Saudi Society of Agricultural Sciences, http://dx.doi.org/10.1016/j.jssas.2016.11.003.

Joyner J. R. and Kumar D. V. 2015. Nanosensors and their applications in food analysis: A review. The International Journal of Science & Technoledge, 3(4):80-90.

Kour H., Naseer A. T., Anisa M., Rajkumari K., Harmeet C., Gupta P., Anju B. and Jagmohan S. 2013. Advances in food packaging – a review. Stewart Postharvest Review, 4(7):1-7.

Mahmoud M. B. 2005. Nanotechnology in food industry; advances in food processing, packaging and food safety. Int. J. Curr. Microbiol. App. Sci. 4(5):345-357.

Marina R., Arantzazu V., Ana C. M. and María C. G. 2015. New trends in beverage packaging systems- a review. Journal of Beverages 1(1):248-272.

Nitaigour P. M. 2014. Advances in packaging methods, processes and systems. Challenges 5:374-389.

Omanović-Mikličanin E. and Maksimović M. 2016. Nanosensors applications in agriculture and food industry. Bulletin of the Chemists and Technologists of Bosnia and Herzegovina, 47:59-70.

Pawar P. A. and Aachal H. P. 2013. Bioderadable polymers in food packaging. American Journal of Engineering Research 2(5):151-164.

Peelman N., Ragaert P., De Meulenaer B., Adons D., Peeters R., Cardon L., Impe, F.V. and Devlieghere F. 2013. Application of bioplastics for food packaging.Trends in Food Science & Technology, 32(2):128-141.

Prasad P. and Kochhar A. 2014. Active Packaging in food industry-a review. Journal of Environmental Science, Toxicology and Food Technology 8(5):01-07.

Risch S. J. (2009). Food packaging history and innovations. J. Agric. Food Chem. 57:8089–8092

Sozer, N., & Kokini, J. L. 2009. Nanotechnology and its applications in the food sector. Trends in Biotechnology, 27(2):82-89.

Tanja I. R., Ivan S. R., Branka M. P. and Aleksandra R. N. 2016. Antimicrobial nanomaterials for food packaging applications. Food and Feed Research, 43(2):119-126.

Functional Properties of Maize-Date Pap Fortified with Palm Oil

*Udeze, M. E.[1] Ikegwu, T. M.[2] and Omologbe F.[3]

1.Department of Food Technology, Nnamdi Azikiwe University, Awka, Anambra State.

*Corresponding author's email: udezemmeso@gmail.com

ABSTRACTS

This study was carried out to evaluate the functional properties of powdered pap enriched with date fruit and fortified with palm oil. The samples (50:40:10), (38.10:47.62:14.28), (42.11:52.63:5.26), (40:30:15), and (33.18:40:10) were obtained from the blends of the maize, date and palm oil in different ratios, while 100% maize flour served the control. The functional properties results showed there were significant difference ($p<0.05$) in the BD, WAC, OAC, FC and LGC of the samples ranged from 0.55 - 0.58g/ml, 1.50 - 4.00 ml/g, 2.00 - 3.50 ml/g, 0.50-4.91% and 12.00 %, respectively. The result revealed that the enrichment and fortification of powdered pap with date and palm oil, respectively enhanced its functional properties and could be used for novel food product in the food industry

Keywords: Functional properties, Maize flour, fortification, Pap,

1.0 Introduction

It is essential to acquire fundamental knowledge about maize and date as each combination has a medicinal attribute that will help some kinds of sickness such as diabetes. According to Awika (2011), maize (Zea mays) is a member of the grass family (Poaceae). It is an established and important human food crop in a number of countries, especially in South America, Latin America, and a few countries in Asia, where maize is consumed as food and contributes over 20% of food calories (Shiferaw *et al*., 2011). Zea mays is a stable cereal very popular due to its high nutritional significance enriched with an abundant amount of macronutrients like starch, fibre, protein and fat along with micronutrients like vitamin B complex, ß-carotene and essential minerals, i.e. magnesium, zinc, phosphorus, copper (Shiferaw *et al*., 2011). The diversity of maize products and uses also have some implications for its commoditization and trade. Specialty maize is suitable for specific end uses but implies the need to maintain product stewardship during production, supply, and distribution chains (Scott *et al*., 2019). Date palm (*Phoenix dactylifera* L.) is found to be low in fat and protein but rich in sugars, mainly fructose and glucose (Awad *et al., 2015)*. It is a high source of energy, as 100 g of flesh can provide an average of 314 kcal. Date palm fruits are a safe, natural alternative and complementary treatment comparable with synthetic drugs to combat many disease conditions. In addition to its traditional and medicinal uses, the exploration of the prospective use of date palm fruits in food and pharmaceutical applications is needed (Zineb *et al*., 2012). Date fruit is used as traditional medicine in some cultures for the treatment of ailments such as intestinal disorders, fever, bronchitis, diabetics and wound healing. Supplementation of cereals such as maize with dates known for its vitamins and minerals would increase the quality and the nutritive values of pap nutrients lost during steeping, milling and sieving processes.

Pap or *Akamu* in Igbo is a fermented cereal paste made from maize. The colour of pap mostly depends on the maize variety used, which may be cream in colour or reddish brown (Akingbala *et al*., 2081). Pap from maize is popular in eastern Nigeria, and has a smooth texture with slightly sweet taste (pH 6-7). This means the best pH level for maize is slightly acidic. Pap is also known as *akamu* or *ogi* in Yoruba and is prepared from paste with hot water after dissolving same with tap water into light thick consistency. It serves as a major weaning food for infants in West Africa or nursing mothers as it enhances breast milk supply, a good vehicle for food nutrients to sick people because it is an energy food rich in carbohydrates with traces of vitamins. It is easily digested and light in the stomach (Oyelana *et al*., 2012). Powdered pap is one that has undergone thorough drying and milling. This product is readily available in both rural and urban areas, due to its easy preparation and availability of raw materials for pap. It is widely consumed by

people of different ages and is usually served as breakfast, it also serves as complimentary foods for infants (Victor-Aduloju *et al*., 2021). It can be supplemented with, Date fruit (Phoenix dactylifera) Soy-bean (Glycine max), to enhance its aroma and taste (Victor-Aduloju *et al*., 2021).

Palm oil which is extracted from the fleshy mesocarp of the palm fruits has been a vital resource in the majority of Nigeria diet (Bassey, 2016). It is processed either traditionally or industrially which is practiced in many countries. Palm oil is also rich in vitamin A, E and K, beta carotene, and unsaturated fatty acids (Sundram *et al*., 2003). Oil palm being native to equatorial west Africa, and preferring high rainfall and a more open kind of long river banks, grow fruits in bunches weighing up to ten kilograms and containing hundreds of fruitless like small plums. The flesh is oily and the oil can be recovered by very simple means so it is well documented that palm oil has been recovered and used for human food for tens of thousands of years.

2.0 Materials and Methods

2.1 Source of Raw Materials

Maize (*Zea mays*), date palm (*Phoenix dactylifera* L.) and palm oil *(Elaeis guineensis*) used in this study were procured from Eke Awka market in Idemili South Local Government, Anambra state.

2.2 Sample Preparation

2.2.1 Production of Maize Flour

The dried maize was weighed (I kg) and soaked in water. The grain was then steeped, drained, and rinsed multiple times. Then the fermented grains were wet milled during which palm oil (50 ml) was added in the process, dehydrated and then sieved by passing through a 1 mm sieve size to yield the flour. The flour was packaged in an air tight container.

2.2.2 Production of Date Palm Flour

First the date palm fruit was sorted manually to remove the spoiled ones and unwanted materials like dirts. Then, it was washed, deseeded, oven dried and milled after that it was sieved using 0.35 mm sieve to obtain a fine powder.

2.2.3 Maize-Date Pap Formulation

The maize-date pap formulations were prepared according to the method described by the Kortney (2000). During Preparation, different formulation of the maize flour fortified with palm oil and date flour are mixed in a Kenwood mixer for 20 min to obtain various sample of instant pap mix blend.

Table 2.2.3: Maize-Date Pap Formulation

Samples Runs M.D.P	Maize (%)	Date (%)	Palm oil (%)
1	100	0	0
2	50.00	40.00	10.00
3	38.10	47.62	14.28
4	42.11	52.63	5.26
5	40.00	30.00	15.00
6	33.18	40.00	10.00

3.0 Results and Discussion

3.1 Functional Properties of Maize-date pap sample

The functional properties of the dried pap were evaluated and the result presented in table 1. There were significant differences ($p<0.05$) in the functional properties of the dried pap samples, which implied that the ratios of the substitution of the different raw materials had effect on the functional properties of the samples. The functional properties of the food materials are very important for the appropriateness of the diet, behavior of nutrients in food during processing, storage and preparation because they affect the general quality of foods as well as their acceptability (Omueti *et al*., 2009).

Table 1: Functional properties of dehydrated maize-date pap fortified with palm oil

Sample Runs M:D:P	Bulk density (g/ml)	Oil absorption (ml/g)	Water absorption (ml/g)	Foaming capacity (%)	Least gelation capacity (%)
100: 0: 0	$0.58^{a}\pm0.05$	$2.50^{d}\pm0.00$	$1.50^{d}\pm0.00$	$0.57^{d}\pm0.06$	$12.00^{a}\pm0.00$
50: 40: 10	$0.55^{b}\pm0.01$	$2.47^{d}\pm0.06$	$3.00^{b}\pm0.00$	$3.97^{b}\pm0.05$	$12.00^{a}\pm0.00$
38.10:47.62:14.28	$0.56^{b}\pm0.00$	$3.50^{a}\pm0.00$	$2.07^{c}\pm0.06$	$4.91^{a}\pm0.00$	$12.00^{a}\pm0.00$
42.11: 52.63: 5.26	$0.55^{b}\pm0.01$	$2.00^{e}\pm0.00$	$2.00^{c}\pm0.00$	$48.90^{a}\pm0.01$	$12.00^{a}\pm0.00$
50: 35: 15	$0.56^{b}\pm0.00$	$3.00^{c}\pm0.06$	$1.53^{d}\pm0.00$	$1.00^{c}\pm0.00$	$12.00^{a}\pm0.00$
33.18: 40: 10	$0.55^{b}\pm0.01$	$3.10^{b}\pm0.10$	$4.00^{a}\pm0.06$	$0.55^{c}\pm0.00$	$12.00^{a}\pm0.00$

Values are mean and standard deviation of triplicate determinations. Values with different superscripts within the same column show significant difference ($p<0.05$). M = Maize; D = Date palm fruit powder; P = Palm oil.

The bulk density of the dried pap ranged from 0.5 – 0.58 g/ml. The bulk density of the control sample (100% maize flour) differed significantly ($p<0.05$) from the other samples. The bulk density of samples with different substation levels of date palm and palm oil showed no significant differences ($p>0.05$). Bulk density is a crucial functional property in food processing as it refers to the mass of a granular or powdered substance per unit volume when it is poured freely into a container. A higher bulk density indicates that the sample is more compact and less porous, whereas a lower bulk density suggests that the sample is less compact and more porous (Omueti *et al*., 2009). Low bulk density is an advantage because it improves digestibility of food and bioavailability of nutrients. For instance, in a study on wheat bran and maize bran, bulk density was found to be influenced by particle size, with smaller particle sizes resulting in higher bulk densities (Chen *et al*., 2017). Hence, the bulk density of dried pap fortified enriched with date and fortified with palm oil could affect its handling, packaging, and storage properties as heavier samples requires more strong packaging materials for containment. A higher bulk density may indicate better compaction and reduced storage volume, but it may also increase the difficulty of dehydration during cooking. Therefore, the choice of bulk density should be based on the desired end-use properties of the fortified dried pap product. The water absorption capacity of the flour samples ranged from 1.50- 4.00 ml/g. Water absorption capacity characteristics represent the ability of a product to associate with water under conditions where water is limited (Singh, 2013). The Sample with the level of substitution 33.18: 40: 10 had the highest water absorption capacity value while the 100% maize had the lowest water absorption capacity. The 100% maize sample was significantly different from all the samples except for sample with the pap formulation 50: 35: 15. Water absorption capacity measures the volume occupied by the starch granules after swelling in excess water which can be used as an index in gelatinization. Recent research has focused on the use of various additives to improve the water absorption capacity of pap. A study by Afolabi and Johnson (2019) investigated the effect of cowpea flour on the water absorption capacity of maize and millet pap. The results showed that the addition of cowpea flour increased the water absorption capacity of both maize and millet pap. Another study by Qbiegbuna *et al.* (2019) evaluated the effect of date flour on the water absorption

capacity of maize and date pap. The results showed that the reduction of date flour increased the water absorption capacity of both maize and date pap. In addition, the results suggest that the fortification of dried pap with date could improve the water absorption capacity of the product, potentially leading to improved texture and hydration properties. Further studies are needed to evaluate the effects of these fortifications on other functional properties. The Oil absorption capacity values ranged from 2.00 – 3.50 ml/g. The value of the oil absorption capacity indicates that there were significant ($p<0.05$) differences between the samples. The sample with the level of substitution 42.11: 52.63: 5.26 had the least value at 2.00 g/ml while sample of the pap formulation had the highest value at 3.50 g/ml. There were significant ($p<0.05$) differences in all the samples.

The Oil absorption capacity is an essential functional property that contributes to enhancing mouth feel while retaining the food products' flavor (Iwe *et al.*, 2016). The ability of flours to bind with oil makes them useful in food applications where optimal oil absorption is desired (Iwe *et al.*, 2016). It aids digestibility of the food in the systemic canal of the neonates as reported by Akanbi *et al.* (2010) suggesting the use of different composite diets as weaning food to improve the nutritional and health status of growing infants. The foaming capacity of the dried pap samples ranged from 0.50 – 4.91% with sample 38.10: 47.62:14.28 level of substitution having the highest foaming capacity value, while sample with 33.18: 40: 10 level of substitution had the least foaming capacity value. There were significant differences ($p<0.05$) among all the samples expect in samples with the substitution level of 38.10:47.62:14.28 and 42.11: 52.63: 5.26 for maize, date and palm oil. The highest foaming capacity could be due to higher protein content of the sample. The protein in the dispersion may cause a lowering of the surface tension at the water- air-interface, due protein forms a continuous cohesive film around the air bubbles in the foam. The least gelation properties of maize-date pap was presented in table 1. Least gelation capacity (LGC) measures the minimum amount of flour needed to form a gel in a measured volume of water. It varies from flour to flour depending on the relative ratios of their structural constituents like protein, carbohydrates, and lipid. There was no significant difference between the 100% maize and other samples. The results showed that the samples had good bulk density, water absorption, oil absorption capacity, foam capacity and least gelation capacity. These findings suggest that fortifying powdered pap with date and palm oil would yield a product with desirable functional properties. However, the results obtained in the present study were different from those reported in other studies by Abdalla and Hansen *et al.*, 2019) which posits that the gelation capacity was 8%.

Conclusion

In the study it provides evidence of the potential benefits of fortifying dried pap with date and palm oil, which could help address micronutrient deficiency, such as vitamin A and malnutrition in developing countries. The functional properties of samples which were evaluated showed evidence that the bulk density of the samples ranged from 0.55 to 0.68, with the samples having similar values and the control (100% maize) having the highest value, indicating that it was the most compact sample. In terms of water absorption capacity, sample with the ratio 33.18:40:10 had the highest value of 4.00, while the100% maize had the least value of 1.50. Overall, the results indicate that the addition of date and palm oil had a significant effect on the functional properties of the dried pap.

References

Abdalla Bahaman, C. A. and Hansen, O.M. (2019). Functional Properties of Complementary Diets in Nigeria. Department of plant biology. University of Ilorin. Ilorin, Pp 219-227.

Afolabi, O. and Johnson, T. (2019). Influence of cowpea flour supplementation on the functional properties of maize and millet pap. Journal of Food Science and Nutrition, 7(3), 120–127.

Akanbi, B. O., Agarry, O.O. and Garba, S.A. (2010). Quality assessment of selected cereal soybean mixtures in Ogi production. African Journal of Food Science 3 (4):113-116.

Akingbala, J. O., Rooney, L.M. and Faubion, J. M. (1981). A Laboratory procedure for the preparation of ogi a Nigerian fermented food. Journal of food science 14:1523– 6. Ilorin, Pp 219-227.

Awad, M. A., Al-Qurashi, A. D. and Mohamed, S. A. (2015). Antioxidant capacity, antioxidant Compounds and antioxidant enzyme activities in five date cultivars during development and ripening. Journal of Science Horticulture 129: 688: 693.

Awika, J. M., Piironen, V. and Bean, S. (2011). Advances in cereal science: implications to food processing and health promotion. *American Chemical Society Atlantic City, NJ, Washington DC* pp. 1–13.

Bassey, O. I. (2016). Overview of oil palm production in Nigeria, comparative social and environmental impacts; the case of the Ekong Anaku community in Cross river state, Nigera, institute of social science, Erasmus unit of Rotterdam, the hague, Netherlands (3)15:1-10.

Chen, M., Sun, Q., Giovannucci, E., Mozaffarian, D., Manson, J. E., Willett, W. C. and Hu, F. B. (2017). Dairy consumption and risk of type 2 Diabetes: 3 cohorts of US adults and an updated meta-analysis. *BMC Medical Ethics* 12: 215-218.

Iwe, M. O., Onyeukwu, G., & Agiriga, A. N. (2016). Functional properties of extrusion-cooked blends of wheat–sorghum–soybean: Effect of soy concentration and feed moisture content. *Nigerian Food Journal*, 34(1): 29–42.

Kortney, A.B. (2000). Preparation and quality evaluation of pap fortified with palm oil and date. Journal of ceral foods research 12(3), 145-152

Omueti, O., Bolanle, Olayinka, .J and Olukayode, A. (2009). Functional Properties of Complementary Diets Developed from date (phoenix dactylifera), maize (zea mays) and Crayfish (Macro brachium spp.). Electronic Journal of Environmental, Agricultural and Food Chemistry 8(8): 563 -573.

Oyelana, R. (2012). Production of Dugi: An improved Ogi (a Nigerian fermented weaning food) with potential for use in diarrhea control. Journal of Tropical. Pediatrics 40: 108-113.

Qbiegbuna, J. E., Nwankwo, J. A., Ozue, J. O. and Okolo, A. C. (2019). Evaluation of Yield and Physicochemical Properties of Single Cereal Grain akamu and Pre- and Post- Processed Multigrain Cereal akamu Powders. International Journal of Food and Nutrition Research, 3:29-33.

Scott, P., Pratt, R. C., Hoffman, N., and Montgomery, R. (2019). Specialty Corns: (Third Edition). AACC International Press, Oxford, pp. 289–303.

Shiferaw, M. A. and Fashakin, J. B. (2012). Physico chemical properties of complementary diet prepared from germinated maize, cowpea and pigeon pea. Journal of Food, Agriculture and Environment, 9: (3–4), 23- 25.

Sundram, M., Kasai, T., Abe, A. and Kondo, Y. (2003). Effects of dietary administration of plant-derived anthocyanin-rich colors to spontaneously hypertensive rats. Journal of Nutritional Science and Vitamin ology 53: 90–93.

Singh, V., Guizani, N., Al-Alawi, A., Claereboudt, M. and Rahman, M. S. (2013). Instrumental texture profile analysis (TPA) of date fruits as a function of its physic -chemical properties. Industrial Crops and Products, 50: 866–873.

Victor-Aduloju, A. T., Okocha, K. S., Ezegbe, C. C. and Anarado, C. S. (2021). Proximate Composition and Organoleptic Properties of Kunun-zaki enriched with Date fruit, 236-237.

Zineb, P.K. (2012). Date fruits (*Phoenix dactylifera*): an emerging medicinal food. Critical Reviews in Food Science and Nutrition, 52, 249–27

Effect of soaking time on the proximate composition and anti-nutritional properties of fermented African oil bean seed (*Pentaclethra macrophylla*).

Ewunonu, O. C
Department of Food Technology, Institute of Management and Technology, Enugu, Nigeria
Correspondence: oewunonu@imt.edu.com

ABSTRACT

The study determined the Effect of soaking time on the proximate composition and anti-nutritional properties of fermented African oil bean seed (*Pentaclethra macrophylla*). The seeds were sorted, washed, boiled, cooled, dehulled, sliced, and then boiled again, cooled and thereafter divided into 4 portions. The first portion was not soaked in water, while the second, third and fourth portions were soaked for 6, 12 and 18 h, respectively, to obtain samples A, B, C and D. Proximate composition and antinutrient analyses of the soaked and fermented "ukpaka" were determined and analyzed using standard methods. The result of the proximate composition showed that the moisture content of the samples ranged from 36.38 – 42.09%, protein (18.47 – 20.02%), fat (17.80 – 19.00%), fibre (2.31 – 4.22%), ash (1.98 – 2.6%) and carbohydrate (13.01 – 21.11%). The anti-nutritional properties of the samples indicated that tannin content ranged from 0.81 – 2.72 mg/100g, oxalate (2.11 – 4.55 mg/100g) and phytic acid (2.03 – 6.72 mg/100g). It was observed that 24 h soaked "ukpaka" had highest protein, and fat with improved fibre, ash, but least in carbohydrates, tannin, oxalate and phytic acids. The finding of the study showed that African oil bean seed soaked for 18 h had improved nutritional composition and reduced anti-nutritional qualities.

Keywords: soaking time, "ukpaka", proximate composition, antinutritional properties

1.0 Introduction

Fermented African oil been seed (*Pentaclethra macrophylla)* is a popular food delicacy in Nigeria especially among Ibo ethnic group (source?). It is rich in protein and is obtained by a solid-state fermentation of the seed of African oil bean tree (Nwokeleme and Obeta-Ugwuanyi, 2015). The natural fermentation of the seed, curently at the house-hold level, produces nutritious, palatable and non-toxic traditional delicacy. Its production, like many African fermented foods, depends entirely on mixed fermentation by microorganism from diverse sources (Duru *et al., 2020*). Fermented African oil bean seed (Ukpaka), has a high rate of susceptibility to microbial spoilage and therefore has a very short shelf life (Duru *et al., 2020*).

African oil bean seeds are irregular and oval, flat, black and hard pods (source). It is composed of oil, protein and small amounts of carbohydrate (Olasupo *et al.,* 2016). Production of "Ukpaka" is still an age long tradition in the rural areas. The fermentation depends on random inoculation of boiled slices of the oil bean seed by microorganism within the immediate environment (Duru *et al., 2020*). Earlier report attributes the sources of the micro-organism to the leaves used in packaging, human handling, container and utensils used in processing (Olasupo *et al.,* 2016).

The "Ukpaka" bean is hard to cook, and therefore requires a longer period of cooking time and invariably higher consumption of energy. Higher energy consumption has implications for the environment, as more fuel or electricity is used during the cooking process (Ikhuoria *et al.,* 2008). Due to its hardness, *Pentaclethra macrophylla* is usually given some form of pretreatment before it is cooked in order to reduce the cooking time and energy consumption (Ahima *et al.,* 2015). The pretreatment methods include steeping in cold water overnight before cooking. Steeping leads to the imbibing of water by African oil bean, making it slightly tender before cooking, and also reduces the cooking time and the flatulence factor (Enujiugha and Akanbi, 2016) as most of the anti-nutrients are leached out during the process.

Ukpaka Fermentation is therefore a mixed wild fermentation with *Bacillus*, *Micrococcus* and *Lactobacillus* as the predominant organisms (Source?). *Bacillus spp* are the organisms, which actually ferment the oil bean seeds (Mbata and Orji, 2008). The oil bean seeds are largely composed of oil, protein and carbohydrate. The ability to break down these major components of the seed is an important characteristic of organisms able to ferment the seeds. Most organism isolated from fermented Ukpaka possessed these characteristics (Nwanjo *et al.,* 2016).

2.0 Materials and Methods

2.1 Procurement of Raw Materials

African oil bean seeds (*Pentaclethra macrophylla*) used for this study was purchased from Ogbete main Market, Enugu, Enugu state, Nigeria.

2.2 Processing of Fermented African Oil Bean Seed

The "Ukpaka" seeds were sorted, weighed, washed from dust and foreign materials. The traditional natural fermentation was carried out as described by Afia (2020). The seeds were boiled for 3 h and the hard coats were peeled off. The cotyledons were cooled, sliced and washed with water. The slices were then boiled for 2 h, cooled, and divided into four portions. One of the four portions was left unfermented (A), while the other three portions were soaked in distilled water for 6 h, 12 h and 18 h to obtain sample B, C and D, respectively. The slices were drained and mixed with 2% salt, packaged, fermented for 48 h, and then taken to the laboratory for analyses.

2.3 Proximate Analysis

Moisture, fat, ash, protein, fibre and carbohydrate contents were determined using the method described by AOAC (2010).

2.4 Determination of Antinutrients

Antinutrient content was determined according to the method described by Njoku *et al.* (2016).

2.5 Statistical Analysis

All analyses were conducted in duplicates. Data were subjected to analysis of variance, and Duncan multiple range test was used to separate the means ($p<0.05$) (Steel *et al.,* 1996).

3.0 Results and Discussion

The results of the proximate composition are as presented in Table 1. The soaking time variations affected the nutrition indices in the "ukpaka". The mean values for moisture content varied significantly ($p<0.05$) and ranged from 36.38 for sample A to 42.09% for sample D. Moisture content increased with higher soaking time. The moisture content of non-soaked sample was least compared to the soaked samples, which might be due to its moisture imbibition during soaking. The moisture values in this study were in line with the research work of Ikhuoria *et al.* (2008). The mean value for protein ranged from 18.47 for sample A to 20.02% for sample D and were significantly different ($p<0.05$). As the soaking time increased, the protein content increased. This increase in protein could be due to the microorganisms involved in the fermentation of the "ukpaka" (Adepoju *et al.,* 2019). It could also be due to the action of extracellular enzymes produced by the fermenting micro-organisms (Olasupo *et al.,* 2016).

The fat contents of the samples varied from 17.80 to 19.00%. The samples differed significantly ($P<0.05$) from each other. The sample soaked for 18 h had the highest fat content. This an indication that soaking for 18 h softened the "ukpaka" and increased its permeability for oil to be easily released. The values obtained were similar to the findings of Eze *et al.* (2014). The crude fiber content of the samples ranged from 2.31 to 4.22%. There was significant difference ($P<0.05$) among the samples. The sample soaked for 6 hours had the highest fibre content when compared to the other soaked samples, with 18 h having the least fibre content. This trend may be due to leaching that may have occurred during soaking leading to aa low fibre content. These values were similar to that obtained by Balogun (2013). Diets that are low in fibre are undesirable as they could cause constipation (Adegunwa *et al.,* 2012). Ash content of the samples ranged from 1.98 and 2.60%. All samples differed significantly ($P<0.05$) from each other. These values give an indication of the level of macro and micro elements in the seeds. The values obtained in this study were slightly lower than the findings of Ikhuoria *et al.* (2008). The carbohydrate content of the samples ranged

from 13.01 to 21.11%. All samples differed significantly (P<0.05) from each other. The decrease in carbohydrate could be attributed to the conversion of complex starch to disaccharide by amylase enzyme and breaking down of complex starch into alcohol and carbon dioxide by the activities of micro-organisms (Enujiugha and Akanbi, 2016).

Table 1: Proximate composition of fermented "ukpaka" (%)

Samples	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
A	$36.38^{d}\pm0.00$	$18.47^{d}\pm0.00$	$17.80^{d}\pm0.00$	$4.22^{a}\pm0.02$	$1.98^{d}\pm0.01$	$21.11^{a}\pm0.01$
B	$39.91^{c}\pm0.01$	$19.43^{c}\pm0.03$	$17.98^{c}\pm0.00$	$3.14^{b}\pm0.00$	$2.45^{c}\pm0.01$	$17.02^{b}\pm0.02$
C	$41.01^{b}\pm0.02$	$19.19^{b}\pm0.12$	$18.04^{b}\pm0.16$	$3.07^{c}\pm0.01$	$2.52^{b}\pm0.00$	$15.52^{c}\pm0.34$
D	$42.09^{a}\pm0.12$	$20.02^{a}\pm0.10$	$19.00^{a}\pm0.11$	$2.31^{d}\pm0.03$	$2.60^{a}\pm0.05$	$13.01^{d}\pm0.56$

Values are means ±SD of triplicate determinations. Mean results with different superscripts along the column are significantly different (p<0.05). Key: A= Not soaked, B = Soaked for 6 h, C= Soaked for 12 h, D= Soaked for 18 h

The results of the anti-nutrient content of "ukpaka" are as shown in Table 2. The tannin content of the samples differed significantly (P<0.05) and ranged from 0.81 to 2.72 mg/100g.Increased soaking time led to reduction in the tannin content of the samples which could be attributed to aqueaous leaching of the tannin in water during soaking. The findings agreed with Oyeleke *et al.* (2014). Tannin had been implicated to form insoluble complexes with proteins thereby reducing digestibility and utilization of food proteins (Ali, 2011). The oxalate content of the samples varied from 2.11 to 4.55 mg/100 g. There were significant differences (P<0.05) the oxalate content pf the samples. The oxalate value in this study was higher than that reported by Balogun (2013). The research showed that the higher the soaking time, the higher the reduction in the oxalate content of the samples. The phytic acid content of the samples ranged from 2.03 to 6.72 mg/100g. The oxalate content of the samples differed significantly (P<0.05) from each other. However, these values were consistent with that obtained by Oyeleke (2014). The low level of phytic acid would ensure availability of divalent cation. Phytate is a very stable and potent chelating food component as well as anti-nutrient by virtue of its ability to chelate divalent minerals and prevent their absorption (Amadike *et al.,* 2013).

Table 2: Anti-nutrient content of "ukpaka" (mg/ 100g)

Samples	Tannin	Oxalate	Phytic acid
A	$2.72^{a}\pm0.16$	$4.55^{a}\pm0.52$	$6.72^{a}\pm0.33$
B	$1.89^{b}\pm0.11$	$3.69^{b}\pm0.01$	$4.07^{b}\pm0.12$
C	$1.17^{c}\pm0.11$	$2.51^{c}\pm0.27$	$3.21^{c}\pm0.22$
D	$0.81^{d}\pm0.60$	$2.11^{d}\pm0.36$	$2.03^{d}\pm0.45$

Values are means ±SD of triplicate determinations. Mean results with different superscripts along the column are significantly different (p<0.05). Key: A= Not soaked, B = Soaked for 6 h, C= Soaked for 12 h, D= Soaked for 18 h

4.0 Conclusion

The findings show that "ukpaka" soaked for 18 h improved the nutritional composition and reduced the anti-nutritional properties of the "ukpaka". The "ukpaka" soaked for 18 h improved protein content and this could be incorporated into protein deficient staple foods, especially in developing countries.

References

Adegunwa, M. O., Adebowale, A. A. and Solano, E. O. (2012). Effect of thermal processing on the biochemical composition, anti-nutritional factors and functional properties of beniseed (*Sesamum indicum*) flour. *American Journal of Biochemistry and Molecular Biology,*2(3): 175–182.

Adepoju, O. T., Dudulewa, B. I. and Bamigboye, A. Y. (2019). Effect of cooking methods on time and nutrient retention of pigeon pea (*Cajanus cajan*). *African Journal of Food Agriculture and Nutritional Development* **19**(3): 18-25

Afia, K. (2020). A review of *Pentaclethra macrophylla* (African Oil bean) seed. Journal of Experimental Science, 5:1-7

Ahima, J., Amissah, A., Owusu, J. and Nartey, E. (2015). Effect of cooking on cooking time, nutritional content and sensory properties of pawpaw-treated bambara groundnut. *International Journal of Technology and Management Research* **4** (1): 24-28

Ali, A. (2011). Major Antinutrients and Phytochemical Investigation Found in an Iranian Edible Plant Source. *Journal of Nature Production Plant Resources,* 1 (2): 56-61

Amadike, E. U., Emmanuel, I. A., Friday, O. U., Chinyere, G. C., Ositadinma, C. U. and Kayode, A. O. (2013). Nutritional and chemical composition of Jatropha curcas (L) seed oil from Nigeria. *International Journal of Biosciences* **3**(5): 125-134

AOAC (2010). Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.

Balogun, B.I. (2013). Evaluation of the Nutritional Potentials of Fermented Oil Beans Seed *Pentaclethra macrophylla*h Benth. *Production Agriculture and Technology* **9** (2): 73-87

Duru, F.O., Ohaegbulam, P. O., Ezeji, C.C. (2020). The yield, sensory characteristics and fatty acid content of oils extracted from African oil bean (*Pentaclethra macrophylla)* seeds at different maturation stages. *International of Educational research 5:41-50*

Enujiugha, V.N. and Akanbi C.T. (2016). "Compositional changes of African oil bean (*pentadethra macrophylla Benth*) seed during thermal processing. *Pakistan Journal of Nutrition.* 4 (7): 27-39.

Eze, V.C., Onwuakor, C.E. and Ukeka, E. (2014). Proximate Composition, Biochemical and Microbiological Changes Associated with Fermenting African Oil Bean (*Pentaclethra macrophylla* Benth) Seeds. *American Journal of Microbiological Research* 2 (5): 138-142

Ikhuoria, E. U., Aiwonegbe, A. E., Okoli, P. and Idu, M. (2008). Characteristics and composition of African oil bean seed (*Pentaclethra macrophylla* Benth). *Journal of Applied Sciences*, 8 (7):1337-1339

Mbata, T.I. and Orji M.U. (2008). Process of Optimization in the production and Preservation of Ugba, a Nigerian fermented food. *Journal of Microbiology* 4:2-6

Njoku, N. E., Ubbaonu, C. N., Alagbaoso, S.O., Agunwa, I.M. and Eluchie, C.N. (2016). Proximate, Anti-Nutritional and Phytochemical Composition of the Yellow Variety of the *Synsepalum Dulcificum* (Miracle Fruit) Berry. *American Journal of Food Science and Technology*, 4(4): 102-108

Nwanjo, H., Iroagba, I., Nnatuanya, I., Eze, N. (2006). Is fermented *pentaclethra macrophylla* Nutritional or antinutritional: Response from haematological studies in protein malnourished guinea pigs. Journal of Nutrition Wellness 4(2):14-19

Nwokeleme, C. O. and Obeta-Ugwuanyi, J. (2015). Evolution of Volatile Flavour Compounds during Fermentation of African Oil Bean (*Pentaclethra macrophylla* Benth) Seeds for "Ugba" Production. *International Journal of Food Science* **1**(1): 1- 8

Ogueke, C. C., Nwosu, J. N., Owuamanam, C. I. and Iwouno, J. N. (2010). Ugba, the fermented african oilbean seeds; its production, chemical composition, preservation, safety and health benefits. *Pakistan Journal of Biological Sciences* **13** (10): 489-496

Olasupo, N. A., Okorie, C. P. and Oguntoyinbo, F. A. (2016). The biotechnology of ugba, a Nigerian traditional fermented food condiment. *Front. Microbiol.* 7(2):1-10

Oyeleke, G. O., Odedeji, J. O., Ishola, A. D. and Afolabi, O. (2014). Phytochemical screening and nutritional evaluation of african oil bean (*Pentaclethra macrophylla*) seeds. *Journal of Environmental Science, Toxicology and Food Technology* **8** (2): 14-17

Steel, R., Torrie, J. and Dickey D. (1996). Principle and Procedures of Statistics. A biochemical approach 3rd Sub Edition McG-Hill, New York, U.S.A, pp 20-90

Quality Evaluation of Energy Bar Produced from Tiger Nut, Groundnut and Beniseed Flavoured with *Uziza* Seed Powder.

Ikegwu, T. M[1]., Okafor, M. O[1] and Omologbe F.[1]

1.Department of Food Technology, Nnamdi Azikiwe University P.M.B 5025, Awka, Anambra State.

Corresponding author's email: Okaformaureen78@gmail.com

ABSTRACT

This work evaluates the proximate properties of snack bar produced from blends of tiger nut, groundnut and beniseed flavoured with uziza seed powder. The snack bar was produced by combining groundnut, benniseed and uziza seeds in different substitution ratios using Minitab (Extreme Vertices Mixture Design). The samples were analyzed using standard methods. The result of the proximate composition showed that the moisture contents ranged from 10.67% to 22.07%. The protein content ranged from 0.07% to 0.16%, fat (6.30 – 20.97%), fibre (5.53- 36.73%), ash (1.67 – 6.00%) while carbohydrate ranged from 26.37 % to 59.63%. The research on the proximate properties of snack bars produced from blends of tiger nut, groundnut, and beniseed flavored with uziza seed powder has demonstrated the potential of these ingredients in developing a nutritionally balanced product. The result revealed that the snack bars produced from these ingredients can serve as a nutritious snack option, suitable for a convenient snack source.

1.0 Introduction

Snack bars are supplemental bars which may contain cereals, nuts, legumes and other high snack foods targeted at people who require quick snack but do not have time for a meal (Tiwari, 2017). They are different from snack drinks, which contain caffeine whereas bars provide food snack. Snack in food comes from all three main food sources: fat, protein, and carbohydrates. A typical snack bar weighs between 45 g and 80 g and is likely to supply about 200–300 Cal (840–1,300 kJ), 3–9 g of fat, 7–15 g of protein, and 20–40 g of carbohydrates (Tiwari, 2017). Snack bars were initially marketed to athletes as a source of snack. However, the growing luxury groups and health-conscious consumers had increased the sales performance of snack bars (Wyatt, 2011; Euromonitor International, 2015).

Nuts are known for their nutritional and health benefits and have been used in traditional medicine for various ailments (Okpako and Asemota, 2012). One of the main nutritional benefits of tiger nuts is their high fiber content, with a 100-gram serving containing up to 33% of the recommended daily intake. They are also a good source of healthy fats, including monounsaturated and polyunsaturated fatty acids, which may help improve heart health. Additionally, tiger nuts contain various vitamins and minerals, including vitamin E, iron, potassium, and magnesium (Yu *et al.,* 2022). Groundnut (*Arachis hypogea L.*) is an annual, self-pollinated, wet season plant growing in many tropical, subtropical and temperate countries of the world (Yanping *et al.*, 2016). The consumption of groundnut has been associated with metabolic benefits in the context of counteracting metabolic dysfunction associated with the increasing prevalence of obesity and metabolic syndrome (Coates and Howe, 2007). The fat content in groundnut has been largely studied. Groundnut seed contains 44-56% oil and 22-30% protein on a dry seed basis and it is a rich source of minerals (phosphorus, calcium, magnesium and potassium) and vitamins (E, K and B group) (Yanping *et al.*, 2016). The chemical composition of groundnut seed has been evaluated in relation to protein level, amino acid composition and fatty acid composition in some cultivars (Coates and Howe, 2007). Beniseed, also known as sesame seed (*Sesamum radiatum*), is a versatile oilseed crop cultivated for its seeds, which are rich in oil, protein, and various nutrients (Bedigian, 2010). It thrives in well-drained, fertile soils and requires adequate moisture for optimal growth (NAERLS, 2013). Beniseed is renowned for its nutritional richness, containing high levels of oil, protein, vitamins (especially vitamin E), and minerals such as calcium, magnesium, and iron. It is also rich in antioxidants and beneficial phytochemicals (Pathak *et al.*, 2014). Consumption of beniseed is associated with numerous health benefits, including improved heart health due to its high content of unsaturated fatty acids, management of blood sugar levels, and support for bone health and immune function (Anilakumar *et al.,* 2010).

Uziza seed (*Piper guineense*) belongs to the family *Piperaceae* and is a close relative of black pepper (*Piper nigrum*) (Akpantah and Bassey, 2018). The seeds are rich in essential oils, particularly monoterpenes and sesquiterpenes, which give them a pungent aroma and flavor (Iweala and Osoniyi, 2018). This work therefore aims at studying the proximate poperties of the snack bar produced from tiger nut, groundnut and beniseed flavoured with uziza seed powder.

2.0 Materials and Methods

The raw materials used in the study include tiger nut, groundnut, beniseed and uziza. The materials were purchased from Eke-Awka market in Awka South Anambra State. The reagents and chemicals used for the experiment was sourced from Department of Food Science and Technology Laboratory, Nnamdi Azikiwe University Awka, and they were of analytical grade.

2.1 Production of Uziza Seed Powder

A 100 g of uziza seeds was sorted to remove contaminants, washed and dried then powdered and packaged in an airtight container before further analysis.

2.2 Production of snack bar

The method adopted by Rahmi *et al.* (2021) with slight modifications was used to produce the snack bar. About 200 g of wholesome dried tiger nut, 100 g of dried groundnut and 100 g of beniseed which was roasted at 160 0C for 5-10 min until it can be crushed with hands then cooled was parched (coarse blending) using a 3D electric blender. In a clean big bowl, all the parched (coarse blended) dry ingredients (tiger nut, groundnut beniseed) were mixed using different substitution levels. Exactly 5 ml spoons of honey were added to bind the dry ingredients after which an electrical mixer or a manual mixer was used to mix the composite such that they were combined properly. At this point, the mixture was very sticky. The mixture was then removed from the bowl and was pressed and spread firmly using a rolling pin into a greased parchment baking dish to form. The mixture was cooled for at least 30 min. Once hardened, a knife was used to cut into little squares and packaged.

3.0 Results and Discussion

3.1 Proximate Composition of Snack Bar

The proximate composition of snack bar produced from tiger nut, groundnut and beniseed flavoured with uziza seed powder is shown in table 2.1. The protein (0.07-0.16 %) content of the snack bar showed that significant difference ($p<0.05$) was observed amongst some samples, while some samples were not significantly different ($p>0.05$) from each other. The result revealed low protein content of the food product which can be attributed to the initial low protein composition of the raw materials used for the production. The values (16.16-22.43 %) recorded by Edima-Nyah *et al.* (2019). On the development and quality evaluation of snack bar from African breadfruit, maize and coconut was found to be higher than the values obtained from the recent study. The values (18.70-30.49 %) recorded by Aljaloudi *et al.* (2024) on the development and characterization of high snack protein bars with enhanced antioxidant, chemical, nutritional, physical and sensory properties was higher than the values obtained from the recent study. The fat content (6.30-20.60 %) of the snack bar showed significant difference between ($p<0.05$) some of the samples, while some samples were not significantly different ($p>0.05$). The results show significant high fat content which could be possibly because groundnut used for production contains about 35-56 % fat. The values (7.31-8.46 %) recorded by Edima-Nyah *et al.* (2019) for the development quality evaluation of snack bar from African breadfruit, maize and coconut was lower than the values obtained from the recent study. The values (8.57-18.97 %) recorded Aljaloudi *et al.* (2024). The differences in the comparative studies with the recent research can be attributed to the use of different raw materials which have different nutritional profile. Fat content in food refers to the amount of fat present in a particular food product, usually expressed as a percentage of the total weight of the food (Awuchi, 2019).

Table 1.1: Proximate Composition of Snack Bar

Sample	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Moisture (%)	Carbohydrate (%)
Control	$0.16^{a} \pm 0.04$	$10.67^{d} \pm 0.29$	$17.50^{d} \pm 0.50$	$6.00^{a} \pm 1.00$	$19.00^{a} \pm 1.00$	$46.68^{c} \pm 0.29$
EN2	$0.13^{ab} \pm 0.59$	$18.93^{c} \pm 0.38$	$7.53^{f} \pm 2.25$	$2.33^{c} \pm 0.58$	$19.13^{a} \pm 0.71$	$51.93^{b} \pm 1.87$
EN3	$0.07^{b} \pm 0.03$	$6.30^{e} \pm 0.17$	$12.20^{e} \pm 1.57$	$3.50^{b} \pm 0.50$	$18.30^{a} \pm 0.52$	$59.63^{a} \pm 1.94$
EN4	$0.12^{ab} \pm 0.08$	$20.97^{a} \pm 0.23$	$5.53^{f} \pm 2.25$	$4.00^{b} \pm 0.50$	$22.07^{a} \pm 5.22$	$47.31^{c} \pm 4.89$
EN5	$0.08^{ab} \pm 0.03$	$10.97^{d} \pm 0.40$	$21.50^{c} \pm 0.87$	$2.33^{c} \pm 0.29$	$20.13^{a} \pm 1.75$	$44.99^{c} \pm 1.25$
EN6	$0.08^{ab} \pm 0.02$	$20.07^{b} \pm 0.74$	$24.87^{b} \pm 0.12$	$1.67^{c} \pm 0.29$	$18.73^{a} \pm 1.72$	$34.59^{d} \pm 2.22$
EN7	$0.13^{ab} \pm 0.00$	$20.60^{ab} \pm 0.26$	$36.73^{a} \pm 1.30$	$5.50^{a} \pm 0.00$	$10.67^{b} \pm 0.15$	$26.37^{e} \pm 1.00$

*Values of Table are mean ± standard deviation of three (3) replicates. Values in the same column bearing different superscript differed significantly ($p<0.05$)

Key; Control: 100 % Tiger nut; EN2: 70 % tiger nut, 20 % groundnut, 5 % beniseed and 5 % uziza

EN3: 65 % tiger nut, 20.50 % groundnut, 10.25 % beniseed and 4.25 % uziza; EN4: 60 % tiger nut, 29.50% groundnut, 8.5 % beniseed and 2 % uziza; EN5: 70 % tiger nut, 20 % groundnut, 8.0 % beniseed and 2.0 % uziza; EN6: 67.5 % tiger nut, 22.5 % groundnut, 6.5 % beniseed and 3.5 % uziza; EN7: 65 % tiger nut, 25.0 % groundnut, 7.75 % beniseed and 2.25 % uziza

The fibre (5.53-36.73 %) content of the snack bar showed that there was a significant difference ($p<0.05$) between some of the samples while some samples were not significantly different ($p>0.05$). The result shows a significant amount of fiber in the food product which can be attributed to the higher fuber content of tiger-nut used for production. The values (10.12-17.76 %) recorded by Edima-Nyah *et al.* (2019). for the development and quality evaluation of snack bar from African breadfruit, maize and coconut was found to be higher than the values obtained from the recent study. Fibre also known as dietary fiber or roughage, is a type of carbohydrate found in plant-based foods that cannot be digested by the human body. Instead of being broken down and absorbed, fiber passes through the digestive system relatively intact (Adesina and Osobamiro, 2012). It plays a crucial role in maintaining digestive health and offers various other health benefits, such as promoting bowel regularity, managing weight, and supporting heart health Abu *et al.* (2020). The ash content (1.67-6.00 %) of the snack bar showed that significant difference ($p<0.05$) was observed amongst the samples. Some of the samples were also not significantly different ($p>0.05$). The results shows that most of the samples were able to retain a significant residual inorganic material after complete combustion. The values (1.77-2.28 %) recorded Aljaloudi *et al.* (2024). Ash levels in the different studies compared to the recent research could possibly because of the different level of inorganic matter present in the different raw materials used for processing the food product. The moisture (10.67-22.07 %) content of the snack bar showed that significant difference ($p<0.05$) was observed amongst some of the samples, while some samples were not significantly different ($p>0.05$) from each other. The result shows a significant moisture content in the food product which is possibly because of poor drying conditions employed during processing. The values (3.76-4.82 %) recorded by Edima-Nyah *et al.* (2019). The values (24.88-30.38 %) recorded Aljaloudi *et al.* (2024). on the development and Characterization of high snack protein bars with enhanced antioxidant, chemical, nutritional, physical and sensory properties was higher than the values obtained from the recent study. Moisture content plays a crucial role in determining the shelf life of foods (Peter-Ikechukwu *et al.*, 2020). It refers to the amount of water present in a food product, usually expressed as a percentage of the total weight. It is an essential factor in food because it directly impacts the growth of microorganisms which is risk factor for food spoilage (Aljaloudi *et al.*, 2024). The carbohydrate (26.37-51.93 %) content of the snack bar revealed that significant difference ($p<0.05$) was observed between some samples, while some samples were not significantly different ($p>0.05$) from each other. The result showed a significant increase in the carbohydrate content of the snack bar. The values (42.16-59.82 %) recorded by Edima-Nyah *et al.* (2019). on the development and quality evaluation of snack bar from African breadfruit, maize and coconut was found to be higher than the values obtained from the recent study. These comparison shows that the level of carbohydrate in food product is dependent on the carbohydrate content of the raw materials from which the food product was made. Carbohydrates come in various forms, including sugars, starches, and fiber (Bhattacharya, 2014).

Conclusion

The research on the proximate properties of snack bars produced from blends of tiger nut, groundnut, and beniseed flavored with uziza seed powder has demonstrated the potential of these ingredients in developing a nutritionally balanced product. The results revealed the interplay between locally sourced raw materials in the production of snack bar. The results revealed that the formulated bars generally had low protein content but relatively high fat and fiber contents, particularly in formulations with higher groundnut and tiger nut inclusion. Moisture and ash contents varied significantly across samples, with implications for shelf life and mineral composition. Carbohydrate levels also differed among formulations, influenced by the types and ratios of raw materials used. The study shows that tiger nut-based snack bars can be produced which possessed high fiber content and could serve to mitigate the effect of gluten-intolerance individuals in wheat products as a result of celiac disease.

References

Abu, M.S., Aso, R.E., Onuche, J.I., Yohanna, R.E., Mashing, R.L. and Ahmad, S. H. (2020). Proximate Composition, Mineral Content and Functional Properties of Composite Flours and Microbiological/Sensory Analysis of Composite Flour Bread. Journal of Research in Agriculture and Animal Science 8(8):01-08

Adesina, A.J. and Osobamiro, T.M. (2012). Proximate composition and Functional Properties of *Cassia fistula* and *Afzelia africana* seed flours. African Journal of Bioscience 5(1):104-105.

Akpantah, A. O. and Bassey, E. A. (2018). Phytochemical and antimicrobial properties of *Piper guineense* seeds. International Journal of Advanced Research in Biological Sciences 5(6):1-10.

AlJaloudi, R., Al-Dabbas, M. M., Hamad, H. J., Amara, R. A., Al-Bashabsheh, Z., Abughoush, M., Choudhury, I. H., Al-Nawasrah, B. A. and Iqbal, S. (2024). Development and Characterization of High-Snack Protein Bars with Enhanced Antioxidant, Chemical, Nutritional, Physical, and Sensory Properties. Foods 13(2): 259. https://doi.org/10.3390/ foods13020259.

Anilakumar, K. R., Pal, A. and Khanum, F. (2010). Nutritional, medicinal and industrial uses of sesame (*Sesamum indicum L.*) seeds—an overview. Agriculturae Conspectus Scientificus 75(4): 159-168.

Awuchi, C.G. (2019). Proximate composition and Functional Properties of different grain composites for industrial applications. *International Journal of Food Science* 2(1):43-64.

Bedigian, D. (2010). Characterization of Sesame (Sesamum indicum L.) Germplasm: A Critique. *Genetic Resources and Crop Evolution* 57: 641-647. http://dx.doi.org/ 10.1007/s10722-010-9552-x.

Bhattacharya, M. (2014). Wheat Flour Lipid Composition and Sensory Properties of Poori, a Deep-Fried Indian Bread. Food Chemistry, 148, 280–285.

Coates, A. and Howe, P. (2007). Edible Nuts and Metabolic Health. *Current Opinion in Lipid* 18: 25-30

Edima-Nyah, A. P.1., Nwabueze, T. U. and Ojimelukwe, P. C. (2019). Development and Quality evaluation of Snack Bars from African breadfruit (*Treculia africana*), Maize (*Zea mays*) and Coconut (*Cocos nucifera*) Blends. Journal of Scientific and Engineering Research 6(5):74-83.

Euromonitor International (2015). Snack bars in Malaysia. Retrieved on July 10, 2015, from http://www.euromonitor.com/snack-bars-in-malaysia/report

Okpako, E. and Asemota, H. (2012). Tiger Nut: as a plant, its derivatives and benefits. *African Journal of Food Science* 6(2):1-7.

Pathak, N., Rai, A. K. and Kumari, R. (2014). Nutritional attributes and health benefits of sesame seeds: A review. *International Journal of Food Science and Technology* 51(9): 1633-1641.

Peter-Ikechukwu, A. I., Ogazi, C. G., Uzoukwu, A. E., Kabuo, N. O. and Chukwu, M. N. (2020). Proximate and Functional Properties of Composite Flour Produced with Date Fruit Pulp, Toasted Watermelon

Seed and Wheat. Journal of Food Chemistry and Nanotechnology 6(3): 159-166.

Tiwari, P., Agrahari, K., Jaiswal, M. and Singh A. (2017). Standardization and development of different types of snack bars. International Journal of Home Science 3(1):370-372.

Wyatt, S. L. (2011). State of the snack industry 2010. Symphony IRI Group. Retrieved on July 14, 2015, from http://www.healthycornerstores.org/wp-content/uploads/2011/11/SNAXPO-2011.pdf

Yanping, L., Jiali, Y., Frank, B. H., JoAnn, E. M., Meir, J. S., Shilpa, N. B. and Walter, C. W. (2016). Association of nut consumption with total and cause-specific mortality. *JAMA Internal Medicine* 176(8): 1134-1145.

Rahmi, Y., Kurniawati, A.D., Widyanto, R.M., Ariestiningsih, A.D., Al Farahi, A.Z.A., Ruchaina, A.N., et al. (2021). The sensory, physical and nutritional quality profiles of purple sweet potatoand soy-based snack bars for pregnant women. Journal of Public Health Research 10: 2241. Doi:10.4081/jphr.2021.2241

Yu, Y., Lu, X., Zhang, T., Zhao, C., Guan, S., Pu, Y. and Gao, F. (2022). Tiger Nut (*Cyperus esculentus* L.): Nutrition, Processing, Function and Applications. Foods 11(4), 601. https://doi.org/10.3390/foods11040601.

NAERLS (2013). Beniseed production and utilization in Nigeria. Extension Bul Horticulture. National Agricultural Extension an Research Liaison Services, Ahmadu Bello University, Zaria.