International Journal of Home Economics, Hospitality and Allied Research, 3(2): 29-41.
DOI: https://doi.org/10.57012/ijhhr.v3n2.003
Received: July 29, 2024
Revised: August 24, 2024
Accepted: August 29, 2024
Published: December 14, 2024

Original Research Report

Chemical Composition and Sensory Evaluation of Products Made From Oats (*Avena Sativa*) and Unripe-Plantain (*Musa Paradisiaca*)

Nkechi G. Onyeke*[1], Nkechi G. Onodugo[2], Scholastica N. Eze[2], Linda O. Okoye[1].

[1]Department of Home Science and Management, University of Nigeria, Nsukka, Enugu State, Nigeria
[2] Department of Nutrition and Dietetics, University of Nigeria, Nsukka, Enugu State, Nigeria
***Correspondence:** Nkechi, G. Onyeke, Department of Home Science and Management, University of Nigeria, Nsukka, Enugu State, Nigeria (Email: nkechi.onyeke@unn.edu.ng)

Abstract: The study accessed the chemical composition and sensory evaluation of products made from oat (*Avena sativa*) and unripe plantain (*Musa paradisiaca*). This research aimed to determine the chemical composition of food products made from unripe plantain and oat composite flours and evaluated the acceptability of such foods through sensory evaluation for the benefits of diabetics and obese persons. Proximate, minerals, and phytochemicals analysis were conducted to ascertain the concentration of essential nutrients composition, Unripe plantain and oats flours were mixed at 50:50, 70:30, and 80:20 in ratios of plantain and oats respectively to formulate the composite flours, and analysed to determine the most preferable and recommend ratio based on chemical composition and sensory properties. Composite flour mixes with 50:50 in ratio proved to be the most preferable in sensory evaluation, general acceptability, minerals composition, and the proximate; it is then recommended for the target population. Unripe plantain and oats composite flours when adopted as part of food varieties or food ingredients for diabetics and obese persons can be used to make foods whether as deserts or main meal components of their diets in form of puddings, dumplings, and swallows.

Keywords: Chemical composition, Composite flour, Oat, Sensory evaluation, Unripe plantain

---

1. Introduction

Recently, attempts had been made to produce foods from non-wheat-based composite flours with high nutritional and sensory properties from locally available food products such as unripe plantain, defatted sesame flour blends, cassava, groundnut, corn starch blends and pigeon pea, cocoyam and sorghum flour blends (Chinma et al., 2012; Noah & Adedeji, 2021). A current trend in nutrition is the consumption of foods advocated by world nutrition bodies due to different health problems related with wheat consumption such as celiac disease, diabetes, and coronary heart diseases (Noah & Adedeji, 2021). This situation has created the need for the consumption of low carbohydrate diets, slowly digested starchy foods as well as an increased intake of foods. The need for strategic development in the use of inexpensive local resources in the production of staple foods has been promoted by organizations such as the Food and Agricultural Organization and the United Nations refugee feeding programs leading to the initiation of the composite flour program (Noort et al., 2022).

The production of foods with good quality would depend on selecting the correct flour for each type and employing appropriate processing techniques. Plantain flour can be added to cereals to produce bread and spaghetti or is prepared in the form of dough meal for diabetic patients (Famakin et al., 2016). Plantain is widely grown in the southern parts of Nigeria and other African countries. In many parts of African countries, plantain is consumed as a cheap source of energy (Eleazu & Okafor, 2015). Although plantain is considered nutritionally poor, because it is deficient in fat and protein, unripe plantain is particularly a good source of energy, dietary fibre, irons, potassium and vitamins (Ilelaboye, 2019). It is agreed that plantain is rich in carbohydrates, dietary fibre, iron, vitamins and minerals and hence an ideal food source for diabetics, pregnant women, and children, and can be a good inclusion in weight loos diet plans (Agu et al., 2014). Composite flour blend of plantain and oats can also be implemented in development of a variety of food products for different groups of persons including children, adults, diabetics, and obese persons. Owing to its particular chemical composition and nutritive and physiological values, oat grain is the object of extensive studies. Oat grain is characterised by a good taste, dietetic properties and an activity stimulating metabolic changes in the body. All this makes its nutritive value high, since it is an excellent source of dietary fibre and nutraceuticals that are of benefits in the management of obesity and diseases such as diabetes (Jideani & Jideani, 2011). Although wheat flour is the most widely used flour for the production of different foods in Nigeria, the products come with various nutritional deficiencies. Therefore, fortifying wheat flour with these indigenous plants (unripe plantain and oats) will increase the overall nutrient content of the meal, increase food variety, and also prevent nutritional deficiency among the consumers.

This study was necessitated by the fact that deficiencies in micronutrients such as such as iron, zinc, and vitamin A, are widespread in low-and middle-income countries like Nigeria, thereby compromising the physical and cognitive capacity of millions of people (Olson et al., 2021). The importance of research on food fortification cannot be overemphasized in accordance with Sustainable Development Goal (SDG) number 2, which aims to enhance nutrition by eradicating all types of malnutrition. According to the World Health Organisation (2024), food fortification is an evidence-based practice that helps prevent, reduce, and control micronutrient deficiencies. It can be used to address a confirmed micronutrient deficiency in the general population or in certain demographic groups, such as children, pregnant women, and social protection recipients. Food fortification is a cost-effective strategy with demonstrated health, economic and social benefits. Its practice offers significant benefits ranging from reducing the prevalence of nutritional deficiencies and economic benefits to societies and economies (Olson et al., 2021). Studies on the fortification of foods have shown positive results not only in the control and prevention of micronutrient deficiencies among vulnerable populations, especially women and children, but also along social, economic and environmental dimensions.

1.1. Theoretical Framework

This study hinges on an emerging food-based strategy that can complement current strategies in the ongoing fight against micronutrient deficiencies called Food-to-food fortification (FtFF). According to Kruger et al. (2020), FtFF means the addition of micronutrient-dense food/s to a recipe to substantially increase the amount of bioavailable micronutrient/s, with the aim of improving the micronutrient status of populations where the intake of bioavailable micronutrients is inadequate. FtFF encourages the utilization of local resources and is increasingly being recognized as sustainable, as it promotes self-reliance and create market opportunities for locally produced foods, thereby also contributing to economic growth (Burchi et al., 2011). FtFF is fundamentally different from conventional fortification in that the goal is to improve both micronutrient content and bioavailability in foods by the addition of food ingredients, rather than raising the content through the addition of individual micronutrient/s mixtures (Kruger et al., 2020). Food-to-food fortification is a method that fortifies another food by using an unusual (i.e., containing valuable amounts of micronutrients), readily available, and accessible local plant or animal resource (Uvere et al., 2010). For this technique, the rate of fortification varies considerably (1%–50%) and depends on the compatibility of the vehicle (the staple food) and the fortificant. Food-to-food fortification often uses foods that are available in the area of the target population to enhance nutrient intake. In Nigeria, it is common to see the association of local food resources, such as leaves (moringa), fruit (pawpaw, mango, and plantain), seeds (from watermelon), legumes (soybean), and some vegetables, as fortificants to improve nutrient content of some deficient foods (e.g. cassava products and wheat flour). The main objective is to improve the nutritional quality of the fortified food without losing sight of the acceptability standards (especially the food organoleptic quality) (Chadare et al., 2019).

1.2. Statement of Problem

Sub-Saharan Africa (SSA) is seeing a rapid shift in diets and lifestyles due to mass urbanization and rising disposable incomes. Consequently, the SSA population is growing more susceptible to the combined effects of obesity and malnutrition (Noort et al., 2022). According to Black et al. (2013), maternal and child undernutrition cause 45% of all deaths in children under five in low and middle-income countries (LMICs) where hidden hunger, also known as chronic lack of essential vitamins and minerals in the diet is widespread (Muthayya et al., 2013). This calls for immediate and sustainable solutions. Micronutrient deficits are generally caused by insufficient intake of nutrient dense foods and nutrient losses due to poor diets, infections, and blood loss during menstruation (women of reproductive age) (Olson et al., 2021). Poor dietary habits have also been linked to the rapid increase in the number of people living with diabetes mellitus in the developing countries; with the cost of treatments beyond the reach of many. This called for the use of cheap and locally available materials such as unripe plantain, rice bran, oats and soybean, to develop flours, dough meals and assess their potential for the management of obesity and diabetes (Agu et al., 2014; Jideani & Jideani, 2011). Oats and unripe plantain holds promise in these respects. Unripe plantain is rich in carbohydrate, its low Glycemic index (GI) has been established to reduce post prandial glucose level. The increased consumption of oats can increase the amount of amino acids intake in the body. The World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO) have implemented four major techniques to improve dietary intake: food fortification, micronutrient supplementation, nutrition education, and disease control measures. Fortifying staple foods is one method that has a proven history of promoting dietary diversity and effectively reducing micronutrient deficits among target population (Olson et al., 2021). Based on this, this study aimed to develop an acceptable flour base with an appropriate fibre fraction ratio such as the combination of unripe plantain and oats for healthier dumpling dough and flours for foods as a strategy to mitigate micronutrient deficiency and related diseases.

1.3. Purpose of the Study

The general purpose of this research is to determine the chemical composition and sensory evaluation of products made from oats (*Avena sativa*) and unripe-plantain (*Musa paradisiaca*). The specific purpose is to:

(a) formulate composite flour blends with oats and unripe-plantain; with a ratio of (50:50, 30:70, 20:80);
(b) determine the proximate composition of the formulated flour blends;
(c) determine the mineral composition of the formulated flour blends;
(d) determine the phytochemicals properties of the formulated flour blends; and
(e) evaluate sensory properties (e.g., taste, texture, and aroma) of the products made.

1.4. Research Questions

The following research question guided the study:

(a) What is the optimal composition of composite flour blends using oats and unripe plantain with ratios of 50:50, 30:70, and 20:80 for the production of fufu and moi-moi?
(b) What is the proximate composition of the newly formulated flour blends of oats and unripe plantain?
(c) What is the mineral composition of the newly formulated flour blends of oats and unripe plantain?
(d) What are the phytochemical properties of the newly formulated flour blends of oats and unripe plantain?
(e) How do consumers perceive the sensory properties (e.g., taste, texture, and aroma) of the products made from the composite flour blends of oats and unripe plantain?

2. Materials and Methods

1.1. Design for the Study

The design involved an experimental research design. Experimental design is the process of conducting research in an objective and controlled manner such that precision is maximized and definite conclusions can be formed about a hypothesis. Generally, the goal is to determine how a factor or independent variable affects a dependent variable (Bell, 2009). Which in this case was to determine the effect of food to food fortification on the nutrient content of some food products.

2.2. Area of the Study

The chemical composition were carried out in the analytical laboratory, while the sensory evaluation of composite flour made from oats (*Avena sativa L.*) and unripe plantain (*Musa paradisiaca*) were carried out in the food laboratory. Both were carried out in the Department of Home Science and Management, University of Nigeria, Nsukka.

2.3. Population and Sample

A thirty panelists consisting of ten lecturers and 20 undergraduate students were randomly selected and trained on sensory attributes for the evaluation of food products from the Department of Home Science and Management, University of Nigeria, Nsukka.

2.4. Instrument for Data Collection and Study Procedure

2.4.1. Sources of Materials

Two kilogram of unripe plantain, 2kg oats and other ingredients were obtained from Ogige market, Nsukka Local Government Area, Enugu State. Unripe plantain and oats were taken to the Department of Plant Science and Biotechnology, Faculty of Biological Science, University of Nigeria Nsukka for identification.

2.4.2. Sample Preparation

The 2kg matured unripe plantains was washed, peeled and cut into thin slices. The plantain slices was dried in a hot conventional oven at 60°C for 12 hours. The plantain slices was milled in a Thomas-Wiley laboratory hammer mill. The sample was sieved through a fine mesh. The sample was packaged and sealed in an air tight pouch bags and stored at a temperature of 28°C ±2. 2kg of oats was also dried using oven drying method for 4 hours and taken to the laboratory mill to be milled into flour using Thomas-Wiley laboratory hammer mill. The sample was properly sieved using a standard mesh. The sample was packaged and sealed in an air tight pouch bags and stored at a temperature of 28°C ±2.

2.4.3. Sample Formulation

Composite flour were formulated from processed unripe plantain and oats using the following ratio

50% unripe plantain and 50% oat: 1:1
70% unripe plantain and 30% oat: 7:3
80% unripe plantain and 20% oat: 4:2

2.4.4. Proximate Analysis procedure

Moisture content, total ash, crude fibre, crude fat and crude protein content of the blended flour samples (homogeneous mixture of unripe plantain flour and oats flour) were determined in triplicate except for carbohydrate contents which was determined by difference. The standard methods of Association of Official Analytical Chemist (AOAC, 2010) was used to determine the chemical composition of the samples.

2.4.5. Minerals Analysis procedure

Minerals content (zinc, iron, calcium and sodium) of the blended flour samples were determined according to method as described by AOAC (2010) using absorption spectrophotometer. All the analyses were in triplicate determinations.

2.4.6. Phytochemical Composition Analysis procedure

Phytochemical composition of the samples included total flavonoids, phenols and saponin were determined as described by standard methods of the Association of Officials Analytical Chemist (AOAC), 2010

2.4.7. Sensory Evaluation Procedure

A thirty-member panel was trained on sensory attributes for the evaluation of food products on a 9-ponit Hedonic scale (where 9= extremely like and 1= dislike extremely). The samples were specifically scored for color, flavor, taste, texture and overall acceptability. The flour was used to prepare moi moi and fufu in different ratios and it was used for sensory evaluation.

2.5. Data Analysis Technique

The data collected was subjected to Analysis of Variance (ANOVA) using the statistical package for Social Sciences (SPSS) Version 22.0. Duncan's Multiple Range Test (DMRT) was used to compare the treatment mean. Statistical significance was accepted at ($p<0.05$).

3. Results and Discussion

Table 1: Proximate composition of oat and unripe plantain composite flour (%/100g)

Sample	Moisture	Crude Fat	Fibre	Protein	Ash	CHO
OP1	14.50 ± 63.36^a	2.50 ± 0.71^a	0.60 ± 0.00^a	23.21 ± 0.37^a	2.00 ± 1.41^a	57.20 ± 8.86^b
OP2	12.50 ± 0.71^a	1.50 ± 0.71^a	0.40 ± 0.28^a	12.61 ± 0.00^b	2.00 ± 1.41^a	70.99 ± 1.13^a
OP3	$1\ 2.00\pm2.83^a$	1.50 ± 0.71^a	0.30 ± 0.14^a	6.65 ± 1.98^c	2.00 ± 0.00^a	77.55 ± 0.00^a

Values are Means ± SD (standard deviation) of duplicate determination. Means on the same column with different superscripts are significantly different at $p<0.05$; CHO = Carbohydrate

Key:

OP 1 = unripe plantain/oat (50%:50%)

OP 2= unripe plantain/oat (70%:30%)

OP 3= unripe plantain/oat (80%:20%)

3.1. Proximate composition of oat and unripe plantain composite flour

Table 1 showed the proximate composition value of oat and unripe plantain composite flour. From the results OP1 which has the highest moisture content of about 14.5% also contains the highest amount of fat (although fat intake is not advised for obese persons), highest fibre and protein contents and less amount of carbohydrates when compared to OP2 and OP3. Furthermore, moisture content ranged from 12% to 14.5% with the 80%:20% unripe plantain - oats composite flour having the least moisture content (12%), while the sample with 50% unripe plantain and 50% oats flours had the highest value (14.5%). In agreement with the reports of Hu et al. (2014) and Orlu et al. (2022), moisture contents of all the formulated composite food samples reported in this study were within the recommended moisture contents for dried foods. Since, high moisture content in food has been shown to encourage microbial growth (Oboh & Erema, 2010), it implies that lower storage moisture content would have better shelf stability of the dried food product (Yu & Anchordoquy, 2009). However, low residual moisture content in food is advantageous in that microbial proliferation is reduced and storage life may be prolonged. From the analysis of moisture content values obtained in this study, the values suggest that moisture content of all corresponding ratios of unripe-plantain and oats flours were within the range reported to have no adverse effect on the quality attributes of dried food products (Onyekwelu & Ogbu, 2017). This implies that properly dehydrated oats and unripe plantain flour blends will reduce storage moisture content. Also Oats-unripe plantain flour blends with 50:50 of the components can be considered a good source of fibre, protein and limits the carbohydrate intake levels for both diabetics and obese persons. The protein content of the samples ranged from 6.65% to 23.21%. The protein content of the sample OP3 (80%:20% unripe plantain - oats composite flour) was the lowest (6.65%), while the sample substituted with 50% unripe plantain and 50% oat flours had the highest protein content (23.21%). The protein content of the samples was observed to increase with increase in substitution with oat flour. Protein is important for tissue replacement, deposition of lean body mass and growth (Mäkinen et al., 2017). Thus, the results showed that the protein contents of the composite flours were high and this was higher than 4%-6.9% protein reported for plantain soy composite flour (Arinola et al., 2019).

Table 2: Mineral contents of the oat and unripe plantain composite flour (mg/100g)

Sample	Iron	Zinc	Sodium	Calcium
OP1	2.15 ± 0.25^a	0.62 ± 0.05^a	97.75 ± 1.63^b	0.30 ± 0.01^a
OP2	1.81 ± 0.01^a	0.29 ± 0.05^b	106.95 ± 1.163^a	0.23 ± 0.01^b
OP3	2.36 ± 0.40^a	0.82 ± 0.05^c	94.30 ± 3.25^b	0.31 ± 0.01^a

Values are Means ± SD (standard deviation) of duplicate determination. Means on the same column with different superscripts are significantly different at $p<0.05$

Key:

OP 1 = unripe plantain/oat (50%:50%)

OP 2= unripe plantain/oat (70%:30%)

OP 3= unripe plantain/oat (80%:20%)

3.2. Mineral contents of the oat and unripe plantain composite flour

Table 2 showed the mineral contents of the oat and unripe plantain composite flour. Comparing the OP1 oats and plantain flour blends OP2 and OP3 mixes, OP1 has the highest amount of iron, high amount of zinc, moderate in sodium content, and has a high amount of calcium. This was in agreement with Ibeanu et al. (2015) that iron deficiency can lead to anemia and other health risks for Type 2 Diabetics, more intakes of the OP1 mixes will contribute to more iron in the body hence, reducing the risk of anemia in Diabetics. Sodium was the mineral with the highest concentration in the composite flours. The sodium content of OP1 (about 97.97) is considered moderate and not too high to cause increase in blood pressure and risks of heart diseases in both Diabetics and obese persons. The OP1 mixes also had a good amount of zinc (about 0.62) which can ensure correct processing, storage and secretion of insulin and helps to prevent oxidative stress induced by diabetes. Research and studies suggest that zinc may lower blood sugar and cholesterol levels in people with Type 2 diabetes. The amount of calcium in the OP1 and OP3 flour mixes is good for diabetics to help in better glucose metabolism. Calcium has a vital role in the prevention of diabetes by improving insulin secretion, sensitivity and pancreatic beta-cells functions since insulin secretion depends on calcium requirements for the body.

Table 3: Phytochemical contents of the oat and unripe plantain composite flour (mg/100g)

Sample	Phenols	Saponin	Flavonoid
OP 1	0.11±0.00[c]	0.40±0.28[a]	0.28±0.20[a]
OP 2	0.87±0.01[b]	0.80±0.28[a]	2.18±0.15[a]
OP 3	0.90±0.00[a]	0.90±0.14[a]	1.12±1.22[a]

Values are Means ± SD (standard deviation) of duplicate determination. Means on the same column with different superscripts are significantly different at $p<0.05$

Key:

OP 1 = unripe plantain/oat (50%:50%)

OP 2= unripe plantain/oat (70%:30%)

OP 3= unripe plantain/oat (80%:20%)

3.3. Phytochemical contents of the oat and unripe plantain composite flour

Table 3 showed phytochemical contents of the oat and unripe plantain composite flour. From the results of the phytochemicals composition of the analysed unripe plantain and oats flour blends, significant differences ($p<0.05$) in the levels of the anti-nutrients in the composite flours were observed. The phenol and Saponin content significantly increased ($p<0.05$) with the increase in unripe plantain substitution. This reduction may be due to nutrient-nutrient interaction with increasing levels of composite flour. The phenols amount in this study may not be as such harmful as expected for consumption. The high amount of phenols is well known to form complexes with proteins and reduced the solubility of proteins and make protein so susceptible to proteolytic attack than the same proteins alone (Amoako & Awika, 2016). It can be observed that the higher the plantain content of any unripe plantain and oats flour mix the higher the value and concentration of phenols, saponin and flavonoids in the mix. OP1 has the lowest amount of phenols, saponin and flavonoids followed by OP2 and OP3 which has the highest amount of phytochemicals in concentration. Nevertheless, to maintain the recommended mix of OP1, diabetics and obese persons are advised to consume more plantain rich foods (in different dishes and varieties) to increase their phytochemical intake since it is observed that the increase in phytochemicals composition of the OP mixes depend on the amount of plantain in the mix.

Table 4: Sensory evaluation scores of moi-moi and fufu made with oat and unripe plantain composite flour with the best nutritional property

Sample	Colour	Flavour	Taste	Texture	General Acceptability

APOM1	6.87±1.76^{a}	6.73±1.60^{a}	6.90±1.49^{a}	6.10±2.26^{ab}	6.47±1.81^{a}
APOM2	6.60±1.81^{a}	5.97±1.87^{ab}	5.80±1.71^{bc}	6.50±1.36^{ab}	6.17±1.80^{a}
APOM3	5.37±2.36^{b}	5.57±2.01^{b}	5.50±2.37^{c}	6.60±1.90b	5.53±2.42ab
BPOS1	5.30±2.39^{b}	4.87±1.87^{b}	4.97±2.00^{c}	3.80±1.75c	3.90±1.71c
BPOS2	6.70±2.20^{a}	5.93±2.21^{ab}	6.67±1.73^{ab}	5.50±2.13^{bd}	5.63±2.41ab
BPOS3	5.33±2.66^{b}	5.33±2.40^{b}	5.67±1.96^{bc}	4.60±1.96^{cd}	4.39±2.39bc

Values are Means ± SD (standard deviation) of thirty panelists. Means on the same column with different superscripts are significantly different at p<0.05

Key:

APOM1 = 50%:50%e unripe plantain - oat moi-moi

APOM2= 70%:30% e unripe plantain – oat moi-moi

APOM3= 80%:20%e unripe plantain - oat moi-moi

BPOS1 = 50%:50%e unripe plantain - oat fufu

BPOS2 = 70%:30% e unripe plantain – oat fufu

BPOS3 = 80%:20%e unripe plantain - oat fufu

3.4. Sensory evaluation scores of moi-moi and fufu made with oat and unripe plantain composite flour with the best nutritional property

Table 4 showed the sensory evaluation scores of moi-moi and fufu made with oat and unripe plantain composite flour with the best nutritional property. The sensory scores of the pudding (moi-moi) prepared from the formulated unripe plantain and oats flour samples showed significant differences (p<0.05) in colour, taste, flavour, texture and overall acceptability. The APOM1 sample (50% oat and 50% unripe plantain moi moi pudding) had significant difference (p<0.05) the highest scores for colour, taste, flavour and overall acceptability compared to the other samples, while the sample BPOS1 substituted with (50% oats and 50% unripe plantain fufu) had the lowest scores. The moi-moi prepared from 50% oat and 50% unripe plantain and the fufu made from 70% unripe plantain and 30% oat flours were generally acceptable. The increase in substitution of unripe plantain resulted in decrease in acceptability of the moi-moi as indicated by the relatively low scores for the moi-moi sample substituted with 80% unripe plantain and 20% oat flours. The fufu increase in substitution of unripe plantain resulted in increase in acceptability of the fufu as indicated by the relatively low scores for the fufu sample substituted with 50% unripe plantain and 50% oat flours. The variation in colour observed could be due to increased substitution of the formulations with oats and unripe plantain flour. However, the moi-moi made from the sample substituted with 50% oat and 50% unripe plantain flours was described by the panelists as having the best taste, flavour and overall acceptability compared to the other test samples.

Limitations of the study

This study is limited in that the vitamin content of the composite flour and the meals were not examined. Also, few phytochemicals and minerals were examined. Hence these variables could not be reported in case.

Suggestions for further research

Further research is recommended on the use of other food items in formulating composite flour in order to improve on the nutritional content of the foods that people normally consume.

4. Conclusion

In this study, composite flours were formulated from oats and unripe plantain at three different proportions. The proximate, mineral, phytochemicals and sensory properties of the formulated flour blends were analysed to suggest the appropriate mixture of these flours based on their concentration and sensory properties. The proximate, mineral and phytochemicals composition of oats and unripe plantain showed the potential to serve as an appreciable source of plant protein, fibre and carbohydrate which means serving as body repair food. All these attributes qualify the composite flour as good source of food which has antioxidant and health promoting characteristics. Composite flour made with 50% oats and 50% unripe plantain had the best nutritional value. The foods produced were accepted by the judges. Therefore, the production of staple foods with 50:50 oats - unripe plantain composite flour respectively could be one of the cost effective way of providing variety of food for diabetic and obese patients.

Acknowledgements

The authors are grateful to the Department of Home Science and Management, University of Nigeria, Nsukka, the laboratory assistants and data analysts for their assistance.

Conflict of Interest

The authors declared no conflict of interest.

Authors Contributions

NGO1 designed the work, wrote and edited the article. NGO2 proofread the article. SNE collected samples used for the research while LOO presented the work at conference level. All the authors participated in carrying out analysis of the samples. All authors approved the final draft for publication.

Data Availability Statement

Original contributions presented in the study are included in the article. Further inquiries can be directed to the appropriate authors.

Funding Information

The authors have no funding to disclose.

References

Agu, H.O., Ezeh, G.C., & Jideani, A.I.O. (2014). Quality assessment of acha-based biscuit improved with Bambara nut and unripe plantain. *African Journal of Food Science, 8*(5), 278 – 285. http://dx.doi.org/10.5897/AJFS2013.1130

Amoako, D., & Awika, J. M. (2016). Polyphenol interaction with food carbohydrates and consequences on availability of dietary glucose. *Current Opinion in Food Science*, *8*, 14–18. https://doi.org/10.1016/j.cofs.2016.01.010

AOAC (2010). Official Methods of Analysis.18th ed. Washington DC, USA, Association of Official Analysis Chemist.

Arinola, S.O., Ogunbusola, E.M., & Adebayo, S.F. (2016). Effect of drying methods on the chemical, pasting and functional properties of unripe plantain (Musa paradisiaca) flour. *Current Journal of Applied Science and Technology*, *14*(3), 1–7. https://doi.org/10.9734/BJAST/2016/22936

Bell, S. (2009). Experimental design. In R. Kitchin, & N. Thrift (Eds.), *International encyclopedia of human geography* (pp. 672-675). Elsevier. https://doi.org/10.1016/B978-008044910-4.00431-4

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R., & Maternal and Child Nutrition Study Group (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet (London, England)*, *382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Burchi, F., Fanzo, J., & Frison, E. (2011). The role of food and nutrition system approaches in tackling hidden hunger. *International Journal of Environmental Research and Public Health*, *8*(2), 358–373. https://doi.org/10.3390/ijerph8020358

Chadare, F.J, Idohou, R., Nago, E., Affonfere, M., Agossaddou, J., Fassinou, T.K., Kenou, C., Honfo, S., Azokpota, P., Linnemann, A.R., & Hounhouigan, D.J. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food Science and Nutrition, 7*(9), 2781-2795. https://doi.org/10.1002/fsn3.1133

Chinma, C.E., Igbabul, B.D. and Omotayo, O.O. (2012) Quality characteristics of cookies prepared from unripe plantain and defatted sesame flour blends. *American Journal of Food Technology, 7*, 398-408. https://doi.org/10.3923/ajft.2012.398.408

Eleazu, C.O., & Okafor, P.N. (2012). Antioxidant effect of unripe plantain (Musa paradisiacae) on oxidative stress in alloxan-induced diabetic rabbits. *International Journal of Medicine and Biomedical Research, 1*(3), 232-241. https://doi.org/10.14194/IJMBR.1311

Famakin, O., Fatoyinbo, A., Ijarotimi, O. S., Badejo, A. A., & Fagbemi, T. N. (2016). Assessment of nutritional quality, glycaemic index, antidiabetic and sensory properties of plantain (*Musa paradisiaca*)-based functional dough meals. *Journal of Food Science and Technology*, *53*(11), 3865–3875. https://doi.org/10.1007/s13197-016-2357-y

Hu, X.Z., Zheng, J.M., Li, X.P., Xu, C., & Zhao, Q. (2014). Chemical composition and sensory characteristics of oat flakes: A comparative study of naked oat flakes from China and hulled oat flakes from western countries. *Journal of Cereal Science*, *60*(2), 297-301. https://doi.org/10.1016/j.jcs.2014.05.015

Ibeanu, V.N., Onyechi, U.A., Ani, P.N., & Ohia, C. (2015). Composition and sensory properties of plantain cake. *Australian Journal of French Studies, 10*, 25-32. https://doi.org/10.5897/AJFS2015.1292

Ilelaboye, N.O. (2019). Chemical, physico-chemical and sensory evaluation of moringa-plantain flour. *Asian Food Science Journal, 6*(4), 1-12. http://dx.doi.org/10.9734/AFSJ/2019/45796

Jideani, I. A., & Jideani, V. A. (2011). Developments on the cereal grains Digitaria exilis (acha) and Digitaria iburua (iburu). *Journal of Food Science and Technology*, *48*(3), 251–259.

https://doi.org/10.1007/s13197-010-0208-9

Kruger, J., Taylor, J.R.N., Ferruzzi, M.G., & Debelo, H. (2020). What is food-to-food fortification? A working definition and framework for evaluation of efficiency and implementation of best practices. *Comprehensive Reviews in Food Science and Food Safety, 19*(6), 3618-3658. https://doi.org/10.1111/1541-4337.12624

Mäkinen, O.E., Sozer, N., Ercili-Cura, D., & Poutanen, K. (2017). Protein from oat: Structure, processes, functionality, and nutrition. In S.R. Nadathur, J.P.D. Wanasundara, & L. Scanlin (Eds.), *Sustainable protein sources* (pp. 105–119). Academic Press. https://doi.org/10.1016/B978-0-12-802778-3.00006-8.

Muthayya, S., Rah, J. H., Sugimoto, J. D., Roos, F. F., Kraemer, K., & Black, R. E. (2013). The global hidden hunger indices and maps: an advocacy tool for action. *PloS one*, *8*(6), e67860. https://doi.org/10.1371/journal.pone.0067860

Noah, A. A. & Adedeji, M. A. (2021). Quality assessment of cookies produced from wheat and red kidney bean flour. *International Journal of Food and Nutritional Sciences, 10*(1), 6-9. https://doi.org/10.4103/ijfns.ijfns_13_20

Noort, M.W.J., Renzetti, S., Linderhof, V., du Rand, G.E., Marx-Pienaar, N.J.M.M., de Kock, H.L., Magano, N., & Taylor, J.R.N. (2022). Towards sustainable shifts to healthy diets and food security in Sub-Saharan Africa with climate-resilient crops in bread-type products: A food system analysis. *Foods*, *11*(2), 135. https://doi.org/10.3390/foods11020135

Oboh, H.A., & Erema, V. G. (2010). Glycemic indices of processed unripe plantain (Musa paradisiaca) meals. *African Journal of Food Science*, *4*(8), 514–521. http://www.academicjournals.org/ajfs

Olson, R., Gavin-Smith, B., Ferraboschi, C., & Kraemer, K. (2021). Food fortification: The advantages, disadvantages and lessons from *Sight and Life* programs. *Nutrients*, *13*(4), 1118. https://doi.org/10.3390/nu13041118

Onyekwelu, C.N., & Ogbu, O.A.C. (2017). Quality assessment of cookies produced from composite flour of wheat, unripe Plantain and Moringa leaf. *Specialty Journal of Agricultural Sciences, 3*(2), 1-7. http://www.sciarena.com/

Orlu, C.C.S., Akusu, O.M., Wordu, G.O., & Chibor, B.S. (2022). Physicochemical, textural and sensory characteristics of instant noodles produced from wheat and plantain flour blends, spiced with ginger. *European Journal of Agriculture and Food Sciences, 4*(6), 34 – 41. https://doi.org/10.24018/ejfood.2022.4.6.549

Uvere, P. O., Onyekwere, E. U., & Ngoddy, P. O. (2010). Production of maize-bambara groundnut complementary foods fortified pre-fermentation with processed foods rich in calcium, iron, zinc and provitamin A. *Journal of the Science of Food and Agriculture*, *90*(4), 566–573. https://doi.org/10.1002/jsfa.3846

World Health Organisation (2024). *Food fortification.* WHO. Retrieved 23rd August, 2024 from https://www.who.int/health-topics/food-fortification#tab=tab_1

Yu, J., & Anchordoquy, T. J. (2009). Effects of moisture content on the storage stability of dried lipoplex formulations. *Journal of Pharmaceutical Sciences*, *98*(9), 3278–3289. https://doi.org/10.1002/jps.21846

Publisher: Department of Home Economics and Hospitality Management Education, University of Nigeria, Nsukka, Nigeria