Evaluation of the Proximate Composition and Functional Properties of *Dioscorea dumentorum* (Bitter yam) and *Musa paradisiaca* (Unripe plantain) Flour Blend for Instant Fufu

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Abstract

The study determined the proximate composition and functional properties of Dioscorea dumentorum (Bitter yam) and Musa paradisiaca (Unripe plantain) flour blend for instant fufu. The bitter yam and unripe plantain flour used in this study were washed, peeled, sliced into small pieces, dried in the desiccator, and milled separately into flour. The formulation of the blended flour was done into five different ratios for instant fufu (A=100BYF: 0UPF; B=70BYF:30UPF; C=60BYF: 40UPF, D=50BYF: 50UPF and E=0BYF:100UPF) and were taken for proximate and functional properties analysis with sample E as the control sample. Three objectives of the study with the corresponding research questions guided the study. An experimental design was used for the study. Statistical analysis (ANOVA) was used on Standard Deviations and Means values of duplicate samples, and Duncan Multiple Range Test was employed to separate means at a 0.05 level of significance. The result of the proximate analysis showed that the moisture content was highest in A(8.76%) and lowest in E(8.10%);the protein was highest in A(6.10%) and lowest in E(2.69%);the crude fat was highest in C(1.25%) followed by A(1.20%) and least in E(0.70%);the crude fiber was highest in A(1.93%)and least in E(0.5%);the ash value was highest in E(3.29%) and least in A (2.29%);the carbohydrate value was highest in E(84.71%) and least in A(79.45%); the energy value was highest in E(355.88Kcal) and lowest in D(352.41Kcal). When compared with the control sample, sample D had the highest BD (0.8g/ml) while A had the least BD value(0.54Gg/ml); A came highest in WAC (295.72%) and SI value (4.96%) respectively and D showed lowest in the LGC (10%). The water absorption capacity, bulk density, swelling index, and least gelation capacity, which are the selected functional properties of the samples were best in A followed by B, C and D when compared with the control. The functional analysis of the flour shows that with an increase in substitution, there is increase in bulk density and least gelation capacity, while decrease in water absorption capacity and swelling index. While all the samples have good proximate values and functional properties, when compared with control sample, A will support normal body growth, manage chronic diseases and be good at baking and producing infants' complementary foods; C will also be good in culinary activities and D will give more energy for work. It is recommended that the food processing industries should encourage the processing of bitter yam and unripe plantain into flour blends suitable for producing shelf-stable and protein-enriched products required for health and nutritional benefits.

Introduction

Fufu is a wet paste and dough-like food made from fresh or fermented cassava, found in West African especially in Nigeria, Cameroon, and Ghana and can be eaten with soup or sauce (Owolarafe, et al., 2018). Instant fufu processing and packaging is an innovative process even though it's just emerging and not still practiced for a long

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scale as most other food products such as sorghum, millet, maize, etc. This could improve food security, diversify manufacturing, generate income, and boost employment (Deniran et al., 2022). Also, to find an easy substitute for the traditional method of preparing this West African staple, the instant fufu is a better option. According to Bamidele, Fasogbon, Oladiran & Akande, (2015), it is available in powdered or pre-cooked form, and it is also greatly desired due to its convenience. In the same vein, Nwadili et al, (2024) implied that instant fufu's nutritional profile can vary from traditional fufu, influenced by ingredients and processing methods, making it crucial for consumers seeking convenience and health benefits.

Furthermore, disease outbreaks or chronic conditions can influence dietary choices, motivating individuals to incorporate diverse foods to boost immune function and overall well-being (Norris, Jilcott Pitts, Reis & Haynes-Maslow, 2023). As a result, an innovative blend of bitter yam and unripe plantain was used to produce flour blend for instant fufu. Plantain, a staple crop in tropical and subtropical regions, is a significant dietary component, rich in complex carbohydrates, rich in major vitamins and minerals (Adegunwa, et al., 2024), dietary fibre, essential for digestive health, maintaining satiety and a significant source of energy (Marta et al,2019). In fact, Ogunbanwo, Sanni & Onilude, (2012) had affirmed that plantain eating has been linked to many health advantages.

On the other hand, bitter yam, a West African tuberous plant, is a traditional food source and has potential health benefits due to its nutritional content and medicinal properties (Salawu, Ajiboye, Akindahunsi & Boligon, 2017). Because of its high fiber content and high mineral values like manganese, potassium, and vitamin C, it promotes digestive health and is a wonderful source of energy (Salawu, Ajiboye, Akindahunsi & Boligon, 2017). Research shows that extracts from bitter yam may offer antioxidant and anti-inflammatory benefits, linked to bioactive substances such as alkaloids and flavonoids (Obidiegwu, Lyons & Chilaka, 2020). Bitter yam, despite its bitter taste, is commonly used in traditional dishes like soups and stews, suggesting potential use in conventional medicine for treating inflammatory and oxidative stress-related disorders (Chijioke et al, 2021).

Objectives of the Study.

The objective of the study was to evaluate the proximate composition and functional properties of instant fufu produced from the *Dioscorea dumentorum* (Bitter yam) and *Musa paradisiaca* (Unripe plantain) flour blend. Specifically, the study sought to:

1. formulate and prepare instant fufu from bitter and unripe plantain flour blend in five different ratios (100BYF:0UPF; 70BYF:30UPF; 60BYF:40UPF; 50BYF:50UPF and 0BYF:100UPF).
2. determine the proximate composition of instant fufu produced from bitter yam and unripe plantain flour blend.
3. determine the functional properties of instant fufu produced from bitter yam and unripe plantain flour blend.

Materials and Methods

The matured unripe plantain (French horn specie) and bitter yam (white specie) were bought from Ogige market Nsukka, Enugu State Nigeria. And the plantain fingers were at stage 2(unripe) while the white species was used due to its affordability and availability in Nsukka. The market was chosen by the researcher because of proximity and affordability of the products in the said market. The tools used were clean and sharp kitchen knife, two big bowls and 5 clean large metal trays for spreading them prior to dehydrating in the oven.

Processing procedure

Flow chart of the processing of Bitter yam *flour.*

Bitter yam, washed, peeled and sliced

↓

Immersed in sodium metabisulphate

↓

Blanched and oven dried

↓

Milled into flour

↓

Packaged and labelled

***Flow chart of the processing of Unripe plantain flour*.**

Unripe plantain, detached, peeled and cut

↓

Rinsed in Citric acid

↓

Drain and oven-dry

↓

Mill into flour

↓

Packaged and labelled.

Product Formulation

The unripe plantain and bitter yam flours were formulated, coded and separated at five different proportions (A=100BYF: 0UPF; B=70BYF:30UPF; C=60BYF: 40UPF, D=50BYF: 50UPF and E=0BYF:100UPF) 100% unripe plantain flour were used as the control samples. The flours were mixed using a B8 (Mega Best Industry Ltd, GuangDong, China) universal spiral mixer at 450 rpm for 20 min until uniform blends were obtained and instant fufu was produced from them all. The different samples of the formulated blended flour were packaged in small-sized Ziplock bags ready to be used at convenience for making fufu at homes.

Proximate Analysis.

The proximate analysis of the product which involves the analytical methods of determining the macronutrients compositions (moisture, protein, crude fat, carbohydrate, ash, crude fiber and energy value) of a food sample. This was done in the laboratory using the AOAC, (2010) methods on 100g of each sample.

Functional Properties Analysis.

The functional attributes of the instant fufu refers to the physical and chemical characteristics of a food that affect its functionality. Four selected functional properties (Bulk density, Water absorption capacity, swelling index and least gelation capacity) were determined in the laboratory using the AOAC, (2010) standard method

Table 1: Proximate composition of instant fufu produced from bitter yam and unripe plantain flour blend.

Samples(%/100 g)	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)	Energy (Kcal)
A	8.76a±0.01	6.39e±0.37	1.20a±0.01	1.93a±0.13	2.29b±0.28	79.45d±0.54	354.12a±0.55
B	8.36a±0.30	5.33d±0.08	1.15a±0.08	1.50b±0.01	2.90a±0.29	80.78c±0.76	354.73a±1.99
C	8.50a±0.23	4.56c±0.00	1.25a±0.06	1.33b±0.04	3.19a±0.00	81.18c±0.13	354.17a±1.08
D	8.45a±0.56	3.65b±0.00	0.75a±0.35	1.25b±0.00	3.14a±0.06	82.78b±0.28	352.41a±4.22
E	8.10a±0.36	2.69a±0.00	0.70a±0.28	0.53c±0.18	3.29a±0.15	84.71a±0.11	355.88a±2.97

Values are mean ± SD of 2 replications. Means with the same superscript within a column are not significantly different at ($p>0.05$), while means with different superscript in a column are significantly ($p<0.05$) different.

Keys: A flour blend with 100-part bitter yam flour: 0-part unripe plantain flour. B =flour blend with 70-part bitter yam flour:30-part unripe plantain flour. C=flour blend with 60-part bitter yam flour:40-part unripe plantain flour. D=flour blend with 50-part bitter yam flour:50-part unripe plantain flour. E=flour blend with 0-part bitter yam flour:100-part unripe plantain flour.

Results

Table 1 shows the percentage values of macronutrients in the five samples of the bitter yam and unripe plantain flour blends which are (A=100BYF: 0UPF; B=70BYF:30UPF; C=60BYF: 40UPF, D=50BYF: 50UPF and E=0BYF:100UPF).Results for sample A are as follows: 8.76% moisture, 6.39% protein,1.2% fat, 1.93% crude fiber, 2.29% ash, 79.48% carbohydrate and 354.12% Energy. Sample B contains 8.56% moisture, 5.33% protein, 1.15% fat, 1.50% crude fiber, 2.90% Ash, 80.78% carbohydrate and 354.73Kcal of energy. Sample C contains 8.50% moisture, 4.56 protein, 1.25% fat, 1.33%crude fiber, 3.39% ash, 81.18%carbohydrate and 354.17Kcal of energy. Sample D has 8.45%moisture, 3.65% protein, 0.75%fats, 1.25% crude fiber, 3.14% ash, 82.78% carbohydrate and 352.4% Energy. Sample E contain 8.10% moisture, 2.69%protein, 0.70%fat, 0.53% crude fiber, 3.29% ash, 84.71% carbohydrate and 355.88Kcal energy. The result also revealed that there is no significant difference($p>0.05$) in the moisture content, fat content and the energy value of the five fufu sample while the protein, fiber, carbohydrate and ash value of the five fufu samples differed significantly($p<0.05$).

Table 2: Selected functional properties of instant fufu flour made from bitter yam and unripe plantain flour blend.(Keys: BD=Bulk density; WAC=Wet absorption capacity; SI=Swelling index &LGC=Least gelation capacity).

Samples(%/100g)	BD (g/ml)	WAC %	SI	LGC %
A (100:0)	$0.54^{b}\pm0.00$	$295.72^{a}\pm5.49$	$4.96^{a}\pm0.40$	$10.00^{c}\pm0.00$
B (70:30)	$0.55^{b}\pm0.00$	$271.15^{b}\pm1.70$	$4.76^{ab}\pm0.08$	$12.00^{b}\pm0.00$
C (60:40)	$0.58^{a}\pm0.01$	$266.18^{b}\pm5.84$	$4.47^{ab}\pm0.04$	$13.00^{ab}\pm1.41$
D (50:50)	$0.58^{a}\pm0.01$	$255.06^{c}\pm3.29$	$4.34^{b}\pm0.20$	$14.00^{a}\pm0.00$
E (0:100)	$0.59^{a}\pm0.01$	$202.34^{d}\pm0.92$	$3.72^{c}\pm0.09$	$14.00^{a}\pm0.00$

Values are mean ± SD of 2 replications. Means with the same superscript within a column are not significantly different at ($p>0.05$), while means with different superscript in a column are significantly ($p<0.05$) different.

Keys: A=flour blend with 100-part bitter yam flour: 0-part unripe plantain flour. B =flour blend with 70-part bitter yam flour:30-part unripe plantain flour. C=flour blend with 60-part bitter yam flour:40-part unripe plantain flour. D=flour blend with 50-part bitter yam flour:50-part unripe plantain flour. E=flour blend with 0-part bitter yam flour:100-part unripe plantain flour.

Results

Table 2 revealed the values obtained from the analysis of the functional properties of the instant fufu flour from bitter yam and unripe plantain flour blend. Sample A contains 0.54g/ml bulk density, 295.7% wet absorption capacity, 4.96 swelling index and 10%least gelation capacity. Sample B has 0.55g/ml, 271.15% wet absorption capacity, 4.76 swelling index and 12% least gelation capacity. Sample C has 0.58g/ml bulk density, 266.18% wet absorption capacity, 4.47 swelling index and 13% least gelation capacity. Sample D has 0.58g/ml bulk density, 255.6% wet absorption capacity, 4.34 swelling index and 14% least absorption capacity. Finally, sample E has 0.59g/ml bulk density, 202.34% wet absorption capacity, 3.72 swelling index and 14% least gelation capacity. The result also showed there was significant different($p<0.05$) in the bulk density values, wet absorption capacity, swelling index and least gelation capacity values across the five samples of the flour blend.

Discussion of findings.

The proximate composition analysis showed that moisture levels in the samples ranged from 8.10% to 8.76%. Sample A had the highest moisture content (8.76%), lower than the 61.6% reported by Emedom (2018), indicating good shelf stability. Sample E had 8.10% moisture, which is close to the 8.8-9.65% range for plantain flour as noted by Yadav et al. (2012), also confirming its stability. Moisture content decreased in samples B, C, and D as unripe plantain flour was substituted with bitter yam flour. According to Singh et al. (2005), flour with moisture levels below 10% is shelf-stable when stored in moisture-proof containers.

The crude protein content of the sample ranged from 2.69 to 6.39% in the samples E and A respectively with that of A (6.39%) being the highest when compared with the control sample E. The protein concentration in the sample A was greater than 5.20% and 5.70% of white and yellow bitter yam respectively as obtained by Adebayo & Phillip, (2020) while the protein content (2.69%) in sample E was shown to be lower than (3.37%) obtained by Adebowale, Oladele and Fadairo, (2019).As can be observed in B, C, and D, the protein content decreased when bitter yam flour was replaced with unripe plantain flour, possibly due to its lower protein level.

The flour samples' crude fiber contents ranged from 0.53 in A to 1.93%in E. when compared with the control, A (1.93%) had the highest fiber value. There is a reduction in the fiber value with the substitution of bitter yam flour with unripe plantain. However, crude fiber suggests stiff dough may offer health benefits like reduced constipation, obesity, and lower blood sugar absorption (Dike, Obembe & Asebiyi, 2012).

Furthermore, the crude fat of the composite flour ranged from 0.70-1.25%. The crude fat content (0.70%) of sample E was seen to be lower than the values 0.2% and 0.26% as recorded by Adebowale, Oladele & Fadairo, (2019). When compared with control, fat content of C (1.25%) was highest. The crude fat content (1.20%) of sample A is comparably higher in value than the values (0.70% and 0.72%) obtained by Adebayo & Phillip, (2020) as the crude fat composition of white and yellow bitter yam respectively. The study by Bradbury & Holloway (1988) found that yam tubers, despite being higher than the 0.1% reported, are not lipid sources, making them suitable for weight management, cardiovascular health, and diabetic conditions (Oyeyinka & Afolayan,2020).

The samples' ash concentrations varied from 2.29 to 3.29% with the ash value of sample A (2.29%) being the lowest when compared with that of the control sample, E (3.29%). As the unripe plantain flour replaced bitter yam flour, there was an increasing ash content in all samples. According to AACC, (2000), the increase in ash content reveals higher flour quality as a result of presence of minerals. Sample A has inadequate mineral values, as evidenced by the lowest ash content in sample A and the greatest ash content in sample E. The values (4.75% and 4.05%) of white and yellow bitter yam respectively as obtained by Adebayo and Phillip, (2020) were higher than 2.29% of ash content of bitter yam flour (sample A) while sample E's total unripe plantain flour's ash concentration (3.29%) was found to be lower than the 6.64% (Adebowale, Oladele, & Fadairo 2019).

The range of the carbohydrate values of the samples was 79.45 to 84.71% with that of A being the lowest(79.45%) when compared with the control sample ,E(84.71%).The highest carbohydrate value was observed in unripe plantain flour (sample E) with score of 84.71% which was also higher than 80.1% carbohydrate content (Adebowale, Oladele & Fadairo, 2019) while the lowest value of carbohydrate (79.45%) was observed in total bitter yam flour (sample A) which was within the range of values 81.86% and 75.95% as gotten in Adebayo and Phillip,(2020). The study found that unripe plantain flour, specifically sample A, has lower carbohydrate value, making it suitable for managing type 2 diabetes and other chronic health conditions, and also suitable for baking and culinary activities (Egbuonu & Nzewu, 2016).

The five flour samples have a rather wide range of calorific content readings; all five samples fell within the range of 352.41-355.88 Kcal/100g. The caloric content of samples largely derived from carbohydrate content, with energy values highest in sample E and lowest in sample D, slightly increased by incorporating unripe plantain flour. The high resistant starch content of bitter yam and unripe plantain flour, which improves digestion and protects against colon cancer, type 2 diabetes, and other cardiovascular diseases (Egbuonu & Nzewi, 2016), may also be the cause of the flour samples' high caloric values (Oladele & Wilson, 2016).

The functional properties analysis showed that the bulk density of the flour samples increased with the substitution of bitter yam flour, as unripe plantain flour has a higher bulk density. Sample A had the lowest bulk density (0.58g/ml) compared to sample E (0.59g/ml), aligning with findings from Engmann & Sanful (2019) and Adebowale et al. (2019). Bulk density, which affects packaging design, was relatively low for all samples. According to Suresh & Samsher (2013), this makes the flour suitable for complementary food recipes and lighter baked goods.

The highest WAC value was obtained in sample A (295.72%) and this could be attributed to the much finer powdery texture and higher surface area of bitter yam flour which makes it more absorbent to moisture. When increasing amounts of unripe plantain flour were combined with bitter yam flour, the WAC values showed a steady decline. The decrease could be due to low protein value in unripe plantain due to absence of gluten (Chandra, Singh & Kumari, 2015). The WAC values of this result were the same with the values obtained by Egbuonu, Nzewi and Egbuonu, (2014) as both revealed a progressive decrease in WAC values when blended with another flours. However, the WAC result of this work differed with the works of Adebowale, Oladele and Fadairo, (2019) and Engmann and Sanful, (2019) in that their works revealed an increase in the WAC values when blended in different ratios with other flours. It has been demonstrated that water absorption ability is an important functional need for foods, particularly those involving the handling of dough (Iwe, Onyeukwu & Agririga, 2016). According to Chandra, Singh and Kumari (2015), a flour's high-water absorption capacity reveals its consistency and makes it ideal for forming a variety of food products, including dough, sausage, processed cheese, and bakery goods.

The SI of the five samples decreased as bitter yam flour was being blended with increasing different ratios of unripe plantain flour and this could be due to low swelling capacity of unripe plantain flours. The SI of sample A (4.96%) was seen to be highest among all the samples when compared with the control sample E (3.72%). The SI of this work were seen to be lower than the SI obtained in the works of Engman and Sanful, (2019) and Adebowale, Oladele and Fadairo, (2019) but higher than the figures obtained in Egbuonu, Nzewi and Egbuonu, (2014). This work and the previous three showed a correlation in that both showed that adding additional flours to bitter yam flour in increasing and varied ratios led to a decrease in the swelling index values. According to Suresh & Samsher (2013), swelling power is a measure of the different rates at which water is absorbed by starch granules in a sample and it is suitable in making cake, muffins or bread and takes less time to cook due to low starch gelatinization temperature.

The least gelation capacity of the flour samples increased as bitter yam flour was replaced by the unripe plantain flour, likely due to the higher LGC value of plantain flour. Sample A had the lowest LGC (10%) compared to the control (14%), while sample D matched the control. All samples showed good gelation properties, attributed to the inclusion of proteins and starch. The low LGC of sample A suggests reduced gluten content, potentially lowering the risk of celiac disease and gluten sensitivity as its ability to form gel has been reduced (Awuchi et al., 2019).

Conclusion and Recommendations

The proximate composition and functional analysis results of the samples revealed that bitter yam and unripe plantain flour blend is a healthy fufu alternative suitable for all age groups, helpful in disease management due to its nutritional values and good for culinary activities in baking industries.

The following recommendations were made from the findings of the study.

1. Sample A's flour blends, particularly those with higher bitter yam proportions, are recommended for shelf-stable products due to low moisture content, and for protein-enriched food products, potentially addressing protein-energy malnutrition in certain populations.
2. The crude fiber content in Sample E (1.93%) indicates that unripe plantain flour is a good source of dietary fiber. These flour blends could be used to develop fiber-enriched products that promote digestive health, reduce the risk of obesity, and manage blood sugar levels, making them suitable for diabetic patients.
3. The relatively low crude fat content across all samples, particularly Sample E (0.70%), makes these flour blends suitable for developing low-fat and heart-healthy food products suitable for individualsmanaging cardiovascular health or those on weight management diets.
4. Sample A's lower carbohydrate content indicates that it could be used in carbohydrate-moderated food products, suitable for type 2 diabetes patients. Sample E's high caloric content indicates that it could be used in high-energy food products, beneficial for athletes or population facing food scarcity.
5. The flour blends, with low swelling index values, are ideal for quick-cooking foods like instant noodles or quick breads. They also have a low least gelation concentration, making them suitable for gluten-free products like puddings or sauces, suitable for those with gluten sensitivity.

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