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Evaluation of Nutrient Content of Plantain-Lima Bean Momo Using Multivariance Analysis Approach

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ABSTRACT

Dietary diversification necessitates the development of nutrient-rich and healthy food products from indigenous and resilient crops for sustainable food and nutrition security in Nigeria. Both plantain and lima bean are resilient and locally available, especially in the south west of Nigeria, though lima bean is underutilized. The study developed pudding (momo) from plantain and lima bean in order to evaluate the functional properties of the flour and nutrient content of the product and enhance lima bean utilization for nutrition and food security. Composite flour from various combination ratios of unripe plantain and lima bean flour was processed into momo products. The functional properties of the flour samples as well as the nutrient content of the momo products were evaluated. The multivariance analysis approach was used to study the relationship between the chemical data, principal components and experimental samples. There was no significant difference ($p>0.05$) n the bulk density of the plantain flour and lima bean flour. Water absorption capacity, oil absorption capacity and swelling power were highest in plantain-lima bean flour (PLF). The higher the lima bean flour in the composite mixture, the higher the protein content of the momo samples. Potassium and phosphorous were the highest in 100% plantain-momo, while iron, antioxidant activity and phytochemical compounds were the highest in momo samples containing 50% plantain flour and 50% lima bean flour. The Principal Component Analysis (PCA) of the momo samples showed the locations of the nutrient data and the samples in the quadrants. The PCA revealed that the momo samples were high in the evaluated chemical nutrients. Plantain-lima momo could be harnessed as a potential functional, nutritious and healthy food.

Introduction

In developing countries, plant foods are the most important dietary sources for food and nutrition security because of their availability and low cost (Seidu et al., 2018). Legumes and starchy foods are important staples in such countries, including Nigeria. Lima bean (*Phaseolus lunatus*) is an indigenous food legume in Nigeria, though underutilized due to stress in its processing. Lima bean like other grain legumes, is an important source of vegetable protein containing about 23.17% protein and 18.40% fibre (Ikechukwu et al., 2010). It is also rich in vitamins such as niacin, thiamine and riboflavin and minerals including potassium, phosphorus, magnesium, calcium and iron (Farinde, 2019). Lima bean has been reported to have anti-diabetic properties as it had significant hypoglycemic and hypolipidemic effects in diabetic rats (Ojo et al., 2013). Lima bean has been reported as the second genus *Phaseolus* species following *Phaseolus vulgaris* in terms of economic interest (Seidu et al., 2018). Although there is a dearth of economic data on lima bean production, on the use in

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households and industries and the contribution to Gross Domestic Products (GDP) in Nigeria, researchers have established that it could be a valuable crop for Nigeria due to its various potentials (Farinde, 2019; Seidu et al, 2018; Ojo et al, 2013; Ikechukwu et al, 2010). Furthermore, lima bean has been used in the development of many value-added food products such as lima bean *daddawa* (iru), lima bean soup (*Gbegiri*), lima bean veggie, baked cooked lima beans, steamed cooked lima beans, and cooked rice and lima beans. Other products are lima bean *moinmoin*, lima bean *akara*, Llima bean *ekuru* muffin, lima bean *ekuru* (steamed), maize-lima *ogi*, lima bean flour, wheat-lima bean biscuit, and wheat-lima *chinchin* (Farinde, 2019). These products are mostly foods that could be consumed as breakfast, lunch and supper or as snacks capable of enhancing the nutritional quality of food intake in Nigeria. Production of each of these products for household consumption and in the food and hospitality services, supermarkets and fast-food industries could initiate the springing up of Small and Medium Enterprises (SMEs) in Nigeria. Also, this could fast-track facilitation and promotion of abundant production of lima bean as another major commodity for home and industrial uses in Nigeria. Based on this understanding, Farinde (2019) documented that lima beans have a lot of potential, including income generation for farmers and food processors, raw materials for industries and foreign exchange for the nation.

Plantain (*Musa paradisiacae*) is a rhizomatous perennial crop cultivated in many tropics and subtropical countries of the world including Nigeria (Salawu, 2015). It ranks as the fourth most important food crop in the world after rice, wheat and maize and is used as food, beverages, fermentable sugars, medicine and flavourings (Adepoju et al., 2012). Plantains are very high in calories and a good source of starch and energy making them a food security crop for millions of people worldwide and are also a good source of vitamins, potassium and antioxidants containing about 23 mg/g of vitamin C and 63 µg/g of vitamin A (Healthline.com, 2021). Plantain is very versatile and can be used as an alternative to yam and potato as is similar in its nutritional composition to these staples. Plantain could be boiled, roasted, fried or baked. Unripe plantain fingers can be processed into flour and used in the processing of many traditional dishes including *akara*, plantain soups and may be reconstituted in boiling water to make *amala* which is a traditional swallow Nigerian food conventionally made from yam flour and eaten with any Nigerian soup (Onuoha et al., 2014). Unripe plantain meals are usually consumed by Nigerian diabetics to reduce postprandial glucose levels because of their low glycemic index (Eleazu and Okafor, 2012).

Momo is a traditional steamed plantain-based pudding native to Nigeria and is commonly consumed by the people of Osun and Ondo states of Nigeria. It is usually prepared from unripe plantain flour. The unripe plantain fingers are normally peeled, sliced, dried and milled into powder. The plantain flour is then reconstituted in water and made into a paste; palm oil, pepper and salt are then added. The plantain paste and the ingredients are mixed, wrapped in cooking leaves and steamed to cook. The steamed cooked momo is then allowed to cool and removed from the cooking leaves. It can be consumed as a sole diet or consumed with other food products such as pap, bread or rice.

This study provided information on dietary diversification using locally available nutritious underutilized legume and staple foods for enhanced food, health and nutrition security. Adding value to plantain using lima bean for momo production will improve lima bean utilization, enhance lima bean production, provide a healthy indigenous local staple food for Nigerians, particularly the people of Ondo and Osun states of Nigeria and will also provide a new product with potential for income generation and initiation of many Small and Medium Scale Enterprises (SMEs).

Materials and methods

Sample collection

Matured dry lima bean seeds, a light brown variety were purchased from a local market at Ita-Ogbolu, via Akure, Ondo State, Nigeria, while matured unripe plantain bunches were purchased from Apata market, Ibadan, Nigeria.

Processing plantain and lima beans into flour

Plantain flour was prepared following the processing steps described by Ndayambaje et al. (2019). The unripe plantain fingers were separated from the bunches, washed, peeled manually, sliced (2 mm thickness) using a stainless-steel kitchen slicer, blanched at 80 °C for 5 min, and dried in a cabinet drier at 65 °C for 48 h. The dried slices were milled, sieved, packaged in a low-density air-tight polyethylene bag, sealed, and stored for subsequent use.

Processing of lima bean seeds into flour was carried out following the method described by Farinde (2021). Lima bean seeds (1kg) were soaked in 3 litres of water (1:3 w/v) for 2 h and then blanched in boiling water for 20 minutes. The blanched seeds were washed under running water to cool the beans down to room temperature (28 ± 2 °C). Temperature of the processing laboratory was measured using an electronic Thermo Hygrometer. The seeds were then mechanically dehulled by shredding 250 g of the seeds in 250 ml of water for 30 sec in a blender (Kenwood BL440, UK). Hulls were removed by washing the lima bean seeds with water, floating off the hulls and sieving. The dehulled lima beans were drained, spread on a aluminium tray, and dried in a cabinet dryer at 60 °C for 24 h to a moisture content of about 10%. The dried lima beans were milled into flour to pass through a 0.25 mm sieve.

Processing of plantain-lima momo

Plantain-lima momo was processed from a composite mixture of unripe plantain flour and lima bean flour following the methods of Otunola and Afolayan (2017). Plantain flour and lima bean flour blends were mixed in varying combination ratios (predetermined from preliminary study) while other ingredients were added in constant ratio as presented in Table 1. The composite flour and the other ingredients including water were mixed in a bowl with a spoon to form a paste; salt was added for taste The mixture was then dispensed into already washed and dried clean cooking leaves (*Thaumatococcus daniellii*) and wrapped. The cooking leaves boost the colour, flavour and enhance the nutritional potential of the product by leaching some biochemical and phytochemical compounds associated with green leaves into the product during cooking (Okwunodulu et al., 2019). The wrapped leaves were placed in a cooking pot containing appropriate boiling water and steamed for about 40 min. Steamed momo samples were removed from fire and allowed to cool. Samples of cooled momo were evaluated for nutrient content.

Table 1. Blends of plantain/lima bean flours and ingredients for momo production

Sample	PF (g)	LF(g)	TF (%)	GP(g)	GO(g)	PO (g)	TI(%)	W	GT(g)
PP	100	-	100	20	30	50	100	300mL	500
PA	90	10	100	20	30	50	100	300mL	500
PB	80	20	100	20	30	50	100	300mL	500
PC	70	30	100	20	30	50	100	300mL	500
PD	60	40	100	20	30	50	100	300mL	500
PE	50	50	100	20	30	50	100	300mL	500

Key:
PF = plantain flour
LF = lima bean flour
TF = total flour
GP = ground pepper
GO = ground onions
PO = palm oil
TI = total ingredient
W = water
GT = grand total

Laboratory analysis

Functional properties of lima bean flour and plantain flour

Bulk density

Bulk density was determined using the method described by Ashraf et al. (2012). Ten grams (10 g) of the plantain flour, lima bean flour and mixture of the two flour samples was measured into a graduated measuring cylinder (50 mL) and lightly tapped on the workbench ten times to attain a constant height. The volume of the sample in the measuring cylinder was recorded. Bulk density (g/ml) was expressed as the weight of the sample divided by the volume of the sample after tapping.

Water and oil absorption capacity

Water absorption capacity (WAC) and oil absorption capacity (OAC) of the flour samples were determined following the methods described by Ojukwu et al. (2012). Two grams (2 g) of the plantain flour, lima bean flour and mixture of the two flour samples was mixed with 20 ml distilled water for water absorption and 20 ml of oil for oil absorption. Each mixture was blended in a blender (Kenwood BL440, UK) at high speed for 30 s. Samples were allowed to stand at 28± 2 °C for 30 in and then centrifuged at 10000 x g for 30 min. The volume of supernatant was measured in a graduated cylinder. The density of water was taken to be 1g/ml and that of oil to be 0.93 g/ml.
Water absorption capacity (WAC) percentage was calculated as:

$$\text{WAC \%} = \frac{Amount\ of\ water\ added - volume\ of\ supernatant\ x\ density\ of\ water}{weight\ of\ sample}\ x\ 100$$

and that of oil as:

$$\text{OAC \%} = \frac{Amount\ of\ oil\ added - volume\ of\ supernatant\ x\ density\ of\ oil}{Weight\ of\ sample}\ x\ 100$$

Swelling capacity

Swelling capacity was determined using the method described by Asouzu et al. (2020). About 25 g of each flour sample was measured into a 100 ml measuring cylinder. The measuring cylinder was then filled with water to a 100 ml benchmark. The mixture was shaken several times and allowed to settle. The volume of the flour in the cylinder was recorded after 15 minutes. The percentage of swelling in the volume was determined by the difference in volume divided by the initial volume.

$$\text{\% swelling property} = (C – D)/A$$

where A is Initial volume (equivalent volume of the 25 g flour sample); B = volume before swelling; C = volume after swelling

Dispersibility

Dispersibility of the lima bean flour sample was determined using the method described by Ohizua et al. (2017). Ten grams of sample was suspended in a 200 ml measuring cylinder and distilled water was added to reach the 100 ml mark. The set-up was stirred vigorously and allowed to settle for 3 h. Dispersibility was obtained by subtracting the volume of the settled particles from 100.

$$\text{Dispersibility} = 100 - volume\ of\ the\ settled\ particle$$

Proximate composition and mineral content of plantain-lima momo

Moisture, protein, crude fat, ash and crude fibre in the plantain-lima bean momo were determined using standard methods (AOAC, 2005). Carbohydrate content was calculated by difference. Mineral content in the plantain-lima bean momo samples was determined using the wet digestion method of AOAC (2005).

Antioxidants and phytochemicals

The antioxidant activity in the plantain-lima bean momo samples was determined using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method, as reported by Bamigbola et al. (2016). Total phenolic content (TPC) in the momo extract samples was determined by a Folin-Ciocalteu assay as described by Farinde et al. (2019). The **r**esults were expressed as gallic acid equivalent (mg gallic acid/g) of the sample. The total flavonoid content of the momo samples was determined following the method described by Salawu et al. (2015). Results were expressed as mg quercetin/g.

Statistical analysis

Analysis of variance (ANOVA) was carried out on the obtained data (functional properties, proximate composition, mineral content and antioxidant properties) using SPSS version 17. Means were separated by the Duncan multiple range test. Results were accepted at a significance level of 5%. Data of the nutrient composition were also subjected to the Multivariance analysis using XLSTAT.

Results and discussion

Functional properties of the plantain flour, lima bean flour and mixture of plantain and lima bean flour

Table 2 presents the functional properties of the plantain flour, lima bean flour and the mixture of the two flour samples. The highest bulk density (1.40 g/cm) was recorded for the lima bean flour while the lowest bulk density (1.00 g/cm)for the plantain flour.. Bulk density of the two flour samples and their mixture was significantly different ($p<0.05$). Bulk density is an important parameter that determines the space that a food sample will occupy, as well as the type of packaging that will be appropriate for the food product (Ngoma et al., 2019). It signifies the behaviour of a product in dry mixes and may vary with fitness and particles (Butt and Batool, 2010). The values of the bulk density in this study are higher than 0.63 g/cm^3 as reported by Amadou et al. (2010) for soybean protein meal. And also higher values than 0.71 g/cm^3 and 0.68 g/cm^3 were observed for cowpea Pigeon pea varieties, respectively (Butt and Batool, 2010). High bulk densities of the flours suggest their suitability for usage in various food preparations (Appiah et al., 2011). The mixture of plantain flour and lima bean flour (PLF) had the highest water absorption capacity (2.79 g/g).

Table 2. Functional properties of plantain and lima bean flour samples

Sample	BD (g/cm)	WAC (g/g)	OAC (%)	SC (%)	Dispersibility (%)
LBF	1.40 ± 0.01[a]	2.77 ± 0.01[b]	1.57 ± 0.02[c]	22.98 ± 0.01[b]	68.00 ± 0.01[b]
PF	1.00 ± 0.02[c]	2.75 ± 0.01[c]	1.67 ± 0.01[b]	23.14 ± 0.03 [b]	75.00 ± 0.02[a]
PLF	1.20 ± 0.01[b]	2.79 ± 0.0[a]	1.74 ± 0.01[a]	26.20 ± 0.01[a]	64.00 ± 0.01[c]

Means are values of three replicates ± standard error. Means followed by different superscript in the same column are significantly different (p< 0.05).

Key:
LBF= lima bean Flour
PF = plantain Flour
PLF = plantain lima bean flour
BD = bulk density
WAC = water absorption capacity
OAC = oil absorption capacity
SC = swelling capacity

This might be due to textural changes and protein interaction with water in the flour mixture compared to the individual flour sample.Similarly, Kisambira et al. (2015) and Fekria et al. (2012) reported water absorption capacity values of 2.80 to 2.90 % in African yam bean seed flour and 3.0% in defatted groundnut flour respectively. Water absorption capacity is the ability of a product to associate with water under conditions where water is limited and it is useful in determining the capability of flour to absorb water and swell for improved uniformity in foods (Ngoma et al., 2019). Flours with better water absorption capacity have been reported to have an impact on the soft texture of the final product (Farinde et al., 2021). The higher value of WAC for the plantain-lima bean flour mixture samples in this study is an indication that the mixture of plantain flour and lima bean four will affect better textural value for product development including the momo in this study. Water absorption capacity (WAC) of the plantain flour, lima bean flour and the mixture of the two flour samples were also significantly different (p<0.05).

Lima bean flour had the lowest oil absorption capacity (1.57%) while the highest oil absorption capacity was found in the plantain-lima bean flour mixture (1.74%). Oil absorption capacity (OAC) is a measure of the ability of food material to absorb oil. Oil absorption capacity (OAC) value recorded for plantain lima bean flour mixture in this study will make it a desirable material for momo production, as oil is one of the ingredients for the production of momo. Better oil absorption in flour enhances flavour and taste in the development of the product +(Appiah et al., 2011). Values for OAC in the plantain and lima bean flour samples are, however, similar to those reported by Kisambira et al. (2015) that ranged from 1.48 to 1.52 % and to those reported by Mountaleb et al. (2017) that ranged from 1.7 to 2.0 g/g of akara made from composite flour of cowpea and potato.

The highest swelling capacity was also recorded in plantain-lima bean flour (26.20%). There was no significant difference (p>0.05) in the swelling capacity of lima bean flour (LBF) and plantain flour (PF). Swelling power (SWP) is a measure of the degree of interaction (hydration capacity) of starch granules with water (Kumar and Khatkar, 2017). It is also related to the water absorption index of the starch-based flour during heating (Adebowale et al., 2012). The swelling capacity obtained for the flour samples in this study is higher than 6.88g/g as reported by Palupi et al. (2021) for lima bean flour.

The highest dispersibiliy was obtained in plantain flour (75%). All flour samples exhibited significant differences (p<0.05) in their dispersibility. Dispersibility is a measure of the reconstitution of floury products in water. The higher the dispersibility of flour products, the better the reconstitution power in water. All flour samples recorded high values for dispersibiltiy, hence will enhance easy reconstitution. The dispersibility values are however lower than the values of 86.50 to 88.00 % reported by Fadimu et al. (2018) for unripe plantain flour.

Proximate composition of the plantain-lima bean momo

The proximate composition of the plantain-lima bean momo samples is presented in Table 3. The moisture content in the samples ranged between 14.42% and 15.51%. There was no significant difference (p>0.05) n the moisture content of momo from 70% unripe plantain flour + 30% lima bean flour (PC) and 60% unripe plantain flour + 40% lima bean flour (PD). Crude protein in the momo samples increased with an increase in lima bean flour. The highest protein content was recorded for plantain-lima bean momo sample with 50% of lima bean (PE)(13.52%) while the lowest protein content of 7.20% was recorded for 100% plantain flour momo. The protein content for the momo samples was close to the value (13.78%) reported by Dania et al. (2021) for cowpea moinmoin.

Table 3. Proximate composition of plantain-lima bean momo (%)

Sample	Moisture	Protein	Fat	Ash	Crude Fibre	Carbohydrate
PA	15.51 ± 0.03^b	11.61 ± 0.01^e	4.94 ± 0.02^b	2.79 ± 0.01^e	4.55 ± 0.04^d	60.60 ± 0.01^b
PB	14.90 ± 0.02^c	11.90 ± 0.05^d	5.00 ± 0.01^b	3.67 ± 0.01^d	4.82 ± 0.02^c	59.71 ± 0.01^b
PC	14.55 ± 0.01^d	13.15 ± 0.01^c	5.12 ± 0.02^a	4.20 ± 0.05^c	5.10 ± 0.01^b	57.88 ± 0.05^b
PD	14.54 ± 0.01^d	13.22 ± 0.02^b	5.15 ± 0.06^a	5.38 ± 0.01^b	5.32 ± 0.01^a	56.39 ± 0.01^c
PE	14.42 ± 0.04^e	13.52 ± 0.01^a	5.22 ± 0.01^a	5.67 ± 0.05^a	5.40 ± 0.01^a	55.77 ± 0.02^c
PP	15.11 ± 0.01^a	7.20 ± 0.01^f	4.25 ± 0.01^c	2.50 ± 0.01^f	3.41 ± 0.04^e	67.53 ± 0.01^a

Means are values of three replicates ± standard error. Means followed by different superscript in the same column are significantly different (p< 0.05).

Key
PA = 90% unripe plantain flour + 10% lima bean flour
PB = 80% unripe plantain flour + 20% lima bean flour
PC = 70% unripe plantain flour + 30% lima bean flour
PD = 60% unripe plantain flour + 40% lima bean flour
PE = 50% unripe plantain flour + 50% lima bean flour
PP = 100% unripe plantain flour

This might be due to the fact that momo contained more moisture than the flour; the higher the moisture content, the lower the protein and other nutrient content of food samples. The protein content values recorded in this study were however much higher than the protein content of 1.25% for plantain pudding reported by Alozie et al. (2020). This might be due to the fact that unripe plantain was used in this study. Unripe plantain has been reported to contain anappreciable amount of protein (Adepoju et al., 2012). Moreover, the inclusion of lima bean flour in momo processing must have increased the protein content of plantain flour into momo. There was no significant difference (p>0.05) in the fat content of PC, PD and PE. Lima bean has been reported to be low in fat (Farinde et al., 2011). The highest fat content was recorded in PE. Higher values obtained for fat in this study might be a result of the plantain flour and the palm oil used during momo processing. The ash content of the momo samples was significantly different in all the momo samples. Ash indicates the quantity of inorganic elements present in food as minerals. The ash content in this study correlates with the mineral content of the plantain-lima momo samples. Similarly, Dania et al (2021) reported ash content between 3.11 1nd 6.40% in enriched cowpea pudding. Crude fibre and carbohydrate content were highest in PE (5.40%) and PP (67.53%) respectively. The lowest crude fibre was recorded in momo sample (PP). Fibre is an important nutrient in the human diet as it reduces the risk of colon cancer, slows down the release of glucose in the blood and decreases the reabsorption of bile salt (Dania et al.,2021). Momo from 100% plantain flour (PP) was significantly high (p<0.05) in carbohydrate compared with all the other momo samples.

Mineral composition of the plantain-lima bean momo

Table 4 shows the result of the mineral content of the momo samples. Momo sample PA and PB were not significantly different (p>0.05) in their calcium content. Calcium, sodium and phosphorous were highest in PB (161.80mg/100 g), PD (272.80 mg/100 g) and PP (160.42mg/100 g) respectively. There was no significant difference (p>0.05) in the calcium content of PA and PB. The highest potassium *was* recoreded in momo sample PP. Potassium content in the momo samples ranged between 244.60 mg/100 g in the PD to 260.40 mg/100 g in PP. Potassium plays a vital role in the maintenance of cellular water balance, the regulation of pH and enhances protein and carbohydrate metabolism in the body (Farinde et al., 2018). Sodium and potassium have been found to regulate and maintain the osmotic pressure of the body fluid. Iron and zinc were highest in PE (16.98 mg/100 g) and 8.89 mg/100 g respectively.

Antioxidant activities and phytochemical content of plantain-lima bean momo

Antioxidant activities (DPPH) and phytochemical content increased with an increase in the inclusion of lima bean flour in the plantain-lima bean momo samples. The highest value for antioxidant activity and the phytochemical compounds (phenolic and flavonoid) was found in the sample PE (50% plantain +50% lima flour momo) (Table 5). PE was significantly different (p< 0.05) in antioxidant activity compared to all other momo samples. The lowest phenolic and flavonoid content (6.10 mg gallic acid/g and 66.50 mg quercetin/g respectively) was recorded in the sample PP (the control). This is an indication that lima bean is richer in phenolic and flavonoid compounds than plantain and has thus enriched the plantain momo with these nutrients. Farinde et al.

(2019) reported high phenolic content of 18.5 and 13.9 mg gallic acid/g/g in baked lima bean and cooked lima bean, respectively. Both phenolic acids and flavonoids are known to be highly active antioxidants. Phenolics have been reported as powerful antioxidants that can protect the human body from free radicals and protect cells from oxidative damage (Eleazu et al., 2011). In a related report, unripe plantain flour has been found to be of medicinal value in the treatment of diabetes and other related diseases associated with the presence of free radicals in the body (Eliazu et al., 2011). Similarly, Duenas et al. (2005) reported that the presence of phenolic acid and flavonoids in unripe plantain and millet flour has a positive role in strengthening the capillary walls, reducing the agglutination of RBCs, preventing cancer and also having anti-inflammatory properties. Flavonoids have been found to have high antioxidant anti-inflammatory properties, thus boosting the immune system and they may also improve the quality of the walls of blood vessels (Szalay, 2015).

Table 4. Mineral content of plantain-lima bean momo (mg/100g)

Sample	Calcium	Sodium	Phosphorous	Potassium	Iron	Zinc
PA	160.80 ± 0.01[a]	265.20 ± 0.02 [c]	115.64 ± 0.02 [c]	249.12 ± 0.01	14.72 ± 0.05 [d]	6.70 ± 0.01 [d]
PB	161.80 ± 0.05[a]	261.80 ± 0.02 [d]	113.96 ± 0.01 [e]	259.40 ± 0.01[b]	15.80 ± 0.01 [d]	6.70 ± 0.01[d]
PC	156.80 ± 0.02 [b]	261.90 ± 0.04 [d]	114.08 ± 0.01[d]	255.80 ± 0.01[b]	16.50 ± 0.01[c]	7.9 ± 0.02 [c]
PD	154.10 ± 0.02 [c]	272.80 ± 0.01 [a]	141.60 ± 0.06 [b]	244.60 ± 0.05 [c]	16.77 ± 0.02 [b]	8.60 ± 0.03 [b]
PE	150.84 ± 0.01[d]	258.50 ± 0.04[e]	141.90 ± 0.04 [b]	255.75 ± 0.01[ab]	16.98 ± 0.01[a]	8.89 ± 0.01[a]
PP	156.10 ± 0.01[b]	270.60 ± 0.02 [b]	160.42 ± 0.01 [a]	260.40± 0.01 [a]	13.90 ± 0.04 [e]	6.66 ± 0.05[e]

Means are values of three replicates ± standard error. Means followed by different superscript in the same column are significantly different ($p< 0.05$).

Table 5. Antioxidant activities and phytochemicals content in the plantain-lima bean momo samples

Sample	Antioxidant activity (DPPH %)	Phenolic (mg GAE/g)	Flavonoids (mg quercetin/g)
PA	59.00± 0.01 [c]	10.8± 0.02 [d]	80.10 ± 0.02[e]
PB	66.05± 0.10 [b]	10.15± 0.02 [d]	87.05± 0.06[d]
PC	63.00± 0.11[b]	12.80 ± 0.01[c]	92.00 ± 0.06[c]
PD	65.00± 0.05[b]	13.10± 0.06[b]	95.00 ± 0.06[b]
PE	75.15 ±0.02[a]	15.95 ± 0.05[a]	115.10 ± 0.06[a]
PP	45.14± 0.11[d]	06.10 ± 0.04[e]	66.50± 0.06[f]

Means are values of three replicates ± standard error. Means followed by different superscript in the same column are significantly different ($p< 0.05$).

Multivariate analysis of the proximate, minerals, antioxidant and phytochemical composition of the momo samples

The principal component analysis of the chemical data showed that principal component 1 (PC1) and principal component 2 (PC2) accounted for 68.74% and 17.28% of the total variation, summing up to 86.02% of the total variation of the chemical data. According to Olawoye and Gbadamosi (2020), a 70% variation is enough to explain variation in the experimental data. If data variation is less than 70%, it will not be accepted. Information obtained from the factor loading showed that proximate and antioxidant composition data, as well as iron and zinc were characterized at the principal component 1. Phosphorus and calcium were characterized at PC 2 while sodium and potassium were characterized at PC 3. The relationship between the chemical data, principal components and experimental samples is explained by the biplot as well as bootstrap eclipse, as shown in Figures 1a&1b. From the biplot, it could be seen that momo samples were classified into four different classes. Class 1 comprised of PD and PE momo samples located in the first quadrant which symbolizes a close correlation between the samples with respect to zinc, ash, flavonoids and phenolics. The second class, which is located it the second quadrant, is made up of PP with a close correlation with carbohydrates. Momo samples that fell under the third quadrant are PA and PB and are closely related to potassium, moisture and calcium content. The last class is made up of PC momo samples located in the fourth quadrant with a close association with antioxidant activity, protein, fat and fibre. The location of the momo samples and chemical data in the same quadrant is an indication that momo samples are high in these chemical components.

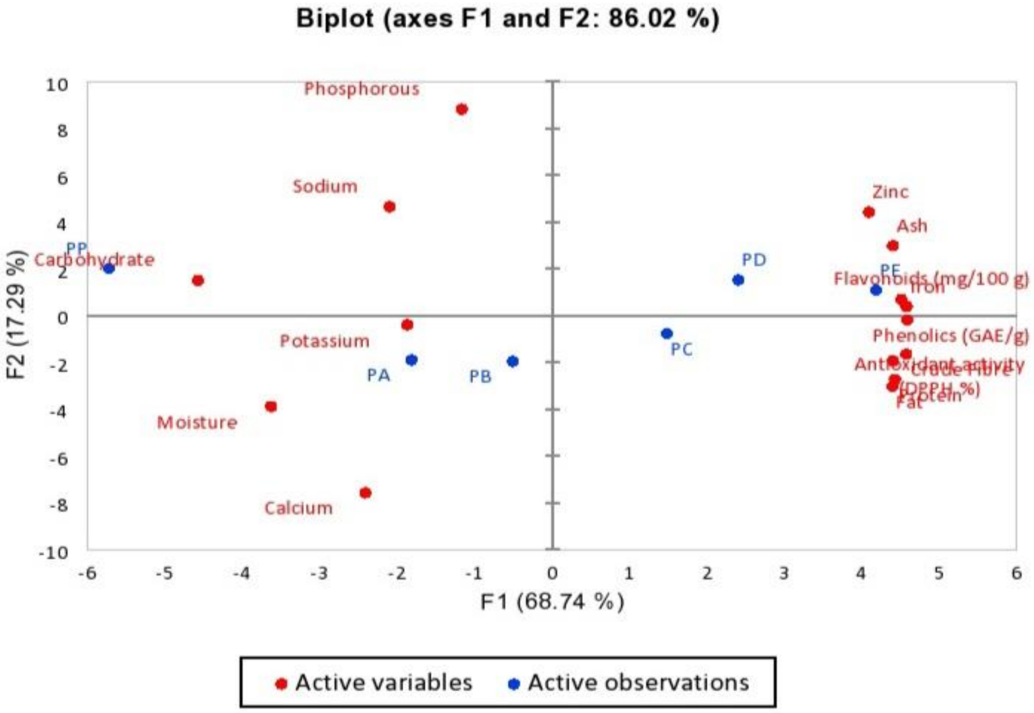

Figure 1a. Biplot showing the relationship between the chemical data, principal components and experimental sample

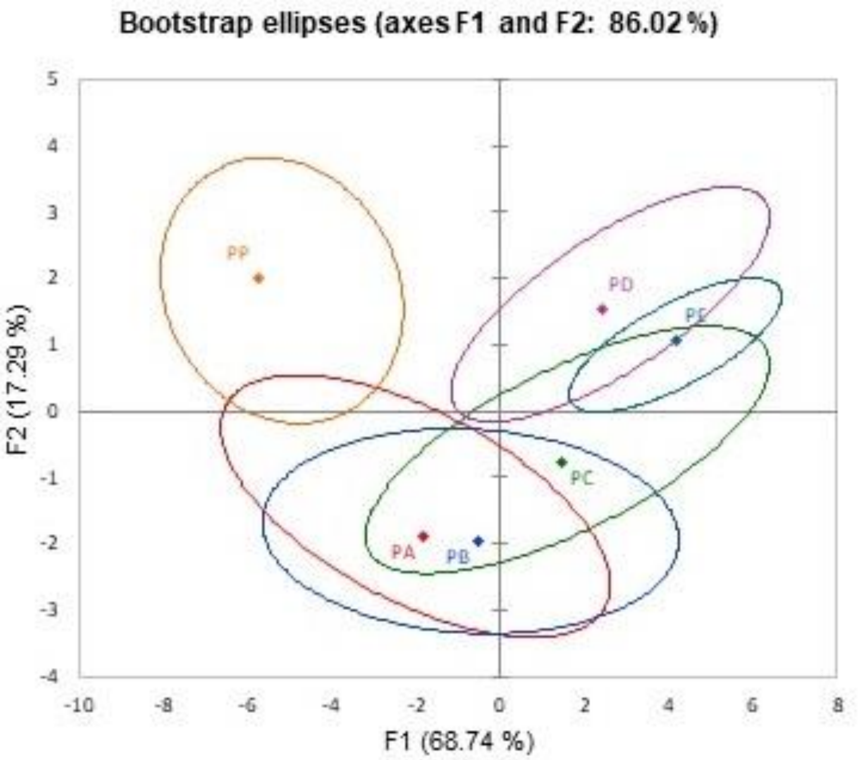

Figure 1b. Bootstrap ellipse showing the relationship between the chemical data, principal components and experimental sample

Conclusions

Supplementation of plantain flour with lima bean flour improved the functional properties of the plantain flour for the development of the momo product,particularly high water and oil absorption capacity, as well as the swelling power. Supplementation of plantain flour with lima bean flour also enhanced the nutrient content of momo samples. Multivariance analysis revealed that plantain-limabean momo samples were found to be high in the evaluated nutrients (carbohydrates, protein, fibre, fat, ash, minerals and antioxidants). The inclusion of lima bean flour inthe plantain flour for momo production added value to the product by making it a nutritious, antidiabetic and antioxidant product of plant origin. Plantain-lima momo of combination ratio 50:50 (plantain flour: limabean flour) could be harnessed as a potential nutritious and healthy food.

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