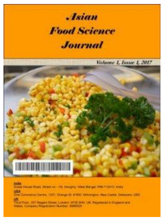

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Chemical, Physico-Chemical and Sensory Evaluation of Moringa - Plantain Flour

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This study investigated the effect of the addition of Moringa leaf powder on the nutrient composition, antinutrient content, functional and pasting properties of the plantain flours, and sensory evaluation of their corresponding stiff dough ("Amala"). The stiff plantain doughs were produced using plantain flour substituted with different levels of Moringa leaf powder, ranging from 0-15 % at the interval of 2.5 %. The proximate composition (moisture, protein, fat, crude fiber, and carbohydrate) and antinutrient content (tannin, oxalate, and saponin) were determined according to the methods described by Association of Official Analytical Chemist. The mineral content was analysed using flame photometer and atomic absorption spectrophotometer. The result showed that addition of Moringa leaf powder increased the moisture, fat, ash, crude fiber and protein, contents, but reduced the carbohydrate content of the plantain flours. The inclusion of Moringa caused the reduction in Na, K and P contents and increased the quantities of Ca, Mg, and Fe in the fortified samples. Similarly, water absorption capacity, oil absorption capacity and the least gelation concentration of the supplemented flours increased, and their bulk density, swelling power, and solubility decreased with increase in Moringa substitution. The antinutrient content of the flour also increased (oxalate, 0.54-0.74 %; phytate, 0.60-0.83 %; saponin, 1.549-1.62 %; tannin, 0.43-0.60 %) after compositing. Fortification reduced the pasting (peak, breakdown, final and setback) viscosity and increased the time and temperature of attaining peak viscosity. The

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result of sensory evaluation for the fortified “Amala” revealed that 2.5 % to 5 % Moringa leaf powder supplementation for plantain flour was equally rated, and are sufficient to improve the proximate and mineral composition of plantain flour “Amala” without having a significant negative impact on the sensory properties.

Keywords: Chemical; physicochemical composition; sensory; stiff dough (“Amala”); plantain flour; Moringa leaf powder.

1. INTRODUCTION

Studies have shown that sensory properties of foods have direct bearing on their consumption, and that many processed foods have failed simply because of their sensory properties. Indeed, many nutrient-rich or functional foods have been used to fortify otherwise less nutritious but popular foods in several communities and successes have been recorded. Lately, Moringa has been rediscovered as a powerful food supplement, and that WHO has recommended their use to improve health and well-being. However, the fact that plantain flour is now acceptable in this study area, paves the way for fortification of the flours with Moringa leaf powder to enhance the nutritional quality and consumers' acceptability of the flours.

Plantain (*Musa paradisiaca*) belong to the Musa genus of the plant kingdom and classified as fruit-bearing herbs, grown abundantly in the humid tropical regions of the world including Nigeria, where it serves as an important starchy staple food, and an economical source of energy [1,2]. Plantains represent the world's second largest fruit crop with an annual production of 144 million metric tons, closely following rice, wheat, and maize, as the fourth most important global food commodity [3]. Mostly obtained from the southern states, the yearly production of plantain in Nigeria is projected to be about 3.09 million metric tons. This places Nigeria fifth after Cameroon, Ghana, Uganda, and Colombia in the world's ranking of plantain production [4]. Olorunda and Adelusola reported in 2006 that lack of storage facilities coupled with inappropriate technologies for food processing led to about 35-60% post-harvest losses [5].

Plantain is rich in dietary fibre (8.82%) and resistant starch (16.2%) and possess low glycemic index [6], thus, its consumption can serve as dietary control for type 2-diabetes, serum cholesterol, heart attack, colon cancer, obesity, blood pressure, diarrhoea and many other diseases [7,8]. Despite the health benefits of plantain as aforementioned, plantain possesses some antinutritional factors such as phytate, oxalate, saponin and tannin, which has a potential adverse impact on their chemical and nutritional properties.

As a staple, the fruit is extremely rich in iron, potassium, and vitamin A [9], and mostly eaten unprocessed as fried, boiled or roasted. On the commercial landscape, there are slowly growing businesses that process plantain into chips, flours, dried pulps, jam and spirits in plantain producing countries [9]. Unripe plantain is traditionally processed into flour in Nigeria and other west and central African countries, that is used to prepare a stiff dough (*“Amala”*), and for making bread, biscuits, instant flour, chin-chin and cake [10,11] Plantain food products contribute mainly dietary carbohydrates and are thus, unable to meet the protein requirements of consumers, especially rural dwellers. Consequently, studies have been carried out on the possibilities of enriching the nutritional content of plantain flours with legumes and other protein-rich plant sources such as Bambara groundnut protein concentrates, *Moringa oleifera* and extruded soybeans [12,13,14]. Considering the relationship between food, health, and nutrition, *Moringa oleifera* is a promising plant which, could compliment the flour when incorporated and improve human diet in terms of essential nutrients and beneficial phytochemicals [13].

Moringa *(Moringa oleifera),* belongs to Moringaceae family. Native to India, it grows in the tropical and subtropical regions of the world, which include the geographical zone of Nigeria. It is drought tolerant, medium-sized and evergreen tree that prefers warm and frost-free climates. It has been used as a "cure-all" remedy for thousands of years [15]. Moringa plant is highly nutritious, and almost every part of the tree can serve as food, consumed either fresh, or cooked, and processed to powder [17]. The extract of the leaves is a powerhouse of protein–rich nutrients, minerals, vitamins and other essential phytochemicals that are suitable for treating malnutrition, augment breast milk in lactating mothers and serve as a remedy for diabetes and cancer [16]. Good health is a function of eating healthy foods, therefore, research efforts are recently geared towards the improvement of the nutritional quality of food products in many developing countries. This research study investigated the effect of the addition of Moringa leaf powder on the nutrient composition, antinutritional factors, functional and pasting properties of plantain flours.

2. MATERIALS AND METHODS

2.1 Sample Procurement

Mature unripe plantain fruits used for this study were collected from a local market at Sayedero Yewa, South Ogun State, Nigeria, and fresh Moringa leaf powder was obtained from Rokarich International Company, Akure Ondo State, Nigeria.

2.2 Preparation of Plantain Flour

Using the method described by Ilelaboye and Ogunsina [17], 20 kg of green plantain fingers were washed, sun-dried for 30 min, and then hand peeled, sliced to a thickness of about 5 mm, and stored in water to avoid browning before drying. The sliced plantain was dried in a hot air oven (Gallenkamp OPL150.TS1.B Plus II Oven, Georgia, United States n) for 6 h at a temperature of 80ºC was milled with a Bentall Superb hammer mill (Model 200 L 09, United Kingdom), sieved through a 75 µm mesh sieve and kept in airtight plastic containers at room temperature for further use.

2.3 Preparation of Various Flour Blends

The plantain flour and Moringa flour were mixed according to the proportion in Table 1, and homogenised using a Cross-Flow blender (5 Cu Ft PK Twin Shell Cross Flow Blender, 316 S/S, Cleveland) for 30 min, and stored separately in tightly covered plastic containers for later use [17].

2.4 Preparation of "Amala"

Fifty (50) g of the composite flour was poured into 200 mL boiling water with continuous stirring to obtain a smooth, thick mixture which was allowed to simmer for about 5 min, stirred, and wrapped with thin labelled polyethylene wraps.

2.5 Chemical Analysis

The proximate composition (moisture, protein, fat, crude fiber, and carbohydrate) of the composite flours was analysed using the procedure of Association of Official Analytical Chemist [18], and the energy value calculated using Atwater factors. Flame photometry method was used to analyse the potassium and sodium content of the samples [19]. Phosphorus was determined using the Vanado-molybdate colourimetric method [19]. Calcium, magnesium, and iron were determined spectrophotometrically by using atomic absorption spectrophotometer (Buck 210, Norwalk, United Kingdom) [20]. The contents of the antinutritional factors (tannin, oxalate, and saponin) of the samples were evaluated using Jenway spectrophotometer (model 6305, United Kingdom) according to the standard methods of AOAC [18], while phytate content was estimated by the solvent extraction-gravimetric method of [21].

2.6 Functional and Pasting Properties

Bulk density was determined using the method as described by Akpapunam and Markakis [22]. Swelling power and solubility index was determined using the modified method described by Takashi and Sieb [23]. Water and oil absorption capacities were determined according to the method described by Okezie and Bello [24]. The least gelation concentration was analysed as the concentration when the cooked suspension from an inverted test tube did not slip [25]. Pasting properties for each of the samples were determined using Rapid Visco Analyzer (New-port Scientific, Australia).

2.7 Sensory Evaluation

Sensory evaluation of the "Amala" samples prepared from the plantain-Moringa flours was performed 4 h after production using the '9 points' Hedonic scale quality analysis [26]. Twenty (20) trained panelists drawn from

Table 1. Formulation Table for Plantain - Moringa leaf flour

Samples	P	PM1	PM2	PM3	PM4	PM5	PM6
Plantain (%)	100	97.5	95	92.5	90	87.5	85
Moringa (%)	0	2.5	5	7.5	10	12.5	15

students and staff of the Federal Polytechnic, Ilaro Ogun State Nigeria, evaluated the coded "Amala" samples for colour, aroma, taste, mouldability consistency and overall acceptability using the 9-point hedonic scale, where one (1) corresponded to like extremely, and nine (8) corresponded to dislike extremely.

2.8 Statistical Analysis

All analyses were carried out in triplicates, with statistical significance established using one-way analysis of variance (ANOVA), Mean comparison and separation was done using Duncan Multiple range (DMR) test at p≤ 0.05, described by the SPSS 16.0 statistical package [27].

3. RESULTS AND DISCUSSION

3.1 Proximate Compositions of the Moringa Leaf Powder– Plantain Flours

According to the proximate composition of the flour samples (Table 2), the addition of Moringa leaf powder to the plantain flour caused significant *(P < 0.05)* decrease in moisture content of the composite plantain flours. The moisture content of all the flours reported in this study was below 15% which is the recommended maximum limit for flours, suggesting longer shelf-life for the blends [28]. However, the moisture content ranged from 10.22% (sample P) to 9.99% (sample PM6).

As shown in Table 2, Moringa leaf powder possesses higher content of protein, fat, fibre, and ash, but a lower moisture content, carbohydrate, and energy relative to plantain flour. This observation was similar to what had been observed in other studies relating to Moringa [29,30,31] and plantain [14]. Protein values of the fortified flours as depicted in Table 2, differed significantly (*P < 0.05.)*, and ranged from 3.98 % to 7.68 %. The rise in protein content of these flours with an increase in the level of Moringa substitution in the blends could be attributed to the additive effect of Moringa *leaf powder* protein [27.14 %] on the plantain flours. The levels of protein in 100 % plantain observed in this study showed that the fruit is low in protein and cannot meet adult protein diet need, which for a healthy adult is about 0.75 g per kg per day [32].

The addition of Moringa leaf powder to plantain flour caused a significant increase in the fat content of the fortified flours as the level of Moringa powder increased, ranging from 1.42 % (sample PM1) to 1.93 % (sample PM6). The low fat content of the composited flour suggest they extended the shelf-life of the flour because fat can promote rancidity in food leading to the development of unpleasant and odorous compounds [33]. However, the increase in fat content of the composited flour, which is as a result of the high fat content of Moringa leaf [34,35], could improve the palatability of the composited plantain flour products. Studies have shown that the functions of dietary fats include increasing food palatability resulting from the absorption and retention of flavours [36].

Crude fibre such as lignin, cellulose, and hemicelluloses represents the content of the non-digestible components of foods. As shown in Table 2, the crude fibre content increased significantly *(P < 0.05)* with an increase

Table 2. The Proximate composition (%) and Energy (Kcal/100g) values of the Moringa fortified plantain flours (%)

**Sample	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate	Energy
M	8.50±.04^{a*}	27.14±.03^{h}	2.85±.03^{e}	9.44±.01^{a}	10.39±..04^{h}	41.68±.03^{a}.	300.93±5.14^{a}
P	10.22±..03^{e}	3.68±.03^{a}	1.37±.04^{a}	2.45±.03^{b}	2.88±.07$^{.a}$	79.4±.04^{g}	344.15±6.19^{b}
PM1	10.20±.01.^{e}	3.95±.06$^{.b}$	1.42±.02^{ab}	2.63±.02^{c}	3.07±.07$^{.b}$	78.74±..07^{f}	343.95±4.10^{b}
PM2	10.15±..00^{d}	4.21±.04.^{c}	1.55±.04.^{b}	2.83±.07^{d}	3.25±0.05^{c}	78.02±.06^{ef}	342.83±5.45^{b}
PM3	10.10±..02^{c}	4.65±.02.^{d}	1.65±.02	2.98±.03^{e}	3.38±.02^{d}	77.26±.07^{e}	342.06±7.12^{b}
PM4	10.04±..03^{b}	5.25±.04^{e}	1.73±.04^{cd}	3.16±.04^{f}	3.63±.07.^{e}	76.21±.14^{d}	341.83±4.76^{b}
PM5	10.02±.00^{b}	5.83±.04^{f}	1.85±.02^{d}	3.35±0.05^{g}	3.77±.00.^{f}	75.19±.14$^{.c}$	340.89±6.43^{b}
PM6	9.99±.02^{b}	6.68±.07.^{g}	1.93±.04.^{f}	3.51±.04^{h}	3.99±.04^{g}	73.91±.14^{b}	339.74±3.94^{b}

**Values are Mean± SD of triplicate determinations, and Mean values in the same column with different superscripts are significantly different at P < 0.05.*

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder.*

in substitution level due to the high fibre content of Moringa leaf powder (9.44 %). This observation indicate that the enriched flours will digest easily hence contribute to the prevention of colon cancer since high in crude fibre facilitate bowel movement [37]. The ash content of Moringa leaf powder was significantly higher (4.25 times) than plantain flour ash content. Hence its inclusion in the flour blends significantly increased the ash content of the fortified flours. This observed increase in ash content agrees with the report of Karim et al. [38] *on* yam flour fortified with 2.5, 5.0 and 7.5 % Moringa leaf powder*.*

The carbohydrate content of Moringa leaf powder (41.68 %) as shown in Table 2, is very low compared to the carbohydrate content of sole plantain flour (79.4 %), therefore, inclusion of Moringa in plantain brought about significant *($P < 0.05$.)* reduction in carbohydrate content of the fortified flours. This observation is similar to that of Ilelaboye and Ogunsina [17] who observed a reduction in carbohydrate content (75.65 to 64.33 %) of "Okara" fortified plantain-sorghum flour with the addition of "Okara" flour. The energy values of the Moringa fortified flours, as shown in Table 2, ranged between 344.15 kcal and 339.74kcal, and did not vary significantly *($P > 0.05$)*. The addition of Moringa leaf powder to plantain flour caused a decline in the energy level of the blends.

3.2 Mineral Compositions of the Moringa Leaf Powder– Plantain Flours

The mineral content of the flour samples presented in Table 3, revealed that sample P had higher content of sodium (Na), potassium (K), and phosphorous (P), while sample M had higher calcium (Ca), magnesium (Mg) and iron (Fe). It was also observed that the minerals varied significantly *($P <0.05$)* at different degrees in the enriched flour blends. The calcium content of the 100% plantain flour was 234.06 mg/100 g, while that of the Moringa fortified flours increased significantly *($P < 0.05$)* from 277.66 mg/100g in PM1 to 478.49 mg/100g in PM6 as the level of Moringa leaf powder increased in the blends. However, consumption of about 100 g enriched flours will provide an estimated 25.24 % to 43.50 % of the recommended daily allowance (RDA) for adult calcium (1100 mg/day) requirements [39], for skeleton firmness and most metabolic processes [40].

The magnesium content of the sample P was 199.06 mg/100g, while the magnesium content of the fortified flours ranged from 203.01 mg/100 g to 222.77 mg/100 g, with the 15 % Moringa substituted plantain flour having the highest value. Addition of Moringa leaf powder to plantain flour at intervals of 2.5% caused no significant (*$P > 0.05$)* difference in magnesium content of the enriched flour except in 15% Moringa substituted plantain flour. Although the inclusion of Moringa leaf powder to plantain flour significantly reduced its phosphorus content, but the increment in the level of Moringa at 2.5 % interval did not cause any significant ($P > 0.05$) difference in the phosphorus content of the enriched flours, which ranged from 216.98±7.44 mg/100g to 209.81±4.03 mg/100 g. Based on the RDA for phosphorus (800 mg/day) for an adult [39], fortification of plantain flour with Moringa leaf powder resulted in reduction of estimated daily derivable phosphorus from consumption of the flour.

Table 3. Mineral composition of flours from the blends of Moringa leaf powder and plantain (mg/100 g)

**Sample	Ca	Mg	P	K	Na	Fe
M	1978.12±59.73^{h*}	357.12±7,43^{c}	135.87±4.73^{a}	1486.12±97.3^{a}	167.79±9.73^{a}	34.75±2.81^{b}
P	234.06±28.41^{a}	199.06± 8.54^{a}	219.06±6.41^{b}	3856.06±84.1^{d}	239.06±8.41^{b}	12.56±1.34^{a}
PM1	277.66±18.44^{ab}	203.01±6.44^{ab}	216.98±7.44^{b}	3796.81±84.4^{cd}	237.28±8.44^{b}	13.11±1.37^{a}
PM2	321.26±18.47^{bc}	206.96±4.27^{ab}	214.90±4.48^{b}	3737.56±84.7^{bcd}	235.498.47^{b}	13.67±1.41^{a}
PM3	364.86±18.51^{cd}	210.91±5,71^{ab}	212.82±5.51^{b}	3678.31±85.1^{bcd}	233.72±8.51^{b}	14.22±1.44^{a}
PM4	401.57±18.29^{de}	214.86±7.54^{ab}	213.97±3.97^{b}	3710.19±92.34^{bcd}	237.41±8.44^{b}	13.96±2.63^{a}
PM5	435.07±32.62^{ef}	218.82±8.58^{ab}	211.89±4.00^{b}	3650.95±94.30^{bc}	235.63±8.47^{b}	14.52±2.67^{a}
PM6	478.49±32.90 ^{fg}	222.77±8.61^{b}	209.81±4.03^{b}	3591.70±90.27^{b}	233.85±8.51^{b}	15.07±2.70^{a}

**Values are Mean± SD of triplicate determinations, and Mean values in the same column with different superscripts are significantly different at $P < 0.05$.*

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder.*

The value of potassium of 100% plantain flours (3856.06 mg/100 g) is higher than that of Moringa leaf powder (1486.12 mg/100 g) and, fortification of plantain flour resulted in significant *(P < 0.05)* reduction of the enriched flours which ranged from 3796.81 mg/100g to 3591.70 mg/100g (Table 3). Thus, consumers of the fortified flours will potentially derive 48.55 % to 70.54 % of RDA for potassium [39]. Table 3 shows that blending of the plantain flour with Moringa leaf powder resulted in non-significant *(P > 0.05)* decrease in the sodium content of the fortified plantain flours. Studies have shown that excess intake of sodium can exacerbate high blood pressure; therefore, the composited flours will be suitable for dietary management of hypertension due to its low sodium content [41]. The amount of iron in Moringa leaf powder is about 2.77 times higher than its value in 100 % plantain flour, (12.56 mg/100 g). Therefore, the iron content of the fortified flours increased significantly *(P < 0.05)* with an increase in the level of Moringa leaf powder inclusion (Tables 3), and the quantities are enough to provide the RDA of iron (5 mg/day) for adult [39].

3.3 Antinutrient Content of the Moringa – Plantain Flours

The oxalate, phytate, saponin and tannin contents of the flour blends, as presented in Table 4 showed that the antinutrient in sample M was higher than those in sample P.

The 100 % plantain flour had low levels of oxalate (0.54 %), phytate (0.60%) saponin (1.54 %) and tannin (0.43 %), but higher than the levels of oxalate (0.51 %), phytate (0.240 %) saponin (1.60 %) and tannin (0.30 %) as reported by Wordu and Akusu [42] for unripe plantain flour. The contents of oxalate, phytate, saponin and tannin in the blended flours increased with increase in the level of Moringa leaf powder, and it ranged from 0.54 % to 0.74 % for oxalate, 0.60 % to 0.83 % for phytate, 1.54 % to 1.62 % saponin and 0.43 % to 0.60 % for tannin. The levels of the antinutrient in the flour samples was below the estimated threshold limit of this antinutrient and would pose no threat to the health of consumers [43]. Studies have shown that high level of oxalates increases calcium absorption in the kidney [44], because high oxalate level in food has been implicated as the cause of kidney stones. Therefore, consumers of the fortified flours, should have low risk of adverse health effect due to oxalate toxicity.

3.4 Functional Properties of the Moringa – Plantain Flours

In this study, it was observed that the functional properties of the composite flours of Moringa leaf powder and plantain flour had bulk density values ranging from 0. 39 to 0. 55 g/cm^3 (Table 5), which decreased with increase in the level of Moringa substitution. The bulk density of sample P agreed with the reports of previous studies on pure plantain flour [13, 17, 45], and this is a pointer to the porosity and the extent of compactness of the flours [46]. Bulk density also functions as the determinant for the packaging requirement, material handling and application in wet processing in the food industry [47].

Water absorption capacity (WAC) of the flours significantly (*P < 0.05)* increased from 78.27% (sample P) to 92.29 % (sample PM6). The addition of Moringa leaf powder to the plantain flour caused an increase in WAC of the flour blends due to its high content of protein. This observation supports other studies which also reported that the water absorption capacity of

Table 4. The antinutrient content of plantain flours fortified with Moringa leaf powder (%)

Sample	Oxalates	Phytate	Saponin	Tannin
M	1.65.04	1.95±0.05	1.87±.02	1.59±0.05
P	0.54±.03^{a}	0.60±.08^{a}	1.54±.09^{a}	0.43±.01^{a}
PM1	0.56±.01^{b}	0.64±.04^{b}	1.55±.13^{ab}	0.46±.06^{ab}
PM2	0.60±.03^{bc}	0.67±±.09^{c}	1.57±.02^{b}	0.48±.02^{bc}
PM3	0.62±.02^{c}	0.72±.01^{d}	1.58±.14^{bc}	0.52±.03^{c}
PM4	0.66±.04^{d}	0.75±.13^{e}	1.59±.06^{bc}	0.53±.09^{cd}
PM5	0.69±.02^{e}	0.78±.10^{f}	1.61±.11^{c}	0.56±0.05^{d}
PM6	0.74±05^{f}	0.83±.11^{g}	1.62±.13^{c}	0.60±.04^{e}

**Values are Mean± SD of triplicate determinations, and Mean values in the same column with different superscripts are significantly different at P < 0.05.*

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder.*

Table 5. The functional properties of Moringa - plantain flours

Sample	***BD(gcm^{-3})	WAC(%)	OAC (%)	SP(g/100g)	SOL(g/100g)	LGC (%)
P	$.55{\pm}.03^{e}$	$78.27{\pm}.10^{a}$	$54.50{\pm}.09^{a}$	$9.92{\pm}.09^{g}$	$6.56{\pm}.14^{e}$	$2.00{\pm}\ .00^{a}$
PM1	$.50{\pm}.01^{d}$	$81.89{\pm}.13^{b}$	$56.35{\pm}.11^{b}$	9.59±.04f	$6.26{\pm}.11^{e}$	$4.00{\pm}\ .00^{b}$
PM2	$.48{\pm}.01^{cd}$	$83.16{\pm}.06^{c}$	$58.03{\pm}.14^{c}$	$9.41{\pm}.04^{e}$	$5.80{\pm}.07^{d}$	$6.00\ {\pm}.00^{c}$
PM3	$.47{\pm}.01^{bcd}$	$85.24{\pm}.08^{d}$	59.20±.21	$9.10{\pm}.07^{d}$	$5.17{\pm}.21^{c}$	$8.00\ {\pm}.00^{d}$
PM4	$.44{\pm}.01^{bc}$	$88.47{\pm}.14^{e}$	$61.47{\pm}.10^{e}$	$8.89{\pm}0.05^{c}$	$4.92{\pm}.07^{c}$	$10.00{\pm}.00^{e}$
PM5	$.43{\pm}.04^{ab}$	$90.53{\pm}.14^{f}$	$63.27{\pm}.21^{f}$	$8.68{\pm}.11^{b}$	$4.55{\pm}.14^{b}$	$12.00\ {\pm}.00^{f}$
PM6	$.39{\pm}.01^{a}$	$92.29{\pm}.23^{g}$	$64.51{\pm}.28^{g}$	$7.95{\pm}.06^{a}$	$4.18{\pm}.07^{a}$	$14.00\ {\pm}.00^{g}$

**Values are Mean± SD of triplicate determinations, and Mean values in the same column with different superscripts are significantly different at p < 00.05.*

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder.*

**** BD = Bulk density; WAC = Water absorption capacity; OAC = Oil absorption capacity; SP = Swelling power SOL = Solubility LOC = Least gelation concentration*

food materials depend on its protein content [13,47,48]. The oil absorption capacity (OAC) followed a similar trend and the reasons are similar as in water absorption capacity. The OAC of flours is influenced by the quantity of protein in the flour which structure consists of both hydrophilic and hydrophobic group [49]. Therefore, sample PM6 with high OAC (64.51 %) will be good for the production of bakery products as it will retain flavour and increase the mouthfeel of the product [50].

Table 6 shows the swelling power and solubility index of the flour blends, and the swelling power obtained in this study for sole plantain flour 9.92 g/100 g is higher than the values reported by Abioye et al. [46], and Ilelaboye and Ogunsina [17] for 100 % plantain flour. The difference may be attributed to the variety of plantain used for the flour. However, the swelling power of plantain flour decreased progressively as the proportion of Moringa leaf powder increased in the mixture. This observation is explained by the addition of Moringa leaf powder which increase the protein content of plantain flour, resulting in the reduction in swelling ability of the starch granules in the flour, since their accessibility to water is reduced [51]. The solubility index of the composite flour presented in Table 5 ranged from 4.18 % to 6.56 %. The solubility index of the flour blends increased slightly as the amount of Moringa leaf powder increased. Therefore, since solubility is an index of protein functionality, the higher the solubility index, the higher the functionalities of the protein in food [52], and the better the reconstitution of the flour.

The result of least gelation concentration (LGC) of the flour blends shown in Table 5, significantly (*$P < 0.05$*) increased from 2.00 % (sample P) to 14.00 % (sample PM6) as Moringa leaf powder inclusion in the flour blends increased. The value reported for sample P is lower than that of Fagbemi [53]. Since variations in the gelling properties of different flours are linked to the ratios of various constituents (carbohydrate, lipids and protein) in the flour, it is suggested that interactions between such components may also have a significant role in their functional properties [54,55]. The high LGC of the fortified flours implies that Moringa leaf powder inclusion in the blends resulted in poor gelation, hence the flours could not form thick gels (low dietary bulk) at lower concentration. This observation suggest that they may serve as good binders in breakfast foods, and may be incorporated into food systems to provide semisolid consistency in beverages [16].

3.5 Pasting Properties of Moringa Leaf Powder- Plantain Flours

The pasting properties of Moringa - plantain flours, as presented in Table 6 are different and are similar to the values reported for plantain-soy flour composites [45]. The peak viscosity, which is the maximum viscosity developed during or soon after the heating portion, significantly *($P < 0.05$)* varied between 3525.73 RVU for P and 2402.04 RVU for PM6. This decrease in peak viscosity as the proportion of Moringa leaf powder increased in the composite flour, suggest that the interaction of components such as fats and proteins from Moringa, with starch in the plantain, lower the peak viscosity of the flours [5]. The relatively low peak viscosity of the enriched flour signifies their adaptability for products requiring low gel strength and elasticity (45). This observation supports the findings of previous work where plantain flour was fortified with soybeans [46].

Table 6. The pasting properties of Moringa - plantain flours

Sample*	Peak viscosity (RVU)	Trough	Breakdown viscosity (RVU)	Final Viscosity (RVU)	Setback viscosity (U)	Pasting Temp °C	Peak Time
P	3525.73	3271.56	254.17	4407.16	1135.61	82.65	5.43
PM1	3437.12	3223.75	213.36	4296.39	1072.64	87.32	5.86
PM2	3192.55	3000.39	192.16	3990.68	990.30	87.68	5.93
PM3	2966.11	2791.62	174.49	3707.63	916.01	87.73	60.05
PM4	2799.61	2649.38	150.22	3499.51	850.12	87.88	6.12
PM5	2605.36	2476.66	128.69	3256.69	780.03	87.94	6.19
PM6	2402.04	2287.19	114.85	3002.55	715.36	87.96	6.23

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder*

The breakdown viscosity of P was 254.17 RVU, and the Moringa leaf powder - plantain flours had lower values in the range of 114.85 to 213.36 RVU. Adebowale et al. [25 reported that samples with high breakdown viscosities have less resistance for heating and shear stress during cooking. Hence, sample PM6 might be able to withstand more heating and shear stress compared to other samples because of its low breakdown value.

The final viscosity ranged from 3002.55 to 4407.16 RVU, and the control sample P had the highest final viscosity, while sample PM6 had the lowest. Since final viscosity is used to indicate the ability of starch to form stable gel after cooling, it implies less stability of starch paste is an indicator of high value of breakdown. Thus, sample P will be less stable after cooling compared to Moringa fortified plantain flour.

Studies have shown that setback viscosity is an indicator of the tendency for the occurrence of syneresis of starch upon cooling [25]. In the current study however, significant decreases (P<0.05) with increasing addition of Moringa leaf powder was observed. It is believed that the protein components of the Moringa leaf powder interacted strongly with the starch component of the plantain flour during pasting, resulting in the slight decrease in the setback value. High setback value has been associated with a higher tendency for retrogradation, especially during storage. Thus, Moringa fortified "Amala", will be more stable than the "Amala" of unfortified sample, especially when the product is not consumed immediately after preparation. The apparent gelatinization (pasting) temperature of P flour was 82.65ºC while those of Moringa - plantain flours varied from 87.32 to 87.96ºC. This increase in temperature may be due to the buffering effect of fat from Moringa leaf powder on starch which interferes with the gelatinization process [56].

3.6 Sensory Properties

An increase in the level of substitution of Moringa leaf powder for plantain flour affected the rating of all the sensory characteristics studied (Table 7). Generally, the control sample ("Amala") from 100% plantain flour), had the best rating for all the parameters. There were no significant differences (P < 0.05.) between the "Amala" from sample P, PM1 and PM2 blend regarding colour and mouldability. The consistency of the control "Amala" sample P (Table 7) varied significantly (P < 0.05.) from the consistency of other "Amala" samples except for sample PM1. "Amala" from flour blends PM3, PM4, PM5 and PM6 were less preferred to "Amala" from sample P as regard colour, aroma, taste mouldability, consistency and overall acceptability. The PM6 blend colour was the darkest due to the dark green colour of Moringa leaf powder which is a reflection of the chlorophyll content of the leaf. The observed increase in colouration of the "Amala" products with an increase in the level of supplementation of Moringa leaf powder conforms with previous reports on fortification of yam flour and plantain flour using *Moringa oliferea* leaves powder [14,38]. The result of the overall acceptability for the fortified "Amala" revealed that samples PM1 and PM2 were equally rated and slightly different from the control which had the best rating. In all, 2.5% to 5% Moringa leaf powder supplementation for plantain flour was sufficient to improve the proximate and mineral composition of plantain flour "Amala" without having a significant effect on the sensory properties.

Table 7. The mean scores for sensory evaluation

Sample	Colour	Aroma	Taste	Mouldability	Consistency	Overall Accep.
P	2.80±1.57[a]	2.90±1.20[a]	2.88±1.64[a]	3.10±1.29[a]	3.40±1.78[a]	2.97±1.29[a]
PM1	30.05±1.14[a]	3.20±1.93[ab]	3.12±1.32[ab]	3.20±1.40[a]	3.50±1.84[a]	3.10±1.84[ab]
PM2	3.18±2.00[a]	3.40±1.35[ab]	3.22±1.43[ab]	3.33±2.35[a]	3.65±2.13[ab]	3.23±2.64[ab]
PM3	3.90±1.66[b]	4.30±1.57[b]	3.80±1.43[b]	4.10±1.97[b]	4.00±20.05[b]	3.67±1.97[b]
PM4	4.10±2.51[b]	4.90±1.97[b]	4.42±20.05[c]	4.30±1.70[b]	4.20±2.35[b]	4.19±1.78[c]
PM5	4.40±2.07[b]	5.00±1.89[bc]	4.80±2.04[c]	4.90±1.79[c]	4.68±1.79[bc]	4.70±2.21[c]
PM6	5.33±2.23[c]	6.00±1.83[c]	4.90±1.91[c]	5.80±2.10[d]	5.30±2.21[c]	5.30±2.10[d]

**Values are Mean± SD of triplicate determinations, and Mean values in the same column with different superscripts are significantly different at p < 00.05.*

***Sample key: P = 100 Plantain: 0 Moringa leaf powder; PM1 = 97.5 Plantain: 2.5 Moringa leaf powder; PM2 = 95 Plantain : 5 Moringa leaf powder; PM3 = [92.5 Plantain : 7.5 Moringa leaf powder; PM4 = 90 Plantain : 10 Moringa leaf powder; PM5 = 87.5 Plantain : 12.5 Moringa leaf powder; PM6 = 85 Plantain : 15 Moringa leaf powder*

4. CONCLUSION

This investigation has showed that the substitution of plantain flour with Moringa leaf powder progressively increased the nutrient content of the samples as the level of supplementation increased. The blends should have a long shelf-life due to their low moisture and fat content. Moringa fortified plantain flour could have the potential to combat protein-energy malnutrition and micronutrient deficiencies. The levels of the antinutrient in the fortified samples were relatively low and below the threshold limit of oxalate, phytate, saponin and tannin, hence consumption of the flours would pose no threat to the health of the consumers. The functional properties of the fortified samples such as the bulk density and water absorption capacity improved and could be advantageous for industrial uses. Though plantain flour supplemented with 15% of Moringa leaf powder (PM6) had the best nutritional quality, the result of sensory evaluation revealed that 2.5% to 5% supplementation were organoleptically acceptable and were sufficient to theoretically improve the nutrient composition of plantain flour *"*Amala" without having a significant effect on the sensory properties.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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