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Nutritional, Physico-Chemical and Sensory Properties of Yam Flour Dough Fortified with *Moringa oleifera* Seed Flour.

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Abstract

Yam (*Dioscorea spp)* is the second most important root/tuber crop in Africa after cassava and is an important source of carbohydrate. Low protein content of yam flour has been a major concern in its utilization, hence the objective of this research was to investigate the effect of addition of *Moringa oleifera* seed flour on the nutritional, physico-chemical as well as sensory qualities of yam flour dough. *Moringa* seed flours obtained through fermentation, germination and regular milling of unprocessed seed were added to yam flour at three inclusion levels (10, 20 and 30 %) and were subjected to analyses. Chemical composition, Pasting properties and sensory evaluation of the products were determined using AOAC methods, Rapid visco analyser and nine point hedonic scale, respectively. Moisture, fat and crude fibre contents of the samples ranged from 10.97 to 12.27%, 2.04 to 2.96% and 1.71 to 2.08%, respectively. Calcium, Iron, Sodium, Potassium and Phosphorus were significantly ($p<0.05$) affected by the *Moringa* flour inclusion, however, copper was not affected. Phosphorus and copper contents (mg/100g) ranged from 90.43 to 156.38 and 0.04 to 0.08, respectively.There were significant differences ($p<0.05$) in water and oil absorption capacity, swelling power and solubility index whereas no significant difference ($p>0.05$) exist in the bulk density of the samples. The highest value of 96.54% was recorded for unfortified yam flour for water absorption capacity while yam flour fortified with 10% fermented moringa seed flour has the lowest value of 89.58%.The swelling power ranged from 10.85 -11.77 while Bulk density is from 0.73-1.81g/ml . Germinated *Moringa* substituted flour showed highest pasting properties (peak, trough, final and setback viscosities) followed by fermented *Moringa* substituted flour. Aside trough viscosity, the pasting properties increased significantly ($p<0.05$) with increased *Moringa* flour inclusion level. Higher (8.17) and lower (5.42) ratings were observed for colour of dough prepared from yam flour fortified with 20% germinated Moringa seed flour and 20% raw *Moringa* seed flour, respectively.

Key words: Fortification, Moringa oleifera, Yam flour, trough, viscosity

Introduction

Moringa oleifera belongs to the family *Moringaceae*, It is one of the best known and most widely distributed and naturalized species of a monogeneric family *Moringaceae* (Fahey *et al*., 2001). *Moringa oleifera* originates from North West region of India, South of the Hamalayan Mountain and now widely cultivated and has become naturalized in many locations in the tropics (Fahey *et al*., 2001). It is widely grown in many parts of Nigeria. It is a tropical tree whose numerous economic application and facility of propagation are arousing growing international interest. *Moringa* tree is cultivated for use as a vegetable (leave, green pods, flowers, roasted seeds), spices (roots), cooking and cosmetic oil (seeds) and as a medicinal plant (all plant parts) (Rebecca *et al*., 2006).

All the parts of *Moringa oleifera* tree are edible and have long been consumed by humans. It is reported to have been used in various applications such as alley cropping (biomass production), animal forage (leaves and treated seed cake), biogas (leaves), blue dye (wood), fertilizers (seed cake), gum (tree trunk), honey and sugar cane juice clarifier (powdered seed) etc (Fuglie, 1999). Almost all the parts of this plant have been used for various ailments in the indigenous medicine of South Asia including the treatment of inflammation and infectious disease along with cardiovascular, gastrointestinal, haematological and hepato-renal disorder (Singh and Kumar, 1999; Morimitsu *et al*., 2000; Siddhuraju and Becker, 2003).

The seeds of *Moringa* are considered to be anti-pyretic, acrid bitter and reported to show antimicrobial activity (Oliveira *et al*., 1999). The seed extract exerts protective effect by decreasing liver lipids peroxides. Antihypertensive compound, thiocarbonate and isothiocyanate glycosides have been isolated from the acetate phase of the ethanolic extract of *Moringa* pods (Faizi *et al*., 1995). The seed can be consumed fresh as peas or pounded, roasted or pressed into sweet, non-dessicating high quality oil commercially known as "Ben oil" . The crushed seed and pressed cake have unique property of containing polypeptides which serve as natural coagulants for water treatment (Ndabigengesere and Narasial, 1998), it can also be used as an antiseptic in the treatment of drinking water (Obioma and Adikwu, 1997).

Yam (*Dioscorea spp)* is the second most important root/tuber crop in Africa after cassava, with the production reaching just under one third of the level of cassava (FAO, 1997). It is an important source of carbohydrate for many people of the sub-Sahara region especially in the yam zone of West Africa (Akissoe *et al*., 2003). There are over 150 species of yam grown throughout the world (Pulseglove, 1991). Yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serve as an important source of income to the people (Babaleye, 2003).

Yam composed mainly of water and carbohydrate. The carbohydrate consists essentially of starch and negligible amount of sugar (usually less than 1%, the main constituent of yam starch is amylopectin). The protein content is low ranging from 1 to 3% of fresh weight; it is low in sulphur containing amino acids, methionine and cystine. Apart from being a good calorie source, yam is also significant source of vitamin C, iron, calcium and nicotinic acid, it also contain traces of vitamin A and B (Asiedu, 1989). It is one of the rich sources of minerals like copper, potassium, manganese and phosphorus.Yam is prepared for consumption in variety of ways including boiling, baking, frying, pounding or may be processed into flour to be reconstituted in boiling water to form a paste or dough. Yam flour has the advantage of being a product that keeps well and is easy to market even at great distance (Martin *et al*., 1984). Yam flour is traditionally prepared by peeling yam tuber, slicing and parboiling of yam slices and then drying in the sun until the moisture has been reduced to about 10%. After which the pieces are ground in mortar or milled in corn mills to yield flour

The quality of yam flour varies from processor to processor and from location to location (Akissoe *et al*., 2001). Indeed, local consumers of yam flour have preference for the product made from a particular area of South West Nigeria (Brica *et al*., 1997). However the low protein content of yam flour has been a major concern in its utilization (Brook *et al*., 1969) hence the objective of this research was to investigate the effect of addition of *Moringa oleifera* seed flour on the nutritional composition, physic-chemical properties as well as acceptability of yam flour dough.

Materials and methods

Dioscorea rotundata variety used for this study was purchased from Sango market Saki West local government area, Saki, Oyo state, Nigeria and the *Moringa oleifera* seed was obtained from Bode, Basorun area in Ibadan Oyo state, Nigeria. Yam was processed into yam flour following the method described by Ige and Akintunde (1981) with slight modification in drying time as shown in Figure 1. *Moringa* seed was subjected to three different processing techniques as shown in Figure 2 to obtain *Moringa* seed flours.

Yamtubers
↓
Washing
↓
Peeling
↓
Slicing (1cm thick)
↓
Blanching (60^{o}C for 11min in water bath)
↓
Cooling in blanching water (24h)
↓
Draining
↓
Oven drying (60^{o}C for 48h)
↓
Milling
↓
Sieving (250µm)
↓
Packaging
↓
Yam flour

Figure 1: Flow chart for yam flour production (Ige and Akintunde, 1981)

Raw moringa seed
↓
Sorting
↓

Dehulling	Soaking (1:3 weight/volume for 24h)	Dehulling
↓	↓	↓
Oven drying (50^{o}C for 4h)	Draining	Boiling (1h)
↓	↓	↓
Milling	Germinating (48h at 30^{o}C)	Cooling
↓	↓	↓

Sieving (250mm)	Dehulling	Wrapping in banana leaf
↓	↓	↓
Packaging	Oven drying (50^{o}C for 48h)	Fermenting (30^{o}C for 72h)
↓	↓	↓
Raw moringa seed flour	Milling	Oven drying (50^{o}C for 48h)
	↓	↓
	Sieving (250mm)	Milling
	↓	↓
	Packaging	Sieving (250mm)
	↓	↓
	Germinated moringa seed flour	Packaging
		↓
		Fermented moringa seed flour

Figure 2: Flow chart for *Moringa* seed flour production

Moringa seed flours were substituted into the produced yam flour at three inclusion levels i.e. 10, 20 and 30% moringa seed flour in yam flour. The substituted yam flours were subjected to analyses.

Proximate analysis

The proximate composition of the product was determined using AOAC (1990) method. The method described by AOAC (2006) was used for mineral analysis of the samples. The samples were ashed at 550^{o}C, the ash was boiled with 10ml of 20% hydrochloric acid in a beaker and then filtered into a 100ml standard flask and made up to mark with deionized water, the resulting solution was used for mineral determination. Sodium (Na) and Potassium (K) were determined using the standard flame emission photometer using NaCl and KCl as standard solutions (AOAC, 2006). Phosphorus was determined colorimetrically using spectronic 20 (Gallenkamp, UK) using KH_2PO_4 as standard solution (Kirk and Sawyer, 1991). Other minerals were determined using Atomic Absorption Spectrophotomer (AAS model SP9). The results were expressed in mg/100g.

Functional properties determination

Water and oil absorption capacities

Water and oil absorption capacity were determined using the method of Sathe and Salunkhe (1981) with slight modifications. Ten millilitres of distilled water/oil was added to 1.0 g of the sample in a beaker. Thesuspension was stirred for 5 min and centrifuged at 3000 rpm for 10min and the supernatant measured in a 10 mL graduated cylinder. Water/oil absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. The water/oil absorption capacity was then calculated as stated below

$$\text{Water/oil absorption capacity} = \frac{\text{Water/oil absorbed (g)}}{\text{Weight of sample (g)}} \times 100$$

Swelling power and solubility index

Swelling power and solubility index were determined following the method described by Henshaw and Adebowale, (2004). 1g of sample was weighed into 50ml centrifuge tube and made up to mark with distilled water. The slurry was heated in water bath at 80^{o}C for 15 min during which the slurry was continuously stirred to avoid clumping together. The tube was then centrifuged at 3000 rpm for 10 min and the supernatant decanted. The weight of sediment was determined and the moisture content of the sediment gel was thereafter determined to get the dry matter content of the gel. The swelling power was calculated as shown below:

$$\text{Swelling power} = \frac{\text{Weight of the wet mass of sediment}}{\text{Weight of dry matter in the gel}}$$

$$\text{Solubility index} = \frac{\text{Weight of soluble (g)}}{\text{Weight of sample (g)}} \times 100$$

Bulk Density

The bulk density of the yam flours were determined by the method described by Eltayeb *et al*., (2011). Ten grammes of the sample were weighed into 50ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench 10 times. The volume was then recorded and bulk density was calculated using the formula below:

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}}$$

Pasting properties

The pasting characteristics were determined with a rapid visco analyser (RVA) series 4 (Newport Scientific,NSW, Australia,1995). Three grammes of flour sample were weighed and 25mls of distilled water was dispensed into canister containing the flour, paddle was placed inside the canister to mix the solution properly,this was placed centrally and then fitted into the RVA machine. The slurry was heated from 50^{0}C to 95^{0}C in 51/2min then held at 95^{0}C for 21/2 min, the sample was subsequently cooled to 50^{0}C over a 31/2min period and held for 21/2min.The rate of heating and cooling was at a constant rate of 12.^{0}C/min. Peak viscosity, trough, breakdown, final viscosity,setback, peak time and pasting temperature were read from the pasting profile with the aid of computer monitor connected to the instrument.

Sensory evaluation

The yam flour dough was prepared for sensory evaluation by stirring 100g of milled yam flour in 47ml of boiling water. It was evaluated for colour, texture, taste and overall acceptability using 30 panelists drawn from among the staff and students of the Polytechnic Ibadan, Saki campus who are familiar with it using nine point hedonic scale with rating 9 for like extremely and 1 for dislike extremely.

Statistical analyses

The procedure for analyses were replicated and the data obtained were subjected to analysis of variance (ANOVA) and the means were separated using Duncan Multiple Range Test (DMRT) using SPSS software package version 19.0.

Results and Discussion

Proximate analysis

Table 1 shows the proximate composition of fortified and unfortified yam flours. Moisture content of the samples ranged from 10.97 to 12.27%. Lower moisture content is an indication of good storability of flour products. There were significant difference ($P<0.05$) between the protein content of unfortified and fortified yam flours. The protein content of fortified yam flour ranged from 3.47%, for yam flour fortified with 10% germinated moringa seed flour, to 16.06% for yam flour fortified with 30% raw moringa seed flour. The increase in protein of fortified yam flour with moringa in three inclusions than unfortified yam flour could be attributed to initial high protein content of moringa seed flour (Anwar *et al*. 2006), a net synthesis of enzymic protein during fermentation (Thierry *et al*., 2013) and germination by germinating seeds (WHO, 1998). Nzeribe and Nwasike (1995) also reported activities of protease during germination of acha and Thierry et al. (2013) reported that protein content of *moringa* increased during fermentation due to activities of *Lactobacillus plantarum*. Tasousi *et al*. (2008) stated that the increase in protein of germinated corn seed was due to mobilization of storage nitrogen producing the nutritionally high quality protein which young plant need for its developments. The protein content increased with increase in level of all inclusions. The fat contents of fortified yam flour ranged from 2.04% to 2.96%. The fat contents were found to be significantly ($P<0.05$) lower in yam flour fortified with fermented *Moringa* seed flour at 20% inclusion (2.04%) than unfortified yam flour (2.77%) i.e. the control. The decrease in fat content of yam flour fortified with fermented moringa seed flour might be attributed to the increase activities of lipolytic enzymes during fermentation and germination which hydrolyse fat component into fatty acid and glycerol (Chima *et al*., 2009). The crude fibre content ranged from 1.71 to 2.08% in yam flour fortified with 20% and 30% raw *Moringa* seed flours respectively. There were significant difference ($p<0.05$) between ash content of both fortified and unfortified yam flours. The ash content ranged from 1.94% to 2.36% in yam flour fortified with 20% raw moringa seed flour and 10% fermented *moringa* seed flour respectively. The carbohydrate content of fortified yam flour decrease with increase in inclusion level of moringa seed flour ranging from 65.70% for yam fortified with 30% raw moringa seed flour to 78.32% for yam flour fortified with 10% germinated *moringa* seed flour. The percentage of carbohydrate of yam flour fortified with raw, fermented and germinated moringa seed flour which decreased with increase in % inclusion especially in germinated moringa might be due to increase in α-amylase activity (Lasekan, 1996). The α-amylase breaks down complex carbohydrate to simple and more absorbable sugars which are utilized by the growing seedling during the early stage of germination.

Mineral composition

Table 2 shows the mineral composition of fortified and unfortified yam flours. There were significant differences ($p<0.05$) in the evaluated minerals for all samples. calcium, iron, sodium, potassium and phosphorus whereas no significant difference ($p>0.05$) was observed in copper for all the samples. The most abundant mineral of both the fortified and unfortified yam flours is potassium with values ranging from147.02mg/100g to 235.04mg/100g in yam fortified with 20% germinated moringa seed flour and 30% fermented moringa seed flour respectively. Next to potassium is phosphorus with values ranging from 90.43 to 156.38mg/100g. Phosphorus performs more functions in the body than other mineral elements.

It associates with calcium in bone and teeth formation and low dietary intakes are associated with poor growth (McDonald, 1995). The values of sodium ranged from 17.34 to 22.06mg/100g in yam flour fortified with 20% and 30% germinated moringa seed flours respectively. The least abundant mineral is copper with values ranging from 0.04 to 0.08mg/100g in yam flours fortified with 20% fermented moringa seed flour and 10% raw moringa seed flour respectively.

Functional properties

Table 3 shows the functional properties of fortified and unfortified yam flours. There were significant differences ($p<0.05$) in water and oil absorption capacity, swelling power and solubility index whereas no significant difference ($p>0.05$) exist in the bulk density of the samples. The highest value of 96.54% was recorded for unfortified yam flour for water absorption capacity while yam flour fortified with 10% fermented moringa seed flour has the lowest value of 89.58%. Water absorption capacity increased with increasing level of moringa seed flour except for yam flour fortified with raw moringa seed flour. The high water absorption capacity has been attributed to loose structure of starch polymers while low value indicates the compactness of molecular structure (Sanni *et al*., 2006). The swelling power ranged from 10.85 in yam flour fortified with 10% germinated moringa seed flour to 11.77 in yam flour fortified with 20% raw moringa seed flour. Increase in swelling power with increase in temperature indicates the need for more energy for disruption of strongly bound sites in the starch granule (Henshaw and Adebowale, 2004). The highest and lowest bulk density values of 1.81 and 0.73g/mL recorded for yam flour fortified with 20% and 30% germinated moringa seed flours respectively. Unfortified yam flour recorded the same value of bulk density (1.74g/mL) as yam flour fortified with 30% fermented moringa seed flour.

Pasting properties

The pasting properties of yam flour dough fortified with raw, fermented, and germinated *Moringa* seed flour substituted for yam flour at three inclusion levels were shown in Table 4. Non substituted yam flour has lower pasting properties (Peak, trough, breakdown, and final viscosities) while the sample fortified with 10% germinated seed flour had the higher pasting properties (peak, trough, and final viscosities) followed by the 30% fermented moringa seed substituted flour. Generally, pasting properties including peak, trough, breakdown, final and setback viscosities, peak time and pasting temperature varied with the different treatments on moringa seeds.

The final viscosity which is used to determine the quality of flour; the higher the value,the more the hardness and elasticity(Osundahunsi et al., 2003). The final viscosity of the yam flour fortified with 30% germinated moringa seed flour recorded the highest value 280.58RVU (rapid viscosity units) while that of 20% germinated moringa flour recorded the lowest value (160..58RVU). Final viscosity of the yam flour containing fermented and germinated moringa seed flour increased with increase in the % level of inclusion while the yam flour containing raw moringa flour consistently decreased as the % level of inclusion increased. Decreased pasting characteristics could be attributed to changes in starch molecules such as starch degradation and debranching to simpler units (Falade *et al*., 2011; Rombo *et al*., 2001, 2004) and Sung (2005) also attributed a decrease in peak, trough and breakdown viscosity to the decrease in size of the starch granules caused by the treatment.

Sensory evaluation

Table 5 shows the sensory evaluation of the dough prepared from both fortified and unfortified yam flours. The highest rating of 8.17 was observed for colour of dough prepared from yam flour fortified with 20% germinated moringa seed flour while the least scored was dough made from yam flour fortified with 20% raw moringa seed flour (5.42). The dough made from both

100% yam flour and yam flour fortified with 20% germinated moringa seed flour recorded the highest score of 7.92 while the lowest score were recorded for dough made from yam flour fortified with 10% germinated and 20% raw moringa seed flours (5.83) in terms of texture. The dough prepared from 100% yam flour was most acceptable to the panelists in terms of overall acceptability followed by the dough made from yam flour fortified with 20% fermented moringa seed flour.

Table 1: Proximate composition of fortified and unfortified yam flours

Sample MF:YF	Protein %	Fat %	Ash %	C. Fibre %	Moisture %	Carbohydrate %
0:100	2.72^{i}	2.77^{c}	1.97^{f}	1.77^{e}	11.26^{f}	79.51^{a}
10:90 RM	7.04^{g}	2.17^{e}	2.06^{e}	1.84^{d}	11.06^{g}	75.85^{c}
20:80 RM	7.35^{e}	2.21^{e}	1.94^{g}	1.71^{f}	12.16^{b}	74.65^{e}
30:70 RM	16.06^{a}	2.96^{a}	2.24^{c}	2.08^{ab}	10.97^{h}	65.70^{i}
10:90 FM	7.13^{f}	2.07^{f}	2.36^{a}	1.95^{c}	11.54^{e}	73.53^{f}
20:80 FM	8.57^{d}	2.04^{f}	2.20^{d}	1.83^{d}	12.17^{b}	74.60^{e}
30:70 FM	12.27^{c}	2.81^{c}	2.27^{b}	2.05^{b}	12.27^{a}	68.35^{g}
10:90 GM	3.47^{h}	2.34^{d}	2.25^{bc}	1.77^{e}	11.86^{c}	78.32^{b}
20:80 GM	7.04^{g}	2.18^{e}	2.19^{d}	1.83^{d}	11.68^{d}	75.09^{b}
30:70 GM	14.02^{b}	2.87^{b}	2.26^{bc}	2.10^{a}	12.24^{a}	66.53^{h}

Values are means of triplicates determinations.Within a column,values with different superscripts are significantly different ($p<0.05$)

MF- Moringa seed flour, YF- Yam flour, RM- Raw moringa seed flour, FM- Fermented moringa seed flour, GM- Germinated moringa seed flour

Table2: Mineral composition (mg/100g) **of fortified and unfortified yam flours**

Sample MF:YF	Ca	Fe	Na	Mg	Mn	K	P	Zn	Cu
0:100	2.72^{a}	1.09^{c}	19.23^{e}	15.57^{c}	0.16^{de}	168.85^{d}	99.65^{e}	1.05^{c}	0.06
10:90 RM	1.13^{e}	0.68^{e}	20.17^{c}	14.48^{f}	0.19^{c}	171.03^{c}	101.02^{d}	1.07^{b}	0.08
20:80 RM	1.23^{c}	0.86^{d}	18.77^{f}	15.33^{d}	0.17^{d}	165.23^{e}	105.35^{c}	0.09^{d}	0.06
30:70 RM	2.64^{a}	0.72^{e}	17.46^{g}	15.06^{e}	0.15^{e}	148.63^{g}	95.47^{f}	1.04^{c}	0.06
10:90 FM	1.16^{d}	0.72^{e}	17.46^{g}	15.06^{e}	0.15^{e}	148.63^{g}	95.47^{f}	1.04^{c}	0.06
20:80 FM	1.09^{f}	0.65^{f}	19.67^{d}	13.63^{g}	0.17^{d}	156.18^{f}	90.43^{f}	0.08^{d}	0.04
30:70 FM	1.27^{b}	1.26^{b}	21.15^{b}	27.17^{b}	0.29^{b}	235.04^{a}	150.11^{b}	1.13^{a}	0.07
10:90 GM	1.06^{g}	0.57^{g}	18.77^{f}	12.54^{h}	0.14^{f}	156.23^{f}	86.25^{h}	0.09^{d}	0.05
20:80 GM	1.12^{e}	0.48^{h}	17.34^{h}	13.66^{g}	0.16^{de}	147.02^{h}	94.46^{g}	0.67^{d}	0.05
30:70 GM	1.20^{c}	1.29^{a}	22.06^{a}	29.35^{a}	0.31^{a}	233.34^{b}	156.38^{a}	1.12^{a}	0.07

Values are means of triplicates determinations.Within a column,values with different superscripts are significantly different ($p<0.05$)

MF- Moringa seed flour, YF- Yam flour, RM- Raw moringa seed flour, FM- Fermented moringa seed flour, GM- Germinated moringa seed flour

Table 3: Functional properties of fortified and unfortified yam flours

Sample MF:YF	Water absorption capacity (%)	Swelling power	Solubility index (%)	Bulk density (g/ml)	Oil absorption capacity (%)
0:100	96.54^{a}	11.46^{b}	10.93^{b}	1.74^{bc}	120.13^{i}
10:90 RM	92.41^{c}	11.37^{c}	10.45^{c}	1.68^{de}	121.16^{g}
20:80 RM	90.46^{f}	11.77^{a}	11.06^{a}	1.76^{b}	125.57^{c}
30:70 RM	91.74^{d}	10.87^{f}	9.70^{i}	1.65^{e}	129.35^{b}
10:90 FM	89.58^{g}	11.38^{c}	10.36^{e}	1.69^{b}	130.06^{a}
20:80 FM	90.45^{f}	11.47^{b}	10.39^{d}	1.58^{f}	124.17^{d}
30:70 FM	93.64^{b}	11.15^{e}	10.16^{g}	1.74^{bc}	122.24^{f}
10:90 GM	90.57^{f}	10.85^{f}	9.67^{i}	1.68^{d}	120.42^{h}
20:80 GM	91.61^{e}	10.87^{f}	9.73^{h}	1.81^{a}	123.65^{e}
30:70 GM	92.47^{c}	11.23^{d}	10.26^{f}	0.73^{g}	121.17^{g}

Values are means of triplicates determinations.Within a column,values with different superscripts are significantly different ($p<0.05$)

MF- Moringa seed flour, YF- Yam flour, RM- Raw moringa seed flour, FM- Fermented moringa seed flour, GM- Germinated moringa seed flour

Table 4: Pasting properties of fortified and unfortified yam flours

Sample MF:YF	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (RVU)	Pasting temp (RVU)
0:100	128.50^{h}	87.42^{g}	41.08^{h}	186.42^{h}	99.00^{c}	5.33^{c}	80.12
10:90 RM	221.42^{c}	157.00^{c}	64.42^{f}	237.08^{e}	80.08^{g}	5.48^{h}	81.45
20:80 RM	222.08^{c}	140.42^{e}	81.67^{b}	233.00^{e}	92.58^{d}	5.01^{f}	80.77
30:70 RM	208.67^{f}	140.75^{e}	67.92^{e}	226.08^{g}	85.35^{f}	5.22^{d}	80.66
10:90 FM	210.67^{e}	144.33^{d}	66.33^{e}	231.42^{f}	87.08^{e}	5.58^{a}	81.25
20:80 FM	234.92^{b}	15.00h	79.92^{c}	256.17^{d}	101.17^{b}	5.12^{e}	80.33
30:70 FM	243.80^{a}	143.92^{d}	99.17^{a}	260.75^{c}	116.83^{a}	5.36^{c}	80.96
10:90 GM	244.08^{a}	175.75^{a}	68.33^{e}	266.25^{b}	90.50^{d}	5.27^{c}	82.05
20:80 GM	175.67^{g}	101.08^{f}	74.58^{d}	160.58^{i}	59.50^{h}	5.19^{d}	81.44
30:70 GM	217.58^{d}	162.42^{b}	55.17^{g}	280.58^{a}	118.17^{a}	5.38^{c}	80.05

Values are means of triplicates determinations.Within a column,values with different superscripts are significantly different ($p<0.05$)

MF- Moringa seed flour, YF- Yam flour, RM- Raw moringa seed flour, FM- Fermented moringa seed flour, GM- Germinated moringa seed flour

Table5: Sensory evaluation result of fortified and unfortified yam flours

Sample MF:YF	Colour	Texture	Taste	Overall acceptability
0:100	7.83^{ab}	7.92^{a}	8.42^{a}	8.25^{a}
10:90 RM	6.50^{c}	5.92^{c}	5.92^{bc}	6.00^{b}
20:80 RM	5.42^{c}	6.17^{bc}	5.33^{c}	6.17^{b}
30:70 RM	7.67^{ab}	5.83^{c}	5.72^{bc}	6.92^{ab}
10:90 FM	7.67^{ab}	6.50^{bc}	6.75^{bc}	6.83^{ab}
20:80 FM	7.50^{ab}	7.83^{b}	7.10^{ab}	7.50^{ab}
30:70 FM	7.58^{ab}	7.08^{ab}	6.83^{bc}	7.00^{ab}
10:90 GM	7.07^{ab}	5.83^{c}	5.33^{c}	6.00^{b}
20:80 GM	8.17^{a}	7.92^{a}	7.25^{ab}	6.83^{ab}
30:70 GM	7.00^{ab}	6.75^{bc}	5.92^{bc}	6.58^{b}

Values are means of triplicates determinations.Within a column,values with different superscripts are significantly different ($p<0.05$)

MF- Moringa seed flour, YF- Yam flour, RM- Raw moringa seed flour, FM- Fermented moringa seed flour, GM- Germinated moringa seed flour

Conclusion

The substitution of *Moringa oleifera* seed flour for yam flour has improved the nutritional value of yam flour especially in terms of protein and mineral composition without negatively influencing the sensory qualities of yam flour dough. It also affected physicochemical properties of the paste by improving its textural characteristics which is a desirable characteristic of starchy meal.

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