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Study on the Proximate, Pasting and Functional Properties of Yam Flour Enriched with *Moringa oleifera* Seed Meal Blend

Kanu, A. N. and Ogunka, N. P.

National Root Crops Research Institute Umudike, P.M. B 7006 Umuahia, Abia State
Corresponding author's email: chisoanns@yahoo.com

Abstract
Yam is rich in carbohydrates and is made up of other nutrients while *Moringa oleifera* is rich nutritionally and is a multipurpose plant. A combination of different food crops can boost the nutritional deficiency of one of the crops. Four yam cultivars were processed into flour and moringa seeds were defatted to get moringa seed meal. Their flours and the moringa seed Meal were mixed at different concentrations to form yam/ moringa seed meal. The study investigated proximate, functional and pasting properties of yam flours from (*Discorea otundata*, *Discorea alata*, *Dioscorea cayenensis* and *Discorea bulbifera*) enriched with *Moringa oleifera* seed meal. Results of the proximate composition showed that the protein content of the unfortified yam flours ranged from 3.40-4.40% while the *Moringa oleifera* fortified yam flours had a higher protein content of 4.63-6.20%. The other proximate parameters for both unfortified and fortified yam flours were: moisture content with values of 8.20-9.8 & 9.0-12.10%, crude fibre (1.30-2.75 and 1.90-5.25%), respectively. The inclusion of moringa seed meal brought an increase in the protein content, crude fiber, crude fat and ash content significantly at (P<0.05). However, the carbohydrate decreased significantly. The increase as seen in this study was concentration-dependent. There is an appreciable enhancement of the functional property in the fortified yam flours compared to the unfortified. The values of some of the unfortified and fortified yam samples were as follows: swelling index (1.32-2.01 & 0.31-1.95), bulk density (0.86-0.94 & 0.74-0.85), water absorption capacity (1.69-2.33 &1.74-2.65), oil absorption capacity (2.44-2.96 $ 2.02-2.46) respectively**.** Fortification of the yam flour with moringa seed meal was able to boost the nutritional content of the samples as was evidenced in the result, suggesting that moringa seed meal can be added to other food to improve the nutrient and functionalities.
Keywords: Yam flour, moringa oleifera seed meal, proximate, pasting, and functional properties

Introduction

The incorporation of crops with different compositions, to expand the utilization can improve their functionality and physicochemical properties. Tharise *et al*., (2014) have reported that the addition of soybeans flour to cereal was able to boost the essential amino acid balance of the food product produced from the flour. There has been a study on the combination of cereal-tuber-legume flour for the production of food forms. This can be supported by the findings of Noorfarahzilah *et al*. (2014) who reported that the protein content of the cassava-soya and the cassava-groundnut breads was found to be higher when compared with that of wheat bread.

Yam is a tuberous crop which belongs to the genus *Dioscorea* spp, they exist in diverse species of over 600 (Tortoe *et al*., 2017). The different species of yam show variation in its utilization for food products and industrial uses. Yam can be consumed by preparing it in many ways, which include boiling, cooking, frying baking etc. (Stephen *et al*., 2013). *Moringa oleifera* is a tropical tree that is indigenous to sub-himalayan valleys. It is a multi-purpose tree whose properties have been researched for so long (Sánchez *et al*., 2012) every part of the *moringa* plant is useful for food or other beneficial applications. The root, the leaf, the seed steam etc posse one benefit or the other (Adegbe *et al*., 2016).

The functionality of a food is the property of a food ingredient, other than its nutritional value, that greatly impacts its utilization (Otegbayo, 2011). Knowledge of technological functional properties and physiological parameters is essential for the food industry, and can be used as a tool to predict and evaluate the processing and cooling stages of crops; there can be some alterations if need be, to suit product and processing demand which are feature desired by consumers Oke *et al*.,.2013). Given the nutraceutical and other functional properties of yam/*moringa* seed, hence the present study is undertaken with the objectives of evaluating the Physiochemical parameters and functional properties of some selected yam flour and its *moringa* seed meal blend (Marqurs *et al*., 2013).

Material and Methods

Source of Sample

The four varieties of yam tubers *(Dioscorea alata, Dioscorea bulbifera, Dioscorea cayenensis* and *Dioscorea rotundata*) were procured from Wuruku Market while samples of the plant (*Moringa oleifera* seeds) were collected from a local settlement in Umudike, Ikwuano Local Government Area of Abia State and was identified at the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture Umudike Umuahia Abia State Nigeria. All samples were deposited at the herbarium of the Department of Pharmacology College of Veterinary Medicine (CVM) Michael Okpara University of Agriculture Umudike Umuahia Abia State Nigeria. A voucher number MOUAU/VPP/17/021 was assigned for *moringa oleifera* seed while voucher numbers MOUAU/VPP/18/008, MOUAU/VPP/18/009, MOUAU/VPP/18/010 and MOUAU/VPP/18/011 were assigned to *Dioscorea alata*, *Dioscorea rotundata*, *Dioscorea cayennes* and *Dioscorea bulbifera* respectively.

Preparation of yam flour

The yam flour was produced according to the method described by Udensi *et al.* (2008)

Moringa seed meal preparation

The *Moringa oleifera* seed was oven-dried at 40^{o}C for 12 hrs. After which it was milled into fine particles. The 500g of the milled samples were added in a cork bottle and 600ml of N-hexane was added. The bottle was then placed in a rotator shaker for 48 hours. The oil was observed to have moved to the top. The mixture of oil and hexane was then decanted. The meal was collected and dried in the oven at 40^{O}C until all the hexane was evaporated from the cake. The dried cake was milled to get a fine powder and was stored in an air-tight container until further used.

Analyses

Proximate compositions were determined by the Association of Official Analytical Chemists (2012). The functional properties that were determined include water and oil absorption capacities, method of Abbey and Ibeh (2012) was used for their determination. Bulk density, swelling index and foam capacity were determined using the method of Onwuka and Onwuka (2015) as described by Amandikwa (2014) Pasting properties were carried out on the samples using rapid Visco- Analyzer (RVA model 3D for windows) (Newport scientific 1998).

Results and Discussion

Results

Proximate Composition of Yam Flour enriched with Moringa Seed Meal

The results of the proximate composition of yam enriched with *moringa* seed meal are presented in Table 1. The protein content of the fortified sample ranged from 3.40% (DCR) to 30.39% MRGA. The inclusion of *moringa* seed meal gave a significant increase in the protein content of the samples, the result showed that as the inclusion level increased from 5% to 10% the protein content increased. The value of the fat contents ranged from 1.30 to 5.85%. The non-fortified yam flours had the lowest values for fat content ranging from 1.30 to 1.90%, The 4 samples fortified with *moringa* seed meal had the highest fat content ranging from 2.20 to 4.20%. The ash content showed a significant (P>0.05) increase with *moringa* seed meal from 5% to 10%. The ash contents of the control (*Dioscorea*) samples varied from 1.40-2.20 %. The supplementation with 5% *moringa* seed meal significantly (P>0.05) increased from 1.77 to 2.47. The moisture content of the flour ranged from 6.90 to 12.10%. The carbohydrate contents of the un-fortified yam flour and the fortified *moringa* blends decreased from 84.80% (in DRC) to 70.90% (in DB90M10). The carbohydrate content of the control samples (100% *Dioscorea*) was higher (80.45 to 84.80%) than the others.

Pasting Properties of Yam Flour enriched with Moringa Seed Meal

The results of the pasting properties of yam flour enriched with *moringa* seeds meal are presented in Table 2. The incorporation of *moringa* seed meal caused a decrease in the peak viscosity (PV) of both *Dioscorea rotundata and Dioscorea cyennesis* at both 5% (257.23 RVU), 10% (186.45 RVU) and 5% (288.27) and 10% (221.27) inclusion level respectively. The trough ranged from 149.12 to 230.23 RVU. There was a constant decrease in breakdown viscosity (BV) of *Dioscorea rotundata* from the control (80.24 RVU) and *moringa* seed meal inclusion at both 5% and 10 % for all sample inclusion levels. The final viscosity ranged from 279.00 to 387.23. The setback viscosity ranged from 75.91 to 148.80. The peak time ranged from 5.23 to 6.11min with DRC having the highest peak time among the control samples. The peak temperature ranged from 82.20 ^{O}C to 98.96 ^{O}C.

Functional Properties of Yam Flour Enriched with Moringa Seed Meal

The results of the functional properties of yam flour enriched with *moringa* seeds meal are presented in Table 3. There was no significant difference (P>0.05) in the swelling index of the samples. The SI values ranged from 0.31 in the DBC to 2.01 in the DC90M10, with DBC (*Dioscorea bulbifera)* control having the highest value) while DC90M10 had the least value. The result showed that the inclusion of *moringa* seed meal at 5% caused a significant (P>0.05) decrease in the swelling index of *Dioscorea rotundata*, *Dioscorea alata,* and *Dioscorea bulbifera* flour; however, 10% inclusion caused an increase for *Dioscorea rotundata* and *Dioscorea alata*. The water absorption capacity of all the control samples ranged from 1.69 ml/g to 2.33 ml/g. There were significant (P>0.05) differences for all other parameters of the functional properties.

Discussion

Proximate composition of yam flour enriched with moringa seed meal

The control samples which are the yam samples with no inclusion of moringa are poor in protein nutrients which conforms to the findings of Ojinnaka *et al.* (2017). Some studies showed that *moringa* leaf powder is high in protein content and its substitution effect brought about an increase in protein content (Sengev *et al*., 2013). Ayo *et al* (2018) reported an increase in the protein content of *acha-moringa* flour as the *moringa* inclusion increased from 5 to 20%. In another study, the inclusion of *moringa* seed cake at 5% and 10% caused an appreciable increase in the protein content (Abioye, 2015). The protein content obtained in the present study was in line with the 31.65% reported by Anwar and Rashid (2005). The protein content of the *moringa* seed meal must have been responsible for the significant increase in the protein content of the yam and *moringa* seed meal blend. This implies that *moringa* seed meal can help to improve the crude protein when incorporated into foods. Protein deficiencies in some plants can be improved and remedied by mixing the food ingredients from different plant types, particularly combining cereals and legumes (Coles, 2016). This will ensure proper growth, development and maintenance of the human body. The fat increased significantly (P>0.05 with an increase in the level of *moringa* seed in the blend. This can be attributed to the high-fat content of *moringa* seed meal (Arise *et al*., 2014). Although the inclusion of *moringa* seed meal significantly (P>0.05) improved the fat content of the yam/ *moringa* blend samples, the value is so small that it cannot support oxidative deterioration which will encourage spoilage and rancidification (Arise *et al*., 2014). Similarly, the crude fibre content increased significantly (P>0.05) with the addition of *moringa* seed meal at 5% and 10% levels. The crude fibre content was comparable with those of the yam and *moringa* leaf blend (1.1% and 2.2%) reported by Karim *et al.* (2013) and Fausat *et al.* (2017) with values were (0.90 to 0.91%). Although the crude fibre content of this study was higher than those of the work of two researchers, however, the values were not so high that will prevent the consumption of other important nutrients. High crude fibre is known to prevent the consumption of other nutrients. Also, the consumption of the food formulation with this blend will digest easily and will prevent colon cancer which is one of the functions of a diet rich in crude fiber (Karim *et al*., 2015). Another study reported that fiber prevents constipation, cleanses the digestive tract through the removal of potential carcinogens and thus, avoids the absorption of excessive cholesterol (Karim *et al*., 2013). The inclusion of *moringa* leaf powder decreased the moisture content. The moisture contents of the sample were low and within the acceptable limit. This will enhance the keeping quality and will not encourage spoilage by the proliferation of microorganism. Similar trends were observed in the study on plantain and *moringa oleifera* leaf powder blends at different levels of substitution. The researchers reported that the increased moisture content of the *moringa* flour inclusion caused a decrease in the carbohydrate content Karim *et al*. (2015). The control samples had higher carbohydrate content than the other samples. The significant decrease in the carbohydrate content of the samples as the *moringa* seed meal inclusion increased may be a result of the low carbohydrate content of the *moringa* seed meal (47.21%). In another study decrease in carbohydrate content was reported to be the dilution effect during the supplementation with *moringa* leaf powder, which had a lower value of carbohydrate (Sengev *et al*., 2013). The use of the yam and *moringa* blend as food will be useful for people who do not require a high intake of carbohydrates in their diets.

Pasting properties of yam flours enriched with moringa seeds meal

The pasting properties of the yam flours and the *moringa* seed meal at different levels are a reflection of their botanical origin as well as the composition of their major component (amylose and amylopectin) which are necessary for predicting the behaviour of flours in food application (Tortoe *et al*., 2017, Kayode *et al*., 2010). The result of the present study showed that the flours have distinct differences in all the parameters that describe the pasting behaviour of flours. Peak viscosity (PV) is the maximum viscosity attained by the paste during the heating cycle (from 50 to 95 ^{0}C), which is resistance to stirring of a swollen mass gel. Starch also can swell freely before its physical breakdown (Ezeocha, and Okafor, 2016). According to Wirko Manu *et al*. (2011) peak viscosity is associated with starch content and the level of damage of this starch content. Sanni *et al*. (2001) reported that the higher the starch damage, the higher the peak viscosity. The result showed that DRC had the highest PV when compared to other control samples. The peak viscosity was higher than the peak viscosity of cassava starch (85.17-178.25 RVU) as reported by Ikegwu *et al*. (2009). As the concentration of *moringa* seed meal (5% and 10%) increased *in Dioscorea alata, Dioscorea bulbifera* and *Discorea cayenensis* there was an increase in the peak viscosity but the *Discorea cayenensis* had a fall in the PV at 10% inclusion. The structure and pasting behaviour of starch granules are influenced by the associative bonding of the amylose fraction (Ikegwu *et al*. (2009). Variation in the peak viscosity in this report might be due to the amylose content of the starch, retention of granular structure upon heating or due to agronomic practices (Zhu, 2015). As the starch content increased, the amylose content increased Wireko-Manu *et al*. (2013). A similar report had it that *Dioscorea rotundata* and *Dioscorea cayenensis* have high starch content (Baah 2009). High peak viscosity is an indication that the samples will be less resistant to swelling and rupturing (Tortoe, 2017). The DRC, DA90M10 DC95M5, DB95M5, and DB90M10 samples will be suitable for the preparation of the product where high swelling and no rupturing are needed. These will be desirable in industrial use where high thickening power at a very elevated temperature is desired. The high peak viscosity of those samples makes them a better choice for the preparation of some products such as jelly or binders, however low viscosity is desirable for weaning food (Ezeocha and Okafor, 2016). The breakdown viscosity (BV) is a reflection of the stability of peak viscosity during processing. Flour with low breakdown viscosity has been known to possess the capacity to withstand heating and shearing during heating (Awolu 2017). Other samples namely *Dioscorea alata. Dioscorea cayenensis* and *Dioscorea bulbifera* increased at 5% inclusion and had a decrease at 10% inclusion. The result indicated that 10% *moringa* meal inclusion for all samples and *Dioscorea rotundata* at control and 5 had lower breakdown viscosities. Adebowale *et al*. (2005) reported that high breakdown viscosity is an indication of a lower ability of the flour to withstand heating, granule rupturing (Abiodun, 2014) and shear stress during cooking. Thus the control flour samples (*Dioscorea alata, Dioscorea cayenensis, and Dioscorea bulbifera*) had lower breakdown viscosity and can withstand heating and shear stress during cooking. However, the samples with 10% *moringa* seed meal can withstand heating and shear stress during cooking than the samples with 5% *moringa* seed meal inclusion level which had high breakdown viscosities. High breakdown viscosity showed that their swollen starch granules are relatively weak against hot shearing (Offia-Olua, 2014). *Awolu et al. (2016*) reported a lower breakdown viscosity as the concentration of the kidney bean increased. Final viscosity is the most commonly used parameter to determine the quality of starch-based samples because it indicates starch/flour's ability to form a gel after cooking (Ajatta 2016. The result shows that *moringa* seed meal caused a slight decrease in the final viscosity. The decrease in the final viscosity was not so pronounced. Starch retrogradation is one of the main mechanisms for staling of bakery products. This increases crumb firmness, changes flavour and aroma, and also causes loss of crispiness (Kong and Singh 2016). Yam paste is known to have a high retrogradation power during cooling. This is linked to the increase in final viscosities. The high final viscosity is influenced by the interaction between starch-water systems which re-crystallizes during cooling (Baah, 2009). Ajatta *et al*. (2006) reported that the increase in the final viscosity might be due to the aggregation of the amylose molecules. The formation of a gel network by amylose and a long amylopectin chain which maintains the integrity of starch granules during heating and shearing is the setback viscosity (Kasem, 2012). The addition of *moringa* seed meal decreased the setback viscosity. The higher setback is associated with a higher tendency for retrogradation (Karim 2005). The fortified *Dioscorea (*DRC, DAC, DCC and DBC*)* samples will give more stable samples than the unfortified samples. This is a desired quality especially if the products prepared from the samples are not to be consumed immediately after preparation. The control samples DRC, DAC, DCC and DBC) are high in setback viscosity and as such have a higher tendency for retrogradation. However, DAC has the least setback among the control samples and therefore, has a lower tendency to retrograde. This finding is in line with the report of Otegbayo *et al*., (2014) who stated that D*ioscorea rotundata* had a higher setback than *Dioscorea alata*. The inclusion of *moringa* seed meal at 5% caused a decrease for samples DR9 5M5, DA95M5, DC95M5 and DB95M5. The 5% inclusion level gave better pasting time than the 10% *moringa* seed meal inclusion level which caused a decrease. The pasting time in the study was in contrast to the pasting time reported by Addy *et al.* (2014) who observed a pasting time of 17.40-17.55 min for yam varieties. Variations of pasting time may be attributed to the varietal differences. Results generated indicated that less time will be required to cook the flour (Wireko-Manu, 2013) and will be suitable for the preparation of food that needs short time cooking such as instant poundo yam. The result showed that the higher the pasting time the higher the pasting temperature. Pasting temperature is the indication of the minimum temperature required for cooking the samples at which they start to thicken. The pasting time depends on the granular size of the starch (Adeoye *et al*., 2017). The pasting temperature ranged from 82.20^0C-93.94^0C for the control samples. The incorporation of *moringa* seed meal lowered the pasting temperature, more especially at the 10% inclusion level. The inclusion of *moringa* seed meal will increase the gelatinization temperature and lesser time/ temperature will be used during cooking of the samples. The pasting temperature was in agreement with the pasting temperature of yam varieties (>78^0C) as reported by Amani *et al.* (2004). The inclusion of *moringa* seed meal decreased the pasting temperature for all the samples at 5% and 10% levels except *Dioscorea rotundata*. High pasting temperature reflects the size of the starch granules (Karim *et al*., 2015). Small granules show many difficulties in rupturing and loss of molecular order (Okafor and Okafor, 2014). Therefore, the addition of *moringa* seed meal at 5 and 10% inclusion levels increased the starch granules thereby, reducing the pasting temperature.

Functional properties of yam flours enriched with moringa seeds meal

Water absorption capacity (WAC) measures the rate at which the flour sample absorbs water and will affect the rate at which the starch granules swell during the reconstitution of the flour (Nwosu, 2013). The ability of starch to absorb water is an indication of its moisture stability which is very important for the food industry (Rosida *et al*., 2017). There was a significant increase in the WAC of all the samples (DC95M5, DA95M5, DR95M5 and DB95M5) containing *moringa* seed meal at 5%. However as the *moringa* seed meal inclusion increased (10%), the water absorption capacity decreased. This can be supported by the work of Annongu *et al.* (2014) that an increased concentration of *moringa* leaf to plantain flour brought a decrease in the water absorption capacity of the flour blend. A high concentration of *moringa* seed meal may have blocked the binding site of water thereby causing a decrease in the WAC as the percentage of *moringa* seed meal increased. The inclusion of *moringa* seed meal in the control samples caused a significant increase however; there was a decrease of WAC at 10% *moringa* seed meal inclusion. This increase may be related to the hydrophilic constitute of soluble fiber of *moringa* seed (Adebanjo *et al*., 2017). High water absorption capacity is needed for food production that requires high viscosity such as dough making and food thickeners (Adeeyo *et al*., 2013). Variation in the water absorption capacity of flour has been reported to be due to the differences in the granule sizes and the availability of water binding sites. Swelling index (SI) is the ability of starch to imbibe water and swell. The work of Jude *et al*. (Singh *et al*., 2004) reported that the inclusion of *moringa* seed at 10%, 20%, and 30% in fermented *Ogi* caused a decrease in the swelling index when compared to the 100% *Ogi*. A similar researcher reported a decrease in hydration index as *moringa* seed flour was incorporated in the orange fleshed sweet (Fausat *et al*., 2017). The decrease in the swelling index may be attributed to weak bonds in the associative forces within the flour granules as a result of the different levels of *moringa* seed mill incorporation (Snni *et al*., 2005). Also, variation in the swelling power is an indication of the level of exposure of the starch internal structure to water. It can also be attributed to the relative ratio of some constituents of the crop such as protein, carbohydrate and lipids as described by Kaur and Sandhu (2010), and Kanu *et al*. (2017). The swelling index can also indicate the water absorption capacity of the flour during heating (Ajatta *et al*., 2016), (Adegunwa *et al*., 2014). The swelling index of all the tested flour samples was high which indicated that the samples can be used for the production of food where the high swelling index is required like in the production of buns and baby formula. The results indicated that the bulk density of the control samples (100% *Dioscorea* flour) was higher when compared with the bulk density of the fortified samples. The inclusion of *moringa* seed meal at 5% and 10% decreased the bulk density, however, *Dioscorea rotundata* control (DRC) and *Dioscorea cayenensis* control (DCC) were the same in the bulk density. An increase in *moringa* meal supplementation decreased the bulk density (Ayo *et al*., 2018). A similar study reported a reduction in the bulk density of rice flour after being supplemented with African yam beans (Iwe et al., 2016). *Dioscorea* species are rich in carbohydrates but the dilution effect as a result of supplementation with *moringa* seed meal was responsible for the decrease in bulk density (Sengev *et al*., 2013). Bulk density is the relative volume of packing material required. The inclusion of *moringa* seed caused a reduction in the bulk density which will make for easy transportation and storability. The reduction of the bulk density of the samples containing *moringa* seed meal may be due to the decrease in starch content of the samples as a result of the addition of *moringa* seed meal. This was supported by the work of Ojinnaka *et al*. *(*2016) who reported that the bulk density of food increased with an increase in starch content. The reduction may also be due to the low bulk density of *moringa* seed (0.81 g/ml). It could also be a result of the reduction of the emulsion capacity brought about by the high content of protein in the *moringa* seed meal. High protein content gives a reduction in surface tension, which will translate into a decrease in bulk density when compared with 100% yam flour. Foam is a colloidal of many gas bubbles trapped in a liquid or solid. It is used to detect texture, consistency and appearance. The foam capacity of a food material varies with the type of native protein, solubility and other factors (PL 2017). The foam capacity for all the samples has different values but they are statistically the same except for samples DRC, DR90M10, DC95M5, DB95M5 and DB90M10. The inclusion of *moringa* seed meal did not increase the foam capacity. Rather it reduced their values and made them statistically the same. The ability of the protein to stabilize against gravitational force and stress is known as foam stability. For every whipping agent to be considered useful, it must have the ability to maintain the whip for a long time. The result showed that the addition of *moringa* seed meal increased the foam stability from 5% inclusion to 10% *moringa* seed meal inclusion, except in samples DB95M5 which had a low value. However, at 10% inclusion, there was an appreciable increase. The samples investigated indicated that sample DCC and DB95M5 had low foam stability while all other samples showed high foaming stability which indicated that they are good whipping agents. Gelatinization temperature is the temperature at which starch granules in food become disrupted and form a gel. The gelatinization temperature of the unfortified and the unfortified samples varied significantly from 81 to 90^{0}C. The addition of *moringa* seed meal increased the values. High gelation temperature is an indication of low starch content. If the starch content is low, it takes a longer time to gel (Ojinnaka *et al*., 2017). Starch concentration, method of observation, granule type and heterogeneities within the granule population under observation govern the initial gelation and the particular point over which it occurs (Baah, 2009). Therefore, the values obtained from this study indicated that the inclusion of *moringa* seed meal at 5 and 10% increased the gelatinization temperature of DCC from 81to 87^{0}C and that of DAC from 84 and 87^{0}C. This is because the addition of *moringa oleifera* seed meal reduced the starch content of the yam flour, thereby increasing the gelation temperature. However, the gelatinization temperature for all the other yam flour at 5 and 10 % *moringa* seed meal inclusion recorded high values. The lower gelation temperature of *moringa* seed blends when compared to the control suggests that lower energy costs will be required during processing into ready-to-eat products (Fausat *et al*., 2017). There was a significant difference in the oil absorption capacity (OAC). The sample without *moringa* seed meal had a higher oil absorption capacity. The inclusion of *moringa* seed meal in the yam flour caused a significant decrease in the values. This can't be far from the oily nature and fat content of the *moringa* seed meal. Fausat *et al*. (2017) stated that orange fleshed sweet potato flour and *moringa* seed flour blend at O80M2 (Orange fleshed sweet potato at 80% and *moringa* seed flour at 20%) had lower OAC at 0.42 ml/g than O100M0 (Orange fleshed sweet potato at 100% and *moringa* seed flour at 0%) at.714ml/g The fat content for the yam samples ranged from 1.30 to 2.75% while that of *moringa* meal is 5.8%. The high content of the *moringa* seed oil will not allow it to absorb more oil, thus resulting in a low value of the OAC of samples with *moringa* seed meal. The inclusion of *moringa* seed meal caused a decrease in the OAC and this makes the sample suitable for products which does not require high OAC.

Conclusion

The fortification of the different yam flours with *moringa oleifera* seed meal enhanced the proximate composition however, the carbohydrate content showed a significant decrease. The functionality and the pasting properties of the unfortified sample were greatly improved after the inclusion of *moringa* seed meal at both 5 and 10% as evidenced in the results. Based on the results gotten from this study, the inclusion of yam flour and *moring*a seed meal at 5 % and 10% levels should be used for the enhancement of the nutritional quality and functional properties of yam flour.

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Table 1: Proximate Composition of Yam Flour, M*oringa* Seed Meal and the Blends

Samples	Crude protein (%)	Crude fiber (%)	Crude fat (%)	Ash (%)	Moisture (%)	Carbohydrate (%)
DRC	$3.40^{j}\pm0.10$	$0.80^{e}\pm0.00$	$1.30^{j}\pm0.10$	$1.40^{i}\pm0.10$	8.30 ± 0.10	$84.80^{a}\pm0.45$
DAC	$4.03^{hi}\pm0.10$	$1.00^{ef}\pm0.00$	$1.70^{i}\pm0.10$	$1.60^{h}\pm0.10$	$8.20^{i}\pm0.00$	$83.47^{b}\pm0.35$
DCC	$4.40^{hi}\pm0.21$	$2.40^{c}\pm0.00$	$2.75^{e}\pm0.05$	$1.80^{g}\pm0.00$	$8.20^{i}\pm0.00$	$80.45^{b}\pm0.34$
DBC	3.73^{h}i±1.33	$1.50^{d}\pm0.00$	$1.90^{h}\pm0.00$	$2.20^{e}\pm0.00$	$9.80^{f}\pm0.00$	$80.87^{b}\pm0.58$
MRGA	$30.39^{a}\pm0.35$	$5.25^{a}\pm0.45$	$5.85^{a}\pm0.15$	$4.40^{a}\pm0.00$	$6.90^{j}\pm0.00$	$47.21^{h}\pm0.40$
DR95M5	$4.63^{g}\pm0.35$	$1.00^{ef}\pm0.00$	$2.20^{i}\pm0.00$	$1.77^{g}\pm0.58$	$10.60^{d}\pm0.00$	$79.80^{b}\pm0.45$
DR90M10	$5.60^{ef}\pm0.10$	$1.52^{d}\pm0.67$	$2.80^{e}\pm0.10$	$2.30^{c}\pm0.10$	$10.33^{e}\pm0.15$	$77.45^{bc}\pm1.50$
DA95M5	$5.30^{f}\pm0.10$	$1.25^{de}\pm0.50$	$2.30^{f}\pm0.10$	$2.00^{f}\pm0.00$	$12.10^{a}\pm0.10$	$77.05^{cd}\pm0.25$
DA90M10	$6.20^{e}\pm0.00$	$1.40^{de}\pm0.00$	$2.80^{e}\pm0.00$	$2.47^{d}\pm0.57$	$11.60^{b}\pm0.00$	$75.53^{de}\pm0.25$
DC95M5	$8.40^{c}\pm0.00$	$3.05^{b}\pm0.50$	$3.40^{d}\pm0.20$	$2.20^{e}\pm0.00$	$9.30^{g}\pm0.10$	$73.65^{e}\pm0.57$
DC90M10	$9.30^{b}\pm0.00$	$3.20^{b}\pm0.00$	$4.20^{b}\pm0.00$	$2.70^{c}\pm0.10$	$9.00^{h}\pm0.00$	$71.60^{g}\pm4.40$
DB95M5	$7.20^{d}\pm0.20$	$2.55^{c}\pm0.05$	$2.50^{f}\pm0.10$	$2.47^{d}\pm0.05$	$10.80^{c}\pm0.00$	$74.48_{e}\pm0.30$
DB90M10	$9.10^{b}\pm0.30$	$2.80^{bc}\pm0.10$	$3.60^{c}\pm0.00$	$3.00^{b}\pm0.00$	$10.60^{d}\pm0.00$	$70.90^{f}\pm0.25$

Values are mean ±SD of 3 replications. Means within a column with the same superscripts were not significantly different (P>0.05). Key: DRC (D. rotundata control), DAC (D. alata control), DCC (D. cayenensis control) and DBC (D. bulbifera control), MRGA (moringa seed meal), DR95M5(95%D.rotundata&5%moringa seed meal), DR90M10(90%D.rotundata&10%moringa seed meal), DA95M5(95%D.alata&5% moringa seed meal), DA90M10(90%D.alata&10%moringa seed meal), DC95M5(95%D.cayenensis&5% moringa seed meal), DC90M10(90%D. cayenensis&10%moringa seed meal), DB95M5(95%D.bulbifera & 5%moringa seed meal), DB90M10(90%D.bulbifera&10%moringa seed meal

Table 2: Pasting Properties of Yam Flour, M*oringa* Seed Meal and the Blends

Samples	Peak viscosity (RVU)	Trough(RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	PeakTime (min)	Peak Tempt (°C)
DRC	$312.25^{a}\pm0.00$	$230.23^{a}\pm0.00$	80.24b±0.00	$380.23^{b}\pm0.00$	$143.22^{b}\pm0.00$	$6.11^{a}\pm0.00$	$82.20^{i}\pm0.00$
DAC	$185.34^{l}\pm0.00$	$163.23^{h}\pm0.00$	34.24g±0.00	$290.99^{i}\pm0.00$	$138.23^{d}\pm0.00$	$5.84^{f}\pm0.00$	$94.34^{b}\pm0.00$
DCC	$269.23^{f}\pm0.00$	$205.45^{e}\pm0.00$	66.17e±0.00	$372.12^{d}\pm0.00$	$148.80^{a}\pm0.00$	$5.81^{h}\pm0.00$	$93.00^{d}\pm0.00$
DBC	$260.50^{g}\pm0.00$	$197.23^{g}\pm0.00$	57.70f±0.00	$364.23^{ef}\pm0.00$	$140.77^{c}\pm0.00$	$5.90^{c}\pm0.00$	$93.94^{c}\pm0.00$
MRGA	$299.23^{c}\pm0.00$	$218.23^{c}\pm0.00$	71.22d±0.00	$368.45^{e}\pm0.00$	$67.23^{k}\pm0.00$	$5.89^{d}\pm0.00$	$86.56^{h}\pm0.00$
DR95M5	$257.23^{h}\pm0.00$	$197.23^{g}\pm0.00$	60.00f±0.00	$356.55^{f}\pm0,00$	$99.66^{e}\pm0.00$	$5.81^{h}\pm0.00$	$98.96^{a}\pm0.00$
DR90M10	$186.45^{l}\pm0.00$	$160.00^{i}\pm0.00$	26.09h±0.00	$279.99^{k}\pm0.00$	$93.66^{f}\pm0.13$	$5.98^{c}\pm0.00$	$94.56^{b}\pm0.00$
DA95M5	$200.12^{k}\pm0.00$	$162.12^{h}\pm0.00$	38.34g±0.00	$288.23^{j}\pm0.00$	$87.12^{h}\pm0.00$	$5.66^{j}\pm0.00$	$93.00^{d}\pm0.00$
DA90M10	$233.49^{i}\pm0.14$	$200.34^{f}\pm0.00$	32.89gh±0.00	$311.20^{g}\pm0.00$	$78.62^{ji}\pm0.00$	$5.87^{e}\pm0.00$	$92.09^{e}\pm0.00$
DC95M5	$288.27^{e}\pm0.12$	$211.22^{d}\pm0.00$	77.01c±0.00	$387.23^{a}\pm0.00$	$98.92^{ef}\pm0.00$	$5.67^{i}\pm0.00$	$86.98^{h}\pm0.00$
DC90M10	$221.27^{j}\pm0.12$	$149.12^{j}\pm0.00$	70.01de±0.00	$301.23^{h}\pm0.00$	$80.23^{i}\pm0.00$	$5.23^{k}\pm0.00$	$88.23^{f}\pm0.00$
DB95M5	$289.23^{d}\pm0.00$	$222.80^{b}\pm0.00$	87.23a±0.00	$379.00^{c}\pm0.00$	$91.23^{g}\pm0.00$	$5.82^{g}\pm0.00$	$87.01^{g}\pm0.00$
DB90M10	$301.22^{b}\pm0.00$	$221.98^{bc}\pm0.00$	78.97b±0.00	$377.98^{c}\pm0.00$	$75.91^{j}\pm0.00$	$6.01^{b}\pm0.00$	$82.88^{i}\pm0.00$

Values are mean ±SD of 3 replications. Means within a column with the same superscripts were not significantly different (P>0.05). Key: DRC (D. rotundata control), DAC (D. alata control), DCC (D. cayenensis control) and DBC (D. bulbifera control), MRGA (moringa seed meal), DR95M5(95%D.rotundata&5%moringa seed meal), DR90M10(90%D.rotundata&10%moringa seed meal), DA95M5(95%D.alata&5%moringa seed meal), DA90M1ly(90%D.alata&10%moringa seed meal), DC95M5(95%D.cayenensis&5% moringa seed meal), DC90M10(90%D. cayenensis&10%moringa seed meal), DB95M5(95%D.bulbifera & 5%moringa seed meal), DB90M10(90%D.bulbifera&10%moringa seed meal)

Table: 3 Functional Properties of Yam Flour, M*oringa* Seed Meal and the Blends

Samples	S.W(ml)	B.K(g/ml)	WAC(ml/g)	OAC(ml/g)	F.C (%)	F.S (%)	G.TEMP (°C)
DRC	$1.49^{d}\pm0.01$	$0.89^{b}\pm0.00$	$2.33^{e}\pm0.01$	$2.65^{b}\pm0.01$	$35.42^{a}\pm0.01$	$80.00^{e}\pm1.00$	$88.00^{b}\pm1.00$
DAC	$1.32^{e}\pm0.01$	$0.86^{c}\pm0.01$	$1.69^{j}\pm0.01$	$2.44^{b}\pm0.10$	$17.39^{ab}\pm0.01$	$78.00^{f}\pm0.00$	$84.00^{c}\pm1.00$
DCC	$1.82^{c}\pm0.01$	$0.88^{b}\pm0.01$	$2.09^{h}\pm0.01$	$2.95^{a}\pm0.01$	$12.50^{ab}\pm0.01$	$21.00^{j}\pm0.00$	$81.00\ ^{d}\pm1.00$
DBC	$2.01^{a}\pm0.01$	$0.94^{a}\pm0.01$	$2.33^{e}\pm0.01$	$2.96^{a}\pm0.01$	$17.76^{ab}\pm0.00$	$76.00^{g}\pm0.00$	$82.23^{d}\pm1.00$
MRGA	$1.28^{f}\pm0.01$	$0.81^{e}\pm0.01$	2.21 ± 0.01	$2.34^{cd}\pm0.00$	$29.79^{ab}\pm0.00$	$79.00^{e}\pm0.58$	0.00
DR95M5	$0.90^{k}\pm0.00$	$0.80^{e}\pm0.00$	$2.63^{b}\pm0.01$	$2.46^{bc}\pm0.00$	$7.84^{ab}\pm0.00$	$100.00^{a}\pm0.00$	$82.00^{d}\pm1.00$
DR90M10	$1.04^{h}\pm0.00$	$0.80^{e}\pm0.00$	$2.65^{a}\pm0.01$	$2.13^{f}\pm0.00$	$4.95^{bc}\pm0.00$	$100.00^{a}\pm0.00$	$84.00^{c}\pm1.00$
DA95M5	$0.93^{j}\pm0.01$	$0.77^{g}\pm0.00$	$2.29^{f}\pm0.01$	$2.02^{f}\pm0.01$	$12.88^{ab}\pm0.00$	$85.04^{i}\pm0.00$	$80.00^{e}\pm1.00$
DA90M10	$0.95^{i}\pm0.01$	$0.74^{h}\pm0.00$	$2.21^{g}\pm0.01$	$2.29^{cd}\pm0.01$	$10.00^{ab}\pm0.00$	$86.00^{d}\pm0.00$	$87.00^{b}\pm1.00$
DC95M5	$1.92^{b}\pm0.01$	$0.79^{f}\pm0.00$	$2.45^{d}\pm0.00$	$2.13^{f}\pm0.01$	$5.89^{b}\pm0.00$	$94.00^{b}\pm1.00$	$87.00^{b}\pm1.00$
DC90M10	$0.31^{l}\pm0.01$	$0.79^{f}\pm0.00$	$1.74^{i}\pm0.00$	$2.17^{e}\pm0.00$	$11.54^{ab}\pm0.00$	$99.67^{a}\pm0.58$	$87.00^{b}\pm1.00$
DB95M5	$1.33^{e}\pm0.01$	$0.83^{d}\pm0.0$	$2.50^{c}\pm0.01$	$2.12^{f}\pm0.001$	$33.61^{a}\pm0.51$	$58.00^{h}\pm0.00$	$90.00^{a}\pm1.00$
DB90M10	$1.06^{g}\pm0.01$	$0.85^{c}\pm0.00$	$2.49^{c}\pm0.00$	$2.31^{c}\pm0.46$	$3.92^{c}\pm0.01$	$92.00^{c}\pm0.00$	$90.00^{a}\pm1.00$

Values are mean ±SD of 3 replications. Means within a column with the same superscripts were not significantly different (P>0.05). Key: DRC (D. rotundata control), DAC (D. alata control), DCC (D. cayenensis control) and DBC (D. bulbifera control), MRGA (moringa seed meal), DR95M5(95%D.rotundata&5%moringa seed meal), DR90M10(90%D.rotundata&10%moringa seed meal), DA95M5(95%D.alata&5%moringa seed meal), DA90M10(90%D.alata&10%moringa seed meal), DC95M5(95%D.cayenensis&5% moringa seed meal), DC90M10(90%D. cayenensis&10%moringa seed meal), DB95M5(95%D.bulbifera & 5%moringa seed meal), DB90M10(90%D.bulbifera&10%moringa seed meal