View metadata, citation and similar papers at core.ac.uk brought to you by CORE

Hrana u zdravlju i bolesti, znanstveno-stručni časopis za nutricionizam i dijetetiku (2015) 4 (1) 48-58

PHYSICOCHEMICAL PROPERTIES OF STIFF DOUGH "AMALA" PREPARED FROM PLANTAIN (*MUSA PARADISCA*) FLOUR AND MORINGA *(MORINGA OLEIFERA)* LEAF POWDER

Olayinka Karim*[1], Rowland Kayode[1], Samson Oyeyinka*[1] and Adewumi Oyeyinka[2]

[1]University of Ilorin, Department of Home Economics and Food Science, PMB 1515, Ilorin Nigeria.
[2]Kwara State University, Department of Food, Agric and Bio-Engineering, PMB, 1530, Malete, Nigeria.

Summary
Plantains are a good source of resistant starch and are currently being used in the dietary management of diabetes when consumed in the unripe stage. They can be used in making *amala*, a stiff dough commonly consumed in some parts of Africa including Nigeria. The addition of fortificant to foods may affect product composition and functionality; therefore this study investigated the effect of *Moringa oleifera* leaf powder at varying concentrations (0, 0.5, 1.0, 1.5, 2.0 and 2.5 %) on pasting and functional properties of the fortified plantain flour. The proximate composition, mineral content and sensory properties of *amala* prepared from the fortified plantain flour were also determined. Protein and carbohydrate were the major components of plantain flour and *Moringa oleifera* leaf powder. Generally, water absorption capacity, bulk densities, swelling power and pasting properties of the fortified plantain flour decreased with increasing concentration of *Moringa oleifera* leaf powder. *Moringa oleifera* leaf powder seems to reduce hydration and swelling power of plantain flour. The protein contents of *amala* prepared from the fortified plantain flour significantly increased from 3.52 to 10.36%. Ash and fat contents of the *amala* also increased from 1.71-2.93% and 1.82 to 2.37% respectively. Similarly, the calcium, magnesium, potassium, sodium and iron contents of the *amala* also increased following the addition of *Moringa oleifera* leaf powder. The use of *Moringa oleifera* leaf powder thus has the potential to combat protein-energy malnutrition and micronutrient deficiencies in developing countries.

Keywords: *Amala*, *Moringa oleifera*, plantain flour, pasting, functional

Introduction

Plantain (*Musa paradisiacae*) is an important dietary source of carbohydrate in many parts of Africa, Asia and South America (Robinson, 1996; Falade and Olugbuyi, 2010). It is consumed mainly for its vitamins and minerals contents.
Plantains are usually harvested at a matured but unripe stage and ripens within 2-7 days (Falade and Olugbuyi, 2010). The high moisture content of plantain predisposes it to spoilage; hence it is dried to increase its shelf life. Plantain may be processed by frying, grilling, boiling and drying at different stages of maturity (Falade and Olugbuyi, 2010). Drying of plantain and subsequent milling into flour seems to be the most effective way of utilizing. The incorporation of plantain flour into foods has been encouraged due to its relatively high resistant starch content which has been recommended for dietary management of *diabetes mellitus* and other related disease (Eleazu et al. 2010; Eleazu et al. 2013).
Plantain flour can make good stiff dough called *amala* either singly or in combination with yam flour (Abulude and Ojediran, 2006). *Amala* is regarded as a starchy gel or stiff dough traditionally prepared from yam (Dioscorea spp) flour (Awoyale et al., 2010; Abiodun and Akinoso, 2014). It is prepared by reconstituting yam flour in boiling water until a dark smooth paste is formed (Karim et al., 2013). A similar paste with whiter appearance can however, be prepared from fermented cassava flour (Karim et al., 2013). *Amala* is majorly consumed in the South Western part of Nigeria (Abiodun and Akinoso, 2014) and some part of Ghana where it is called Kokonte (Jimoh and Olatidoye, 2009). According to Awoyale et al. (2010), *amala* contains

*Corresponding author: Olayinka Karim, (olayinkakarim@yahoo.com); Samson Oyeyinka (sartf2001@yahoo.com)

majorly carbohydrates and as a result does not provide adequate nutrients especially among rural dwellers. Efforts are therefore geared towards improving the nutritional value of such staples through the incorporation of legumes and other protein-rich plant foods. For example, supplementing yam flour with 35% distillers spent grain was reported to increase the protein content of yam by over 100% (Awoyale et al., 2010). Similarly, Jimoh and Olatidoye (2009) reported an increase in protein content from 3.16 to 18.21% for yam flour fortified with 30% soybean flour.

Consumers' awareness of the relationship between food, health and nutrition has spurred the need to develop foods with functional ingredients especially from plant materials such as *Moringa oleifera*. The leave of Moringa has been used as an alternative food source to combat malnutrition, especially among children and infants (Anwar et al., 2007). It contains substantial amounts of proteins (19-29%) (Jongrungruangchok et al., 2010) vitamins and minerals (Jongrungruangchok et al., 2010; Hekmat et al., 2015). These nutrients are known to scavenge free radicals when combined with a balanced diet and may have immunosuppressive effects (Danmalam et al., 2001). In Africa, the use of *Moringa Oleifera* as a food fortificant is on the increase. Many studies have reported the use of the leaves and flower in food applications such as in making soups (Babayeju et al., 2014), fortifying weaning foods (Arise et al., 2014), and in enriching yoghurt (Hekmat et al., 2015). Recently, the fortification of yam flour with *Moringa Oleifera* Leaf Powder (MOLP) at 2.5% level was reported to be sufficient to improve the proximate and mineral composition of yam flour without having any negative influence on the sensory properties (Karim et al., 2013). The addition of fortificant to foods may affect product composition and functionality. For instance, Jimoh and Olatidoye (2009), reported an increase in protein, ash and fat contents of yam flour fortified with soybean flour. However, the peak viscosity, water absorption capacity and swelling index of the fortified yam flour decreased significantly with increasing concentration of soybean flour. The use of *Moringa Oleifera* Leaf Powder to improve the nutritional composition of plantain flour has not been reported. Therefore, this study investigates the functional, pasting, proximate and sensory properties of *amala* prepared from plantain flour and *Moringa oleifera* leaf powder.

Materials and methods

Plant materials

Freshly harvested plantains were obtained from a farm in Ilorin, Nigeria. Dried *Moringa oleifera* leaves were obtained from University of Ilorin Agricultural commercial farms Ilorin, Nigeria.

Plantain flour

Plantation flour was prepared following the methods of Falade and Olugbuyi, (2010). Briefly, the fingers were removed, rinsed in clean water and peeled manually with knives. Peeled plantain were cut into slices, steamed for 15 min to inactivate enzymes and dried at 60^{o}C for 24 h in a hot air oven (D-37520, Thermo Fischer Scientific, South Africa). Dried plantain slices were milled in a Warring blender (HGBTWTS3, Torrington USA) and sieved (Sieve aperture size: 350 µm) into flour, sealed and used immediately for analysis.

Plantain flour-moringa leaf formulation

Moringa oleifera leaf powder (MOLP) was added to plantain flour in concentrations ranging from 0, 0.5, 1, 1.5, 2 and 2.5 % on dry weight basis. These levels of incorporation was adopted based on our previous studies on yam flour fortified with MOLP (Karim et al., 2013). A 2.5% level of MOLP to yam flour was found acceptable for making *amala*. Plantain flour without MOLP (0%) served as the control. Each sample contained 200 g of the plantain flour packaged in polythene bags.

Functional properties of raw and fortified plantain flour

Water absorption capacity

The water absorption capacity (WAC) of raw and fortified plantain flour was determined as described by Oyeyinka et al. (2013) with few modifications. Briefly, one gram of each sample was weighed into a dry, clean centrifuge tube. Water

(10 mL) was poured into the tube and properly mixed by vortexing. The suspension was allowed to stand for 30 min and centrifuged (Centrifuge Model: Ependorf 5810R, Germany) at 3,500×g for 30 min. Supernatant was discarded and the tube with its content reweighed. Gain in weight expressed, as a percentage of water bound, was calculated as the WAC of the sample.

Loose and Packed Bulk Density

A measuring cylinder (100 mL) was filled with flour to mark (100 mL), and the content weighed. The packed bulk density was also obtained by following the same procedure but tapping the side of the measuring cylinder several times until the flour volume was constant. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (g/mL) (Oyeyinka et al., 2013).

Swelling power

Swelling power of raw and fortified plantain flour was determined by methods described by Madruga et al.(2014) with slight modification. Briefly, flour samples (0.1 g starch in 10 ml of distilled water) were stirred and placed in a water bath for 30 min at 90°C with constant stirring. The suspension was centrifuged (Centrifuge model: Ependorf 5810R, Germany) at 3400×g for 20 min and the supernatant discarded. Swelling power was obtained by weighing the residue after centrifugation and dividing by original weight of flour on dry weight basis.

Pasting

Pasting characteristics of the plantain flours fortified with MOLP were determined using a Rapid Visco Analyser (Model RVA 3D; Newport Scientific, Narrabeen, NSW, Australia). Plantain flour (3 g) was weighed into a dried empty canister and 25 mL of distilled water was added. The mixture was thoroughly stirred, and the canister was fitted into the RVA as recommended. The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling was at a constant rate of 11.25°C min^{-1}. Peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer (Falade and Olugbuyi, 2010).

Preparation of amala

Amala was prepared by the method of Karim et al., (2013). Briefly, plantain flour was poured into boiling water with continuous stirring until a homogenous paste was formed. The paste was covered and left on the fire for about 5 min to cook. It was further stirred, packed and wrapped with thin labeled polythene wraps.

Proximate composition

Moisture, ash and fat contents of *Moringa oleifera*, plantain flour and *amala* were determined using standard methods (AOAC, 2000) The protein content was determined by kjeldahl method (N x 6.25) and total carbohydrate was calculated by difference.

Mineral composition

Amala sample were digested as described in Amonsou et al. (2014) and the mineral content analysed using Inductively Coupled Plasma Mass Spectrometry (ICP)-Mass spectrometer (Perkin-Elmer). Samples (0.5 g) were acid digested using 65% nitric acid. Digested samples solutions were then quantified against standard solutions of known concentrations.

Sensory evaluation

A 9- point hedonic preference scale and a multiple comparison test were used to assess the acceptability of *amala* made from plantain flour fortified with MOLP using 50 trained panelists. Panelists were selected from student of the Department of Home Economics and Food Science, University of Ilorin, Nigeria. The selected students were those accustomed to eating *amala*. Prior to the sensory analysis, they were screened with respect to their interest and ability to differentiate food sensory properties. The samples were evaluated for colour, aroma, mouldability, consistency, mouth feel and overall acceptability.

Statistical analysis

All experiments were conducted in duplicate. Data were analysed using analysis of variance (ANOVA) and means were compared using Fischer’s Least Significant Difference Test ($p<0.05$).

Results and discussion

Proximate and mineral composition of *Moringa oleifera* leaves and plantain flour

Protein and carbohydrate were the major components of *Moringa oleifera* leaves and plantain flour (Table 1). The protein (24.55%) and ash (6.52%) contents of *Moringa oleifera* leaves were higher than those of plantain flour (protein: 3.54%, ash: 1.76%). Similar composition have been reported for *Moringa oleifera* leaves (Jongrungruangchok et al., 2010) and plantain flour (Akubor et al., 2003; Zakpaa et al., 2010).
The calcium and potassium contents of Moringaoleifera leaves and plantain flour were very high whiletheir sodium and iron contents were low (Table 2). Plantain flour had lower (approx. 5 times) magnesium content compared to the Moringaoleifera leaves.. The potassium content of plantain flour was however higher than for *Moringa oleifera* leaves. Sodium and iron contents of both *Moringa oleifera* leaves and plantain flour were very low. However, the iron content of *Moringa oleifera* leaves was substantially higher than for plantain flour.

Table 1. Proximate composition of Moringa oleifera leaves and plantain flour (%)[1]

Samples	Moisture	Protein	Fats	Ash	Carbohydrate
Moringa leaves	10.11±0.02	24.55±0.02	2.48±0.01	6.52±0.01	56.34±0.01
Plantain flour	6.01±0.04	3.54±0.02	1.86±0.01	1.76±0.01	80.07±0.01

[1]Mean ± SD. Values are expressed on dry weight basis

Table 2. Mineral composition of *Moringa oleifera* leaves and plantain flour (mg /100 g)[1]

Samples	Calcium	Potassium	Magnesium	Sodium	Iron
Moringa leaves	2480.31±0.02	1782.15±0.01	448.23±0.01	26.52±0.01	26.34±0.01
Plantain flour	193.06±0.04	4658.36±0.02	94.43±0.01	46.20±0.01	2.40±0.01

[1]Mean ± SD.Values are expressed on dry weight basis

Functional properties of plantain flour fortified with MOLP

The water absorption capacity (WAC) of the plantain flour decreased from 1.11 to 0.77 g water/ g flour with increasing concentration of Moringa oleifera leaf powder (MOLP) (Figure 1). Although the WAC of the fortified plantain flour decreased, the decrease was not very substantial. Variation in the WAC of flours has been suggested to depend on differences in the granule structure and the degrees of availability of the water binding sites among the flours (Wootton and Bamunuarachchi, 1978). The added MOLP thus, may have partially blocked the sites available for water binding thereby reducing the amounts of water absorbed by the plantain flour. Akubo et al. (2003) also reported a reduction in water absorption capacity of plantain flour following the addition of cowpea (Vigna unguiculata) flour.
The loose and packed bulk densities of plantain flour did not vary significantly ($p\leq.05$) when MOLP was added (Figure 1). The loose bulk density varied from 0.53 to 0.54 g/mL, while packed bulk density varied from 0.72 to 0.78 g/mL. Expectedly, the packed bulk density of both fortified plantain flour and the control were higher than their loose bulk density. The slight decrease in loose and packed bulk densities of the fortified plantain flours suggest that the requirements for packaging these flours will not change significantly, but rather it will allow the use of a more economical package (Osundahunsi and Aworh, 2002). The LBD and PBD of the fortified plantain flour is within the range reported by previous authors for plantain flour (Falade and Olugbuyi, 2010; Falade and Oyeyinka, 2014).

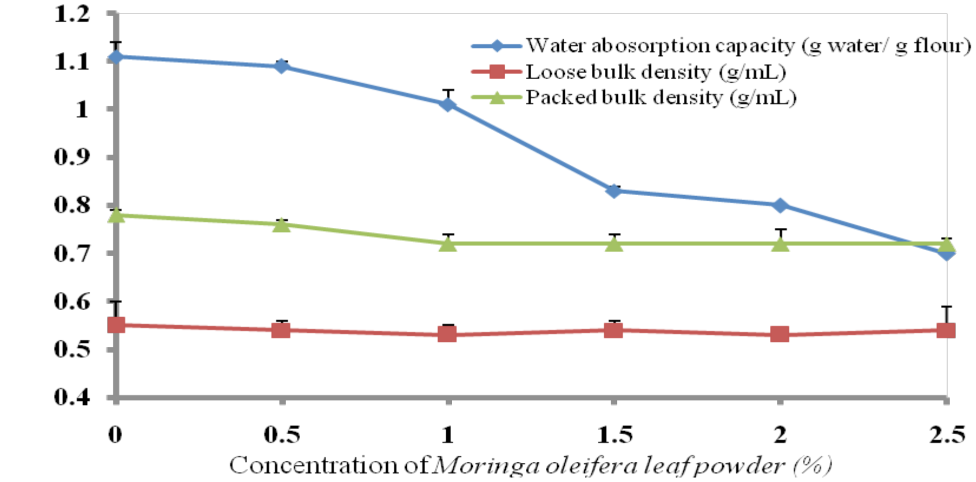


Figure 1. Water absorption capacity and bulk densities of plantain flour fortified with MOLP

The swelling ability of plantain flour in water was not significantly ($p<0.05$) affected by MOLP (Figure 3). A reduction from 6.78 to 6.70 g water per g flour was recorded following the addition of MOLP. MOLP may possibly have covered starch granule surface slightly restricting hydration and swelling. Swelling of flour is an important phenomenon that aids paste formation. Similar reduction in swelling power following the addition of soybean to plantain flour has been reported (Abioye et al., 2011).

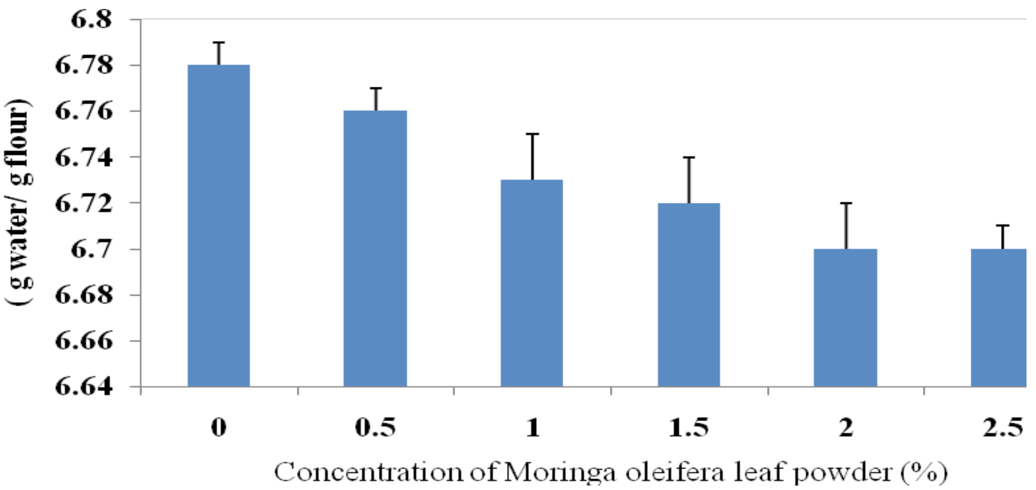
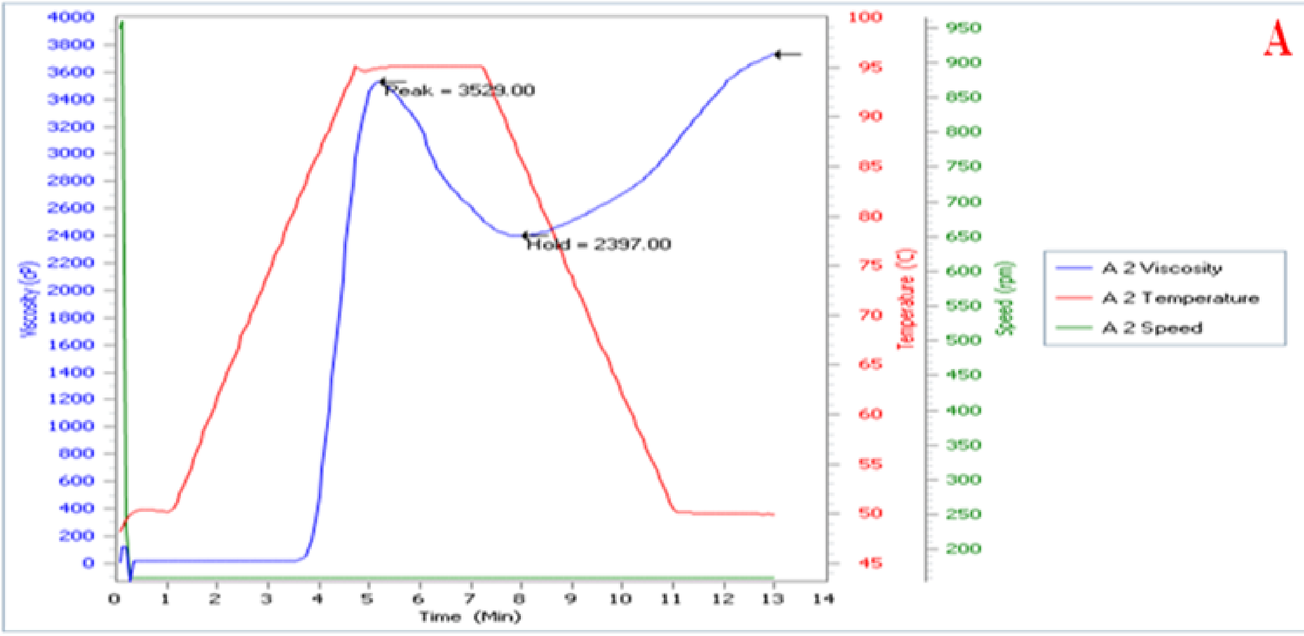


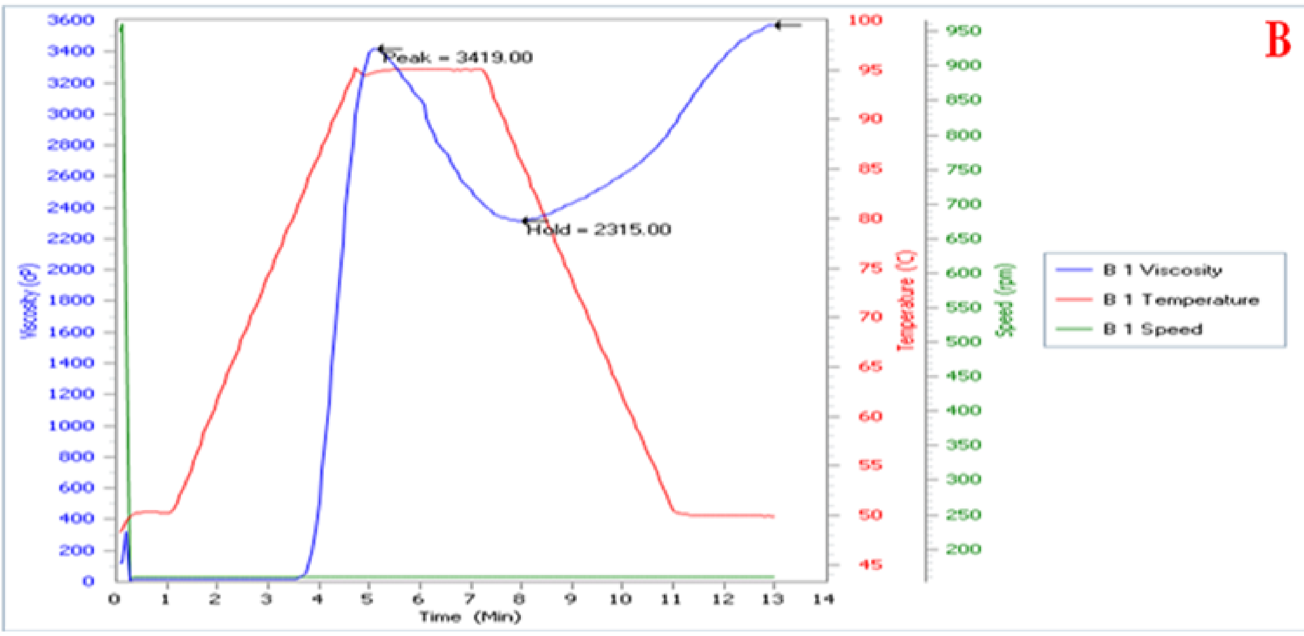
Figure 2. Swelling power of plantain flour fortified with MOLP

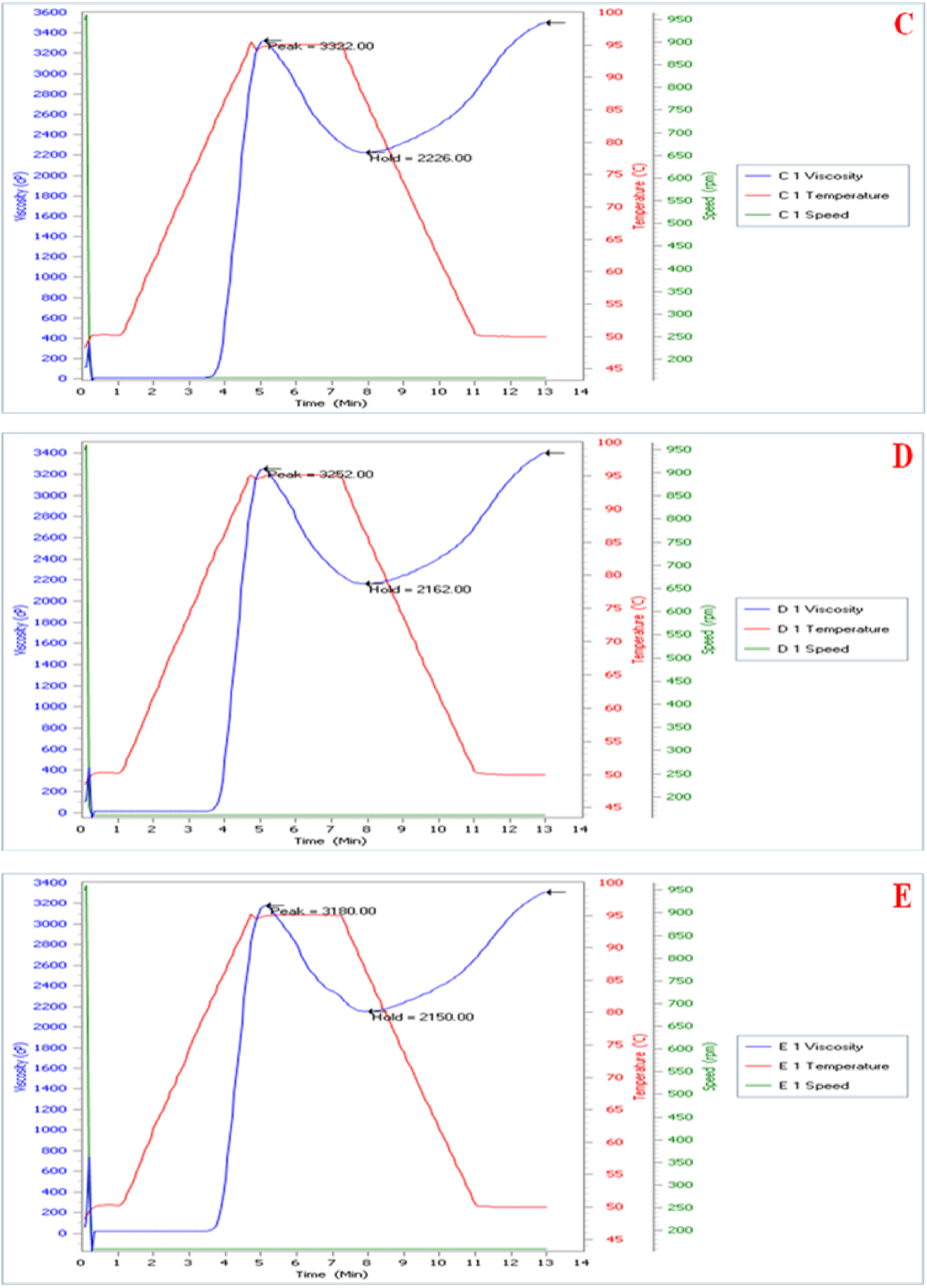
Pasting properties of plantain flour fortified with MOLP

Plantain flour without MOLP (A) had higher peak (3551.00 RVU), trough (2425.50 RVU), breakdown (1125.50 RVU) and final (3771.00 RVU) viscosities compared to the fortified plantain flours (Figure 3). A slight, but progressive decrease in these viscosities was observed with increasing concentration of MOLP. The slight reduction in peak viscosities of plantain flour confirms the minimal change in swelling behaviour (Figure 2) and water absorption capacities (Figure 1). The addition of MOLP did not significantly change the pasting properties of the plantain flour. With the addition of 2.5% MOLP, the peak viscosity of the plantain flour decreased by approximately 8%. Jimoh and Olatidoye (2009) reported a higher decrease (approx. 17%) in peak viscosity for yam flour fortified with 10% soybean flour. Similarly, approximately 19% decrease in peak viscosity was reported for plantain flour fortified with soybean flour (Abioye et al., 2011). The higher decrease in peak viscosity reported by the above authors may be attributed to the higher concentration of the fortificant (soybean) used.

The slight reduction in the final viscosities of the fortified plantain flour, in this study may be advantageous in the preparation of the stiff dough 'amala', since the energy required to create shear may be reduced. Set back viscosity which measures tendency for syneresis of starch upon cooling also decreased with the addition of MOLP. It seems that MOLP interacted with the starch component of the plantain flour during pasting causing a slight decrease in the set back value. High set back value has been associated with higher tendency for retrogradation especially during storage. MOLP fortified amala, thus, will be more stable than the unfortified sample especially when the product is not consume immediately after preparation. Although, the time to peak and pasting temperature also decreased with increasing concentration of MOLP, the decrease was not very significant. Higher pasting temperatures have been attributed to the presence of resistant starch (Maninder et al., 2007).






C
Peak = 3322.00
Hold = 2226.00
C 1 Viscosity
C 1 Temperature
C 1 Speed
Viscosity (cP)
Temperature (°C)
Speed (rpm)
Time (Min)
D
Peak = 3252.00
Hold = 2162.00
D 1 Viscosity
D 1 Temperature
D 1 Speed
E
Peak = 3180.00
Hold = 2150.00
E 1 Viscosity
E 1 Temperature
E 1 Speed

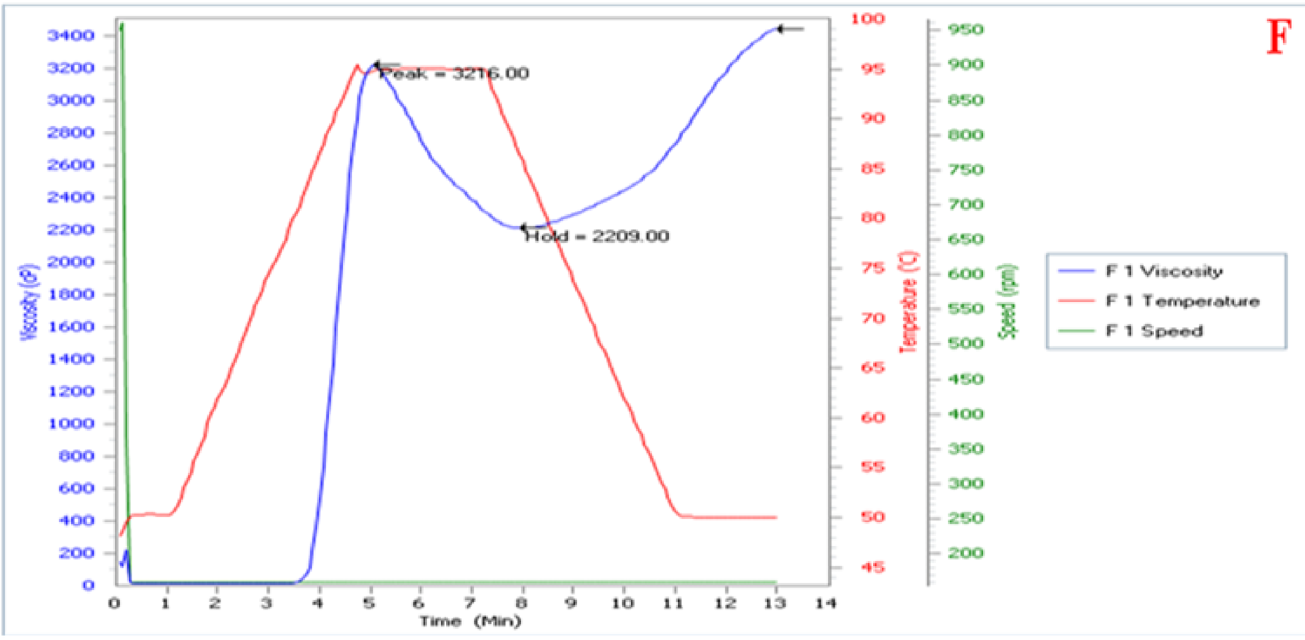


Figure 3. Pasting curves of plantain flour fortified with MOLP

A= Plantain flour amala without MOLP
B= Plantain flour amala fortified with 0.5% MOLP
C= Plantain flour amala fortified with 1.0% MOLP
D= Plantain flour amala fortified with 1.5% MOLP
E= Plantain flour amala fortified with 2.0% MOLP
F = Plantain flour amala fortified with 2.5% MOLP

Proximate composition of amala prepared from plantain flour fortified with MOLP

Stiff dough (amala) prepared from plantain flour fortified with MOLP had higher protein (6.64-10.36%), ash (2.11-2.93) and fat (1.95-2.37%) contents compared to amala without MOLP (Table 3). However, the moisture and carbohydrate content of amala prepared from fortified plantain flour were lower than the control. Amala fortified with MOLP at 2.5% showed significantly higher protein (approx 3 times) and ash (approx. 1.7 times) contents compared to the control. The increase in protein of the amala following the addition of MOLP may be associated with the higher protein content of Moringa oleifera leaves (Table 1). Previous studies by Karim et al. (2013) similarly reported increase in protein content of amala prepared from yam flour fortified with MOLP. However, the protein content of plantain amala fortified with 2.5% MOLP in this study was higher (1.6 times) compared to those reported for MOLP fortified yam flour amala (Karim et al., 2013). The differences in protein content may be attributed to higher protein content of plantain flour compared to yam flour.

Table 3. Proximate composition of amala prepared from plantain flour fortified with MOLP (%)

Samples	Moisture	Protein	Fats	Ash	Carbohydrate
$PFAM_0$	$74.29^{ab}\pm0.00$	$3.52^{a}\pm0.03$	$1.82^{a}\pm0.04$	$1.71^{a}\pm0.00$	$18.66^{d}\pm0.01$
$PFAM_{0.5}$	$74.26^{ab}\pm0.10$	$6.64^{b}\pm0.02$	$1.95^{a}\pm0.01$	$2.11^{b}\pm0.00$	$15.04^{bc}\pm0.03$
$PFAM_{1.0}$	$72.29^{a}\pm0.02$	$8.51^{c}\pm0.00$	$2.12^{b}\pm0.04$	$2.71^{bc}\pm0.02$	$14.37^{b}\pm0.03$
$PFAM_{1.5}$	$72.14^{a}\pm0.04$	$8.71^{d}\pm0.10$	$2.02^{b}\pm0.04$	$2.79^{bc}\pm0.04$	$14.34^{b}\pm0.02$
$PFAM_{2.0}$	$70.29^{a}\pm0.05$	$10.21^{e}\pm0.02$	$2.06^{b}\pm0.20$	$2.71^{bc}\pm0.04$	$14.73^{b}\pm0.03$
$PFAM_{2.5}$	$70.36^{a}\pm0.04$	$10.36^{e}\pm0.04$	$2.37^{c}\pm0.02$	$2.93^{bc}\pm0.04$	$13.98^{a}\pm0.06$

Mean ± SD. Mean with different superscript along a column are significantly different ($p<0.05$).
PFAM0= Plantain flour amala without MOLP
PFAM0.5= Plantain flour amala fortified with 0.5% MOLP
PFAM1.0= Plantain flour amala fortified with 1.0% MOLP
PFAM1.5= Plantain flour amala fortified with 1.5% MOLP
PFAM2.0= Plantain flour amala fortified with 2.0% MOLP
PFAM2.5 = Plantain flour amala fortified with 2.5% MOLP

Mineral composition of amala prepared from plantain flour fortified with MOLP

Generally, the mineral content of the amala increased with increase in MOLP, which may be attributed to high contents of these minerals in the leaves (Table 2). Calcium and potassium were the major minerals in the prepared amala, while magnesium, sodium and iron were relatively low (Table 4). Calcium contents of the amala increased from 190.03 to 254.42 mg/100 g, magnesium, from 4612.10 to 4915.10 mg/100 g, potassium from 94.06 to 132.04 mg/100 g, sodium from 45.11 to 54.12 mg/100 g and iron contents increased from 2.43 to 3.29 mg/100 g. Previous studies on amala prepared from yam flour similarly reported increase in mineral content following the addition of MOLP (Karim et al., 2013). However, the increase in mineral composition in this study was much higher than those reported by these authors, possibly due to the higher mineral content of the plantain flour.

Table 4. Mineral contents of amala prepared from plantain flour fortified with MOLP (mg/100 g)

Samples	Calcium	Potassium	Magnesium	Sodium	Iron
PFAM0	$190.03^{a}\pm0.03$	$4612.10^{a}\pm0.02$	$94.06^{a}\pm0.23$	$45.11^{a}\pm0.14$	$2.43^{a}\pm0.02$
PFAM0.5	$204.12^{b}\pm0.06$	$4672.02^{a}\pm0.00$	$102.71^{b}\pm0.12$	$46.71^{a}\pm0.23$	$2.67^{a}\pm0.05$
PFAM1.0	$224.20^{b}\pm0.14$	$4742.12^{a}\pm0.01$	$105.04^{b}\pm0.11$	$52.71^{b}\pm0.14$	$2.72^{a}\pm0.04$
PFAM1.5	$245.13^{b}\pm0.03$	$4743.02^{a}\pm0.12$	$123.36^{c}\pm0.22$	$50.79^{b}\pm0.24$	$2.86^{bc}\pm0.12$
PFAM2.0	$248.29^{b}\pm0.12$	$4812.21^{ab}\pm0.14$	$129.33^{c}\pm0.32$	$53.71^{b}\pm0.02$	$2.88^{bc}\pm0.03$
PFAM2.5	$254.42^{b}\pm0.12$	$4945.10^{ab}\pm0.03$	$132.04^{cd}\pm0.12$	$54.12^{b}\pm0.20$	$3.29^{c}\pm0.04$

Mean ± SD. Mean with different superscript along a column are significantly different (p<0.05).
PFAM0= Plantain flour amala without MOLP
PFAM0.5= Plantain flour amala fortified with 0.5% MOLP
PFAM1.0= Plantain flour amala fortified with 1.0% MOLP
PFAM1.5= Plantain flour amala fortified with 1.5% MOLP
PFAM2.0= Plantain flour amala fortified with 2.0% MOLP
PFAM2.5 = Plantain flour amala fortified with 2.5% MOLP

Sensory properties of amala prepared from plantain flour fortified with MOLP

Amala prepared from the unfortified plantain flour, which served as the control had the highest rating for colour, aroma, mouldability, consistency, mouthfeel and overall acceptability compared to the fortified amala (Table 5). With the exception of amala prepared from plantain flour with 2.5% MOLP, the ratings for overall acceptability of the fortified samples were comparable to the control. The colour rating for amala with 2.5% MOLP was very low. This may be attributed to the colouration of the amala by chlorophyll from the MOLP which may have masked the colour of the amala as previously reported (Karim et al., 2013). Karim et al. (2013) reported that 2.5% level of MOLP to yam flour was sufficient for making amala with acceptable qualities. Our finding agree with previous reports by Karim et al. (2013) who suggested the use of MOLP at 2.5% as sufficient to improve the proximate and mineral composition of yam flour amala without having significant effect on the sensory properties.

Table 5. Mean sensory scores of amala prepared from plantain flour fortified with MOLP

Samples	Colour	Aroma	Mouldability	Consistency	Mouth feel	Overall Acceptability
PFAM0	7.29c±0.01	7.86d±0.02	6.86c±0.03	6.71c±0.04	7.43c±0.02	7.64bc±0.02
PFAM0.5	5.36b±0.12	6.64c±0.00	5.71bc±0.02	5.71b±0.03	6.50bc±0.05	6.89b±0.01
PFAM1.0	5.29b±0.01	5.71b±0.01	6.00c±0.01	5.71b±0.04	5.86b±0.04	6.93b±0.02
PFAM1.5	5.93b±0.03	5.71b±0.12	5.36bc±0.02	5.79b±0.04	5.00b±0.12	6.09b±0.03
PFAM2.0	5.29b±0.04	5.21b±0.14	5.36bc±0.02	5.71b±0.02	6.36cbc±0.03	6.07b±0.04
PFAM2.5	3.36a±0.06	4.36a±0.03	4.57a±0.02	3.93a±0.00	4.21a±0.04	5.90a±0.05

Mean ± SD. Mean with different superscript along a column are significantly different (p<0.05).

PFAM0= Plantain flour amala without MOLP
PFAM0.5= Plantain flour amala fortified with 0.5% MOLP
PFAM1.0= Plantain flour amala fortified with 1.0% MOLP
PFAM1.5= Plantain flour amala fortified with 1.5% MOLP
PFAM2.0= Plantain flour amala fortified with 2.0% MOLP
PFAM2.5 = Plantain flour amala fortified with 2.5% MOLP

Conclusions

The addition of Moringa oleifera leaf powder to plantain flour improves the nutritional quality of stiff dough without substantial changes in the functional properties. The use of Moringa oleifera leaf powder thus has the potential to combat protein-energy malnutrition and micronutrient deficiencies in developing countries. However, the effect of Moringa oleifera leaf powder on digestibility may be a subject of further research. Further, the effect of the Moringa leaf on storage stability of the flours may also be investigated.

References

Abiodun, O., and Akinoso, R. (2014): Textural and sensory properties of trifoliate yam (Dioscorea dumetorum) flour and stiff dough 'amala'. J. of Food Sci. and Technol., 52 (5): 2894-2901.

Abioye, V., Ade-Omowaye, B., Babarinde, G., and Adesigbin, M. (2011): Chemical, physico-chemical and sensory properties of soy-plantain flour. Afr. J. of Food Sci., 5(4), 176-180.

Abulude, F. O., and Ojediran, V. A. (2006): Development and quality evaluation of fortified 'amala'. Acta Sci. Pol., Technol. Aliment, 5(2), 127-134.

Akubor, P. I., Adamolekun, F. O., Oba, C. A., Obari, H., and Abudu, I. O. (2003): Chemical composition and functional properties of cowpea and plantain flour blends for cookie production. Plant Foods for Hum Nutri., 58(3), 1-9.

Amonsou, E. O., Siwela, M., and Dlamini, N. (2014): Chemical composition and microstructure of Bauhinia grains. J. of Food Sci. and Technol., 51(9), 2263-2269.

Anwar, F., Latif, S., Ashraf, M., and Gilani, A. H. (2007): Moringa oleifera: a food plant with multiple medicinal uses. Phytotherapy Res., 21(1), 17-25.

AOAC. (2000): Official methods of analysis (17th ed.). Washington DC: Association of official Analytical Chemists.

Arise, A., Arise, R., Sanusi, M., Esan, O., and Oyeyinka, S. (2014): Effect of Moringa oleifera flower fortification on the nutritional quality and sensory properties of weaning food. Croatian J. of Food Sci. and Technol., 6(2), 65-71.

Awoyale, W., Maziya-Dixon, B., Sanni, L., and Shittu, T. A. (2010): Nutritional and sensory properties of amala supplemented with distiller's spent grain (DSG). J. of Food, Agric. & Environ., 8(3&4), 66-70.

Babayeju, A., Gbadebo, C., Obalowu, M., Otunola, G., Nmom, I., Kayode, R., Toye, A., and Ojo, F. (2014): Comparison of Organoleptic Properties of Egusi and Efo Riro Soup Blends Produced with Moringa and Spinach Leaves. Food Sci. and Quality Management, 28, 15-18.

DanMalam, H., Abubakar, Z., and Katsayal, U. (2001): Pharmacognosostic studies on the leaves of Moringa Oleifera Nig. J. of Natural Products and Med., 5(1), 45-49.

Eleazu, C., Okafor, P., and Ahamefuna, I. (2010): Total antioxidant capacity, nutritional composition and inhibitory activity of unripe plantain (Musa paradisiacae) on oxidative stress in alloxan induced diabetic rabbits. Pakistan J. Nutr., 9, 1052-1057.

Eleazu, C. O., Okafor, P. N., Amajor, J., Awa, E., Ikpeama, A. I., and Eleazu, K. C. (2013): Chemical composition, antioxidant activity, functional properties and inhibitory action of unripe plantain (M. Paradisiacae) flour. Afr. J. of Biotechnol., 10(74), 16937-16947.

Falade, K. O., and Olugbuyi, A. O. (2010): Effects of maturity and drying method on the physico□chemical and reconstitution properties of plantain flour. Int. J. of Food Sci. & Technol., 45(1), 170-178.

Falade, K. O., and Oyeyinka, S. A. (2014): Color, Chemical and Functional Properties of Plantain Cultivars and Cooking Banana Flour as Affected by Drying Method and Maturity. J. of Food Process. and Preserv. doi:10.1111/jfpp.12292.

Hekmat, S., Morgan, K., Soltani, M., and Gough, R. (2015): Sensory Evaluation of Locally-grown Fruit Purees and Inulin Fibre on Probiotic Yogurt in Mwanza, Tanzania and the Microbial Analysis of Probiotic Yogurt Fortified with Moringa oleifera. J. Health Popul Nutr., 33(1), 60-66.

Jimoh, K., and Olatidoye, O. (2009): Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. J. of Applied Biosci., 13, 703-706.

Jongrungruangchok, S., Bunrathep, S., and Songsak, T. (2010): Nutrients and minerals content of eleven different samples of Moringa oleifera cultivated in Thailand. J Health Res., 24(3), 123-127.

Karim, O. R., Kayode, R. M. O., Adeoye, O. S., and Oyeyinka, A. T. (2013):Proximate, Mineral and Sensory Qualities of 'Amala'Prepared from Yam flour fortified with Moringa leaf powder. Food Sci. and Quality Management, 12, 10-22.

Madruga, M. S., de Albuquerque, F. S. M., Silva, I. R. A., do Amaral, D. S., Magnani, M., and Queiroga Neto, V. (2014): Chemical, morphological and functional properties of Brazilian jackfruit (Artocarpus heterophyllus L.) seeds starch. Food Chem., 143, 440-445.

Maninder, K., Sandhu, K. S., and Singh, N. (2007): Comparative study of the functional, thermal and pasting properties of flours from different field pea (Pisum sativum L.) and pigeon pea (Cajanus cajan L.) cultivars. Food Chem., 104(1), 259-267.

Osundahunsi, O. F., and Aworh, A. C. (2002): A preliminary study on the use of tempe-based formula as a weaning diet in Nigeria. Plant foods for human nutrition, 57(3-4), 365-376.

Oyeyinka, S., Oyeyinka, A., Karim, O., Kayode, R., Balogun, M., and Balogun, O. (2013): Quality attributes of weevils (Callosobruchus maculatus) infested cowpea (Vigna unguiculata) products. Nig. J. of Agric, Food and Environ, 9 (3), 16-22.

Robinson, J. (1996): Bananas and plantains, crop production science in horticulture 5. CAB International, Wallingford.

Wootton, M., and Bamunuarachchi, A. (1978): Water binding capacity of commercial produced native and modified starches. Starch□Stärke, 30(9), 306-309.

Yameogo, C. W., Bengaly, M. D., Savadogo, A., Nikiema, P. A., and Traore, S. A. (2011): Determination of chemical composition and nutritional values of Moringa oleifera leaves. Pakistan J.of Nutr., 10(3), 264-268.

Zakpaa, H., Mak-Mensah, E., and Adubofour, J. (2010): Production and characterization of flour produced from ripe "apem" plantain (Musa sapientum L. var. paradisiacal; French horn) grown in Ghana. J. Agric. Biotech. Sustainable Develop., 2(6), 92-99.