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Full Length Research Paper

Mango doughnuts technology process for innovative prevention of post-harvest loss of mango fruits in Burkina Faso

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The present study involved the processing and testing of two formulations of mango doughnuts. The mango pulp formulations were combined either with maize or rice flour. The dough from both formulations was fried in immersion oil using a gas-fueled fritter and a crepe maker in controlled conditions. Levels of moisture, titrable acidity, total ash, fat, proteins, total sugars and beta-carotene were determined for the dough and for the mango doughnuts by using physicochemical standard methods. Sensory evaluation of the end-products with respect to aroma, color, taste and texture were performed. Results showed that the moisture contents of mango doughnuts obtained using the gas fryer which contained maize (DMMgf) or rice (DMRgf) flour were significantly lower than the same formulations obtained using the crepe maker (DMMcm, DMRcm). The highest fat contents for the DMRgf and DMMgf doughnuts were 25.34 and 29.78%, respectively. The beta-carotene contents of the doughnuts fried with the crepe maker (110.32 and 107.92 µg/100 g) were significantly higher than those doughnut fried with the gas fryer (90.91 and 85.49 µg/100 g). The yellow color of the DMRcm formulation was found to be very attractive by 70% of the tasters. In contrast, the DMMcm sample was found to be fairly attractive by 56.70% of the tasters. This method of processing mangos into doughnuts is convenient, requiring only common household equipment. The product is an innovative way of utilizing and adding value to over-ripe mango fruit, to reduce post-harvest loss and increase food and nutrition security.

Key words: *Mangifera indica*, mango doughnuts, sensory analysis, nutritional characteristics, Burkina Faso.

INTRODUCTION

In Burkina Faso, mango (*Magifera indica* L.) trees produce about 337,101 metric tons of fruits per year (CEFCOD, 2013). Since mango is a climacteric fruit, post-harvest losses are estimated to be between 30 and 40% (PAFASP, 2011). Different methods of processing mango fruit are practiced in artisanal, small and medium

enterprises such as DAFANI in Burkina Faso. Mango fruit products include mango juice, dried mango, jam etc. The most common and widely used form of processing is dried mango (Kanté-Traoré et al, 2017). Dried products are commercialized and consumed around the world. However, the drying process needs specialized equipment such as solar dryers or gas dryers, which are not easily available to individuals. Frying could be an alternative way of processing mango for diversifying mango preservation. An advantage of this process, in relation to sensory appeal for consumers, is that it generates complex products with crisp textures which are also rich in flavors. These characteristics are responsible for the success of fried products around the world (Banks, 1996; Gonzalez., 2007; Mestdagh et al., 2008). Fried products of animal origin are the most common. Fried products of vegetable origin are those based on starchy items such as potatoes (Moreira et al., 1999). Fried products of fruit origin come mainly from plantain bananas; these include "fufu", plantain chips, "alloko", doughnuts as “cracro”, cakes and pancakes made from plantain flour (Eggleston et al., 1991; N’daAdopo, 1993; Rojas-Gonzalez, 2007; Planta Innovation, 2011; Bikoï et al., 2012.; Fongang Fouepe et al., 2016). Several studies describing chip processing, based on local potato varieties are available in several countries such as Nigeria and Côte d'Ivoire (Ogazi, 1987; Onyejegbu and Orolunda, 1995; Diaz et al., 1996; Vitrac and Raoult-Wack, 2002). However, studies of fried products based on mango have not been previously described. The present study looks at an innovative process for transforming mango pulp into doughnuts using local cereal flours. It adds to our knowledge about product diversification for mangos, which may contribute to a reduction in post-harvest losses of this climacteric fruit. Adoption of doughnut production at both the household and commercial level would help reduce the enormous post-harvest losses of mango and contribute to food and nutritional security.

MATERIALS AND METHODS

Plant materials

Fresh mango (*Mangifera indica* L.) of the Keitt variety was purchased from the local fruit market in
Ouagadougou, in July 2016. The fruits, at physiological maturity, were kept at room temperature for ripening under natural conditions.

Rice kernels (*Oryza sativa* L.) of the TS2 variety, originating from Taiwan, were obtained. This variety has been introduced to Burkina Faso since 2002 and has been improved upon by the National Institute for Environment and Agricultural Research (INERA). Currently, the TS2 variety is grown in lowlands, either rain-fed or with irrigation. For the purposes of this study, 10 kg of the TS2 variety was purchased at one of the outlets in the city of Ouagadougou.

Maize kernels (*Zea mays*) of the Espoir variety used were from the maize, originating from INERA's varietal selection. Kernels (10 kg) were purchased at the INERA depository in Bobo-Dioulasso.

Preparation of the raw material

Once the purchased mangoes reached gustative maturity, they were sorted, weighed and washed with tap water. They were then wiped, hand-peeled and the seed removed. The pulp obtained was blended using a mixer, weighed, packaged in food bags and stored in the freezer at -20°C.

The maize or rice kernels were washed and dried for 24 h at room temperature at the technopole workshop. Kernels were then ground using a disc mill (Metro Expoters Pvt. LTD, India). The resulting flour was left to cool at room temperature for 10 min and then sieved through a 250µm pore. The flour was then packaged, sealed in food bags and stored in plastic bins in a dry, clean room at room temperature (25°C). The flours were used within one week after initial storage.

Formulation of the mango dough

Formulation of the dough involved measuring the required proportions of raw materials and ingredients, then mixing them to produce the dough for the mango doughnuts. Eight formulations were prepared in two batches. The first batch consisted of mango pulp, wheat or maize flour, sweet potato (orange flesh) or rice flour, and eggs, in proportions of 76:20:4. For the second batch, the same ingredients were used by the proportions 81:15:4. The doughnuts produced from these dough formulations were then subjected to sensory analysis tests. The results of this test showed that the dough formulations that produced doughnuts with the best acceptance were those obtained using mango pulp with maize flour, and mango pulp with rice flour, both containing 4% eggs.Thus, the rest of the study focused on these two formulations as shown in Table 1.

Mango doughnuts processing

The raw material (mango pulp) and ingredients (maize/rice flour and eggs) were mixed in a kneader (Panasonic MK-GB1, China) for 10 min.

The dough obtained was then fried in refined palm oil (Dinor, Sania Cie) using either a gas fryer or a crepe maker (Geepas GPS-1382) according to the diagram summarized in Figure 1. The doughnuts were fried by two methods: i) immersed in a gas fryer at 155°C for 10 min, and ii) using an electric crepe maker at 135°C for 5 min, with a controlled quantity of oil (Figure 1). A sensory evaluation was carried out on the doughnuts with the crepe maker to test the acceptability of this new product by the consumers.

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Table 1. Formulations of mango dough.

Ingredients	Formulation I	Formulation II
	Mango pulp/ Maize flour (MM)	Mango pulp/ Rice flour (MR)
Mango pulp (%)	81	81
Maize flour (%)	15	-
Rice flour (%)	-	15
Egg(%)	4	4
Total	**100**	**100**

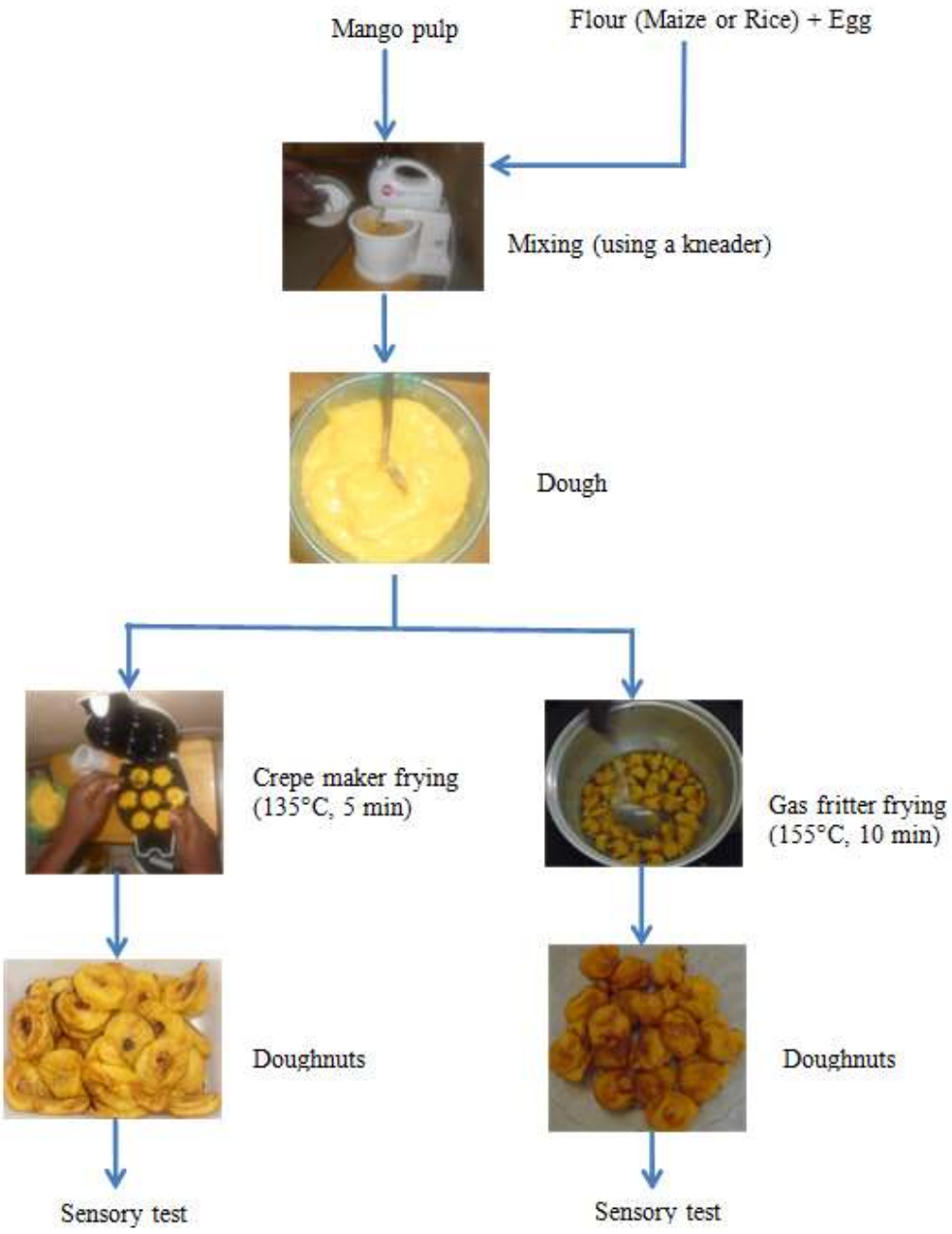

Figure 1. Diagram of mango doughnuts processing.

Doughnuts sampling for analysis

Two samples of each produced dough and mango doughnuts were stored in an airtight bottle in a freezer at -20°C for physico-chemical analysis at a later date.

The sensory evaluation was conducted on freshly-prepared doughnuts, within three hours of preparation.

Physico-chemical analyses

The moisture contents of samples of the different products were determined using to AFNOR standard method.

The titrable acidity expressed as citric acid equivalent was performed by titrating 5 g of mango dough and doughnuts using 0.1 N NaOH as described by AFNOR (1986). The total ash was determined according to the ISO 2171 (2007) method.

The fat was extracted in triplicate with Sohxlet apparatus according to ISO 659 (1998) method. Thereafter, 5 g of dried mango doughnuts were weighed and extracted in n-hexane for 4 h. After extraction, the solvent was evaporated with a Rotavapor. The flask containing the lipids and the traces of the solvent was placed in an oven at 105°C for 1 h, cooled in a desiccator for 30 min and then weighed. The total protein content was determined in triplicate by Kjeldalh method according to the French standard V03-050 (1970) method.

The total sugar content was estimated using a colorimetric method involving acid hydrolysis, intra-molecular dehydration of sugar into furfurals, followed by condensation of the furfural with phenols to obtain colored hemi-acetals or acetals (Montreuil and Spik, 1969).

The β-carotene content of mango doughnuts was determined using the High Performance Liquid Chromatography (HPLC) method as described by Somé et al. (2004). The external standard solution for calibration was prepared by mixing various quantities of pure β-carotene powder weighed into 3 ml of hexane to produce the stock solution. The stock solution was then diluted by 1/10, 1/100 and 1/1000. Optical densities of the eluted compounds were read at 450 nm. The concentration of the solution having an optical density between 0.1 and 0.9 was calculated. From these standard solutions whose concentrations were determined accurately, precise volumes were taken to produce a final solution of 60 pmol/20 µl. The β-carotene in the samples was extracted by successive vortexing of 1 g of finely ground mango doughnut for 2 min with 1 ml of extraction solvent. The solvent was a heterogeneous mixture of hexane, 3M sodium chloride, and ethanol (1/1/1). After vigorous stirring, the mixture was centrifuged at 3000 rpm^{-1} for 5 min at -5°C. This process was repeated three times; thereafter, the hexanic phases were then pooled. The hexane extract (1 ml) was evaporated under a stream of nitrogen while the obtained residue was re-dissolved in 1 ml of acetonitrile. After micro-filtration (0.5 µm), the sample was injected into a LC-18 Supelcosil column (Bellefonte, USA), 25 cm in length and 4.6 in diameter, using a loop of 20 µl. The mobile phase was a mixture of acetonitrile, dichloromethane and methanol in proportions of 7/2/1, respectively. The elution was in an isocratic mode. During elution, the carotenoids were identified by their retention time of 6.22 min ± 0.26, compared to an external standard, using a pump Jasco PU-980 (Tokyo, Japon), a detector Jasco UV 975 (Tokyo, Japon), and online interface with a computer with an operating Software Galaxy work station version 1.9.3.2.

Sensory evaluation

A sensory test was carried out on the mango doughnuts produced by frying in the crepe maker. It involved the evaluation of the sensory profile according to the ISO 11035 (1994) method. This evaluation tested sensory attributes such as color, aroma, taste, texture in the mouth, and texture by feeling between the fingers. The test was performed in two sessions during two days by 30 panelists from the Departments of Institute of Applied Sciences and Technologies CNRST, Burkina Faso. Participants had minimum education. The panelists consisted of 13 men and 17 women distributed into the three age groups as follows: 15 - 30 years: 40%, 31 - 40 years: 46.70%, over 40 years: 13.30%. The doughnut samples of each formulation were randomly placed onto plates with a three-digit code (Cochran and Cox, 1957), and were served to each panelist. Panelists were isolated to avoid inter-communication during evaluation.

Statistical analysis

All physico-chemical data were generated in triplicate. ANOVA, following Newman-Keuls test (SNK) was performed using XLSTAT (2014) to analyze and compare the physic-chemical parameters. The data from the organoleptic evaluation were analyzed by SPSS 20.

RESULTS AND DISCUSSION

Sensory evaluation of mango doughnuts

Results of the sensory tests of the mango doughnuts are shown in Figures 2 to 6. The yellow color of the doughnuts samples (mango pulp + rice flour + egg) was found to be very attractive by 70% of the panelists. On the other hand, the yellow color of doughnut samples DMMcm (mango pulp + maize flour + eggs) was perceived moderately attractive by 57% of the panelists (Figure 2).

The mango flavour was judged to be weakly intense for the DMMcm doughnut by 67% of the panelists compared with 40% for the DMRcm doughnut (Figure 3).

Concerning the texture, DMMcm was judged to be moderately soft by 48% of the panelists and weakly by 52% of them. DMRcm was judged to be very soft by 74% and moderately soft by 22% of the panelists (Figure 4).

The texture in the mouth was judged to be moderately oily by 45% and of low oiliness by 41% of the panelists for DMMcm, whereas DMRcm was found to be very oily by 31% and moderately oily by 52% of the panelists (Figure 5). These results corroborate those of physic-chemical analysis where the fat content of DMMcm and DMRcm were 13.09 and 15.87% respectively.

Regarding the acid taste, 78% of the panelists found the mango doughnut obtained with maize flour (DMMcm) to be weakly acidic. The DMRcm was judged to be moderately acidic by 56% and weakly acidic by 41% of the panelists (Figure 6). The results of the sensory test of DMMcm and DMRcm with regard to acid taste also confirm those of the physico-chemical analysis whose acidity was low, leading to a less acid taste. In summary,

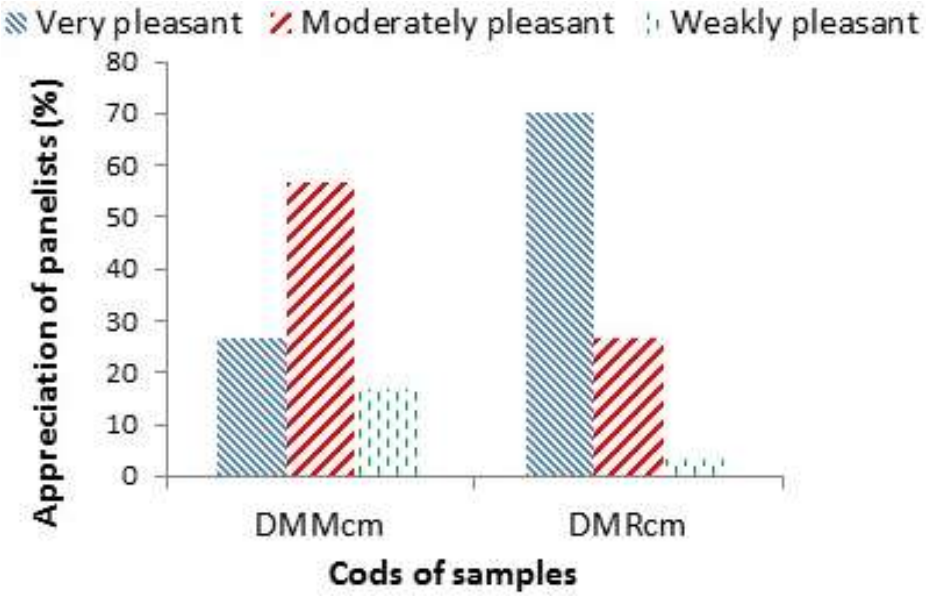

Figure 2. Appreciation of the yellow color of mango doughnuts; Where, DMMcm = Mango doughnut obtained with dough (Mango pulp + Maize flour) fried in crepe make and DMRcm = Mango doughnut obtained with dough (Mango pulp + Rice flour) fried in crepe maker.

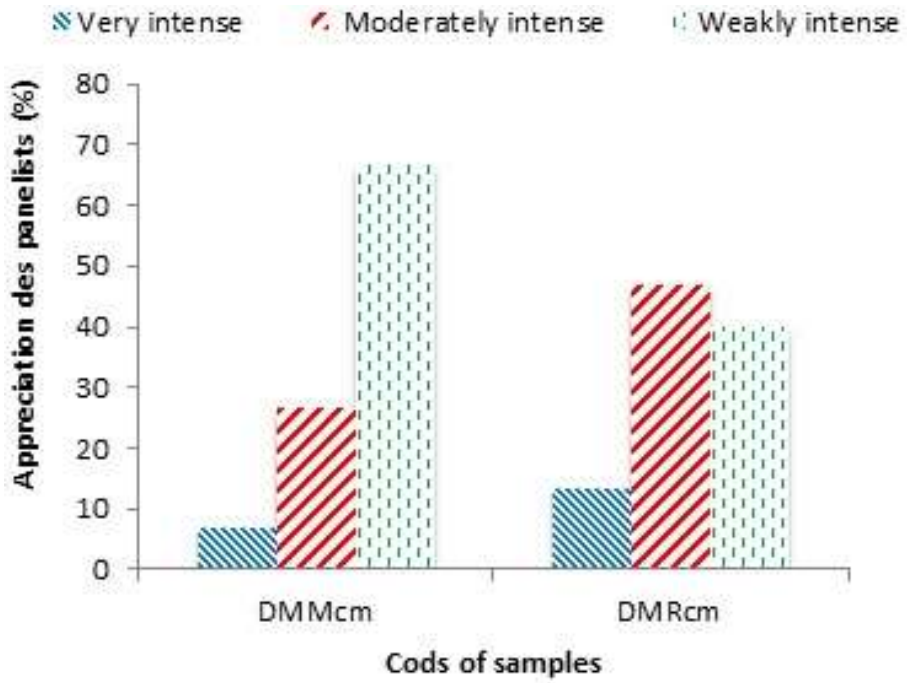

Figure 3. Appreciation of the flavor of mango doughnuts; Where, DMMcm = Mango doughnut obtained with dough (Mango pulp + Maize flour) fried in crepe make and DMRcm = mango doughnut obtained with dough (Mango pulp + Rice flour) fried in crepe maker.

both doughnut formulations were very appreciated by the panelists.

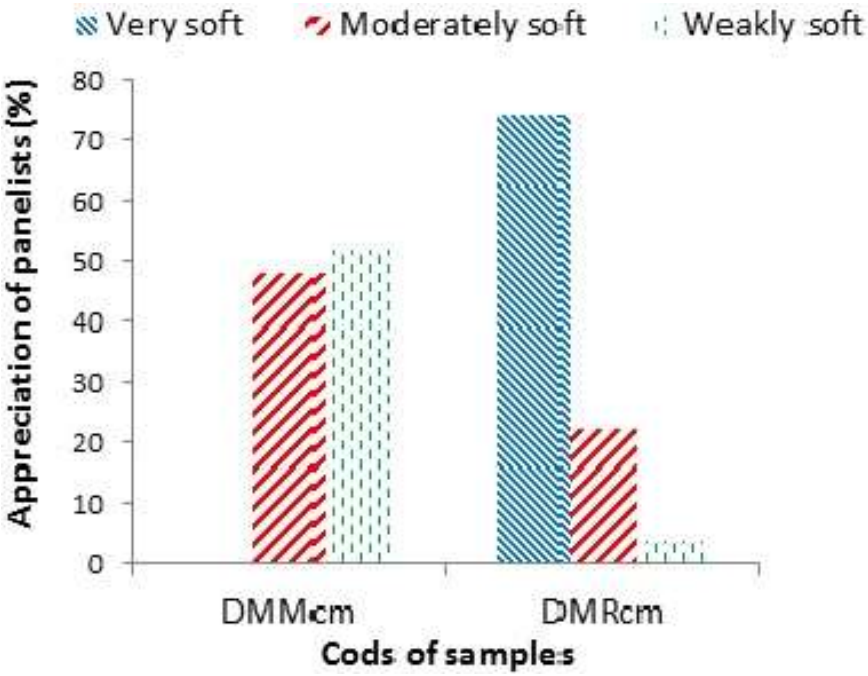

Figure 4. Appreciation of the texture on fingers of mango doughnuts; Where, DMMcm = Mango doughnut obtained with dough (Mango pulp + Maize flour) fried in crepe make and DMRcm = Mango doughnut obtained with dough (Mango pulp + Rice flour) fried in crepe maker.

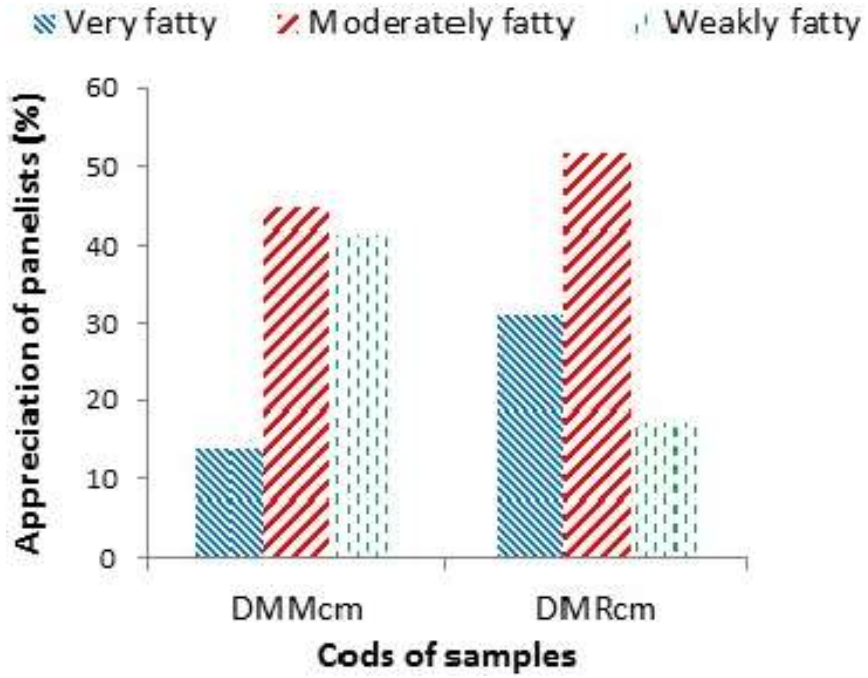

Figure 5. Appreciation of the texture in mouth of mango doughnuts; Where, DMMcm = Mango doughnut obtained with dough (Mango pulp + Maize flour) fried in crepe make and DMRcm = mango doughnut obtained with dough (Mango pulp + Rice flour) fried in crepe maker.

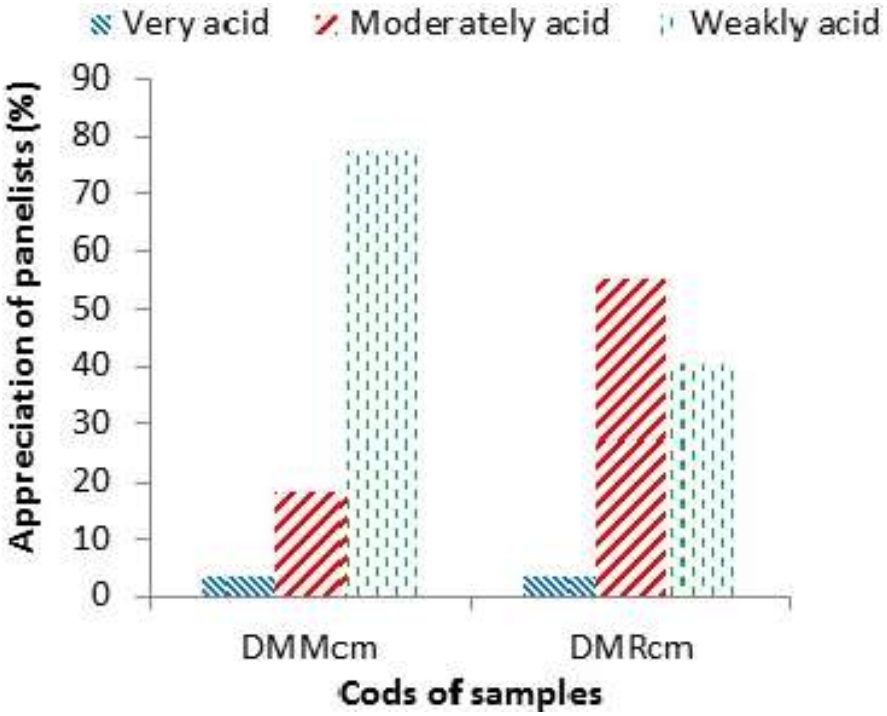

Figure 6. Appreciation of the acid taste of mango doughnuts; Where, DMMcm = Mango doughnut obtained with dough (Mango pulp + Maize flour) fried in crepe make and DMRcm = Mango doughnut obtained with dough (Mango pulp + Rice flour) fried in crepe maker.

Nutritional characteristics

The biochemical characteristics (moisture, tritrable acidity, total ash, fat, total sugars, proteins) of the dough and the mango doughnuts are displayed in Table 2. It can be seen that dough from formulation I, composed of mango pulp, maize flour and egg (DMM), and dough from formulation II, composed of the mango pulp, rice flour, and egg (DMR), contained the same level of moisture (68.68% ± 0.07). The moisture levels of the doughnuts prepared by crepe maker (DMMcm or DMRcm), and those prepared by gas fryer (DMMgf or DMRgf) ranged from 52.60 to 55.12% and 44.06 to 49.90%, respectively. Thus, the moisture content was significantly higher ($p<0.0001$) in doughnuts made with crepe maker than those made with gas fryer. The decrease in moisture content observed in the doughnut samples compared with dough is not surprising as this has also been reported by Shaker (2014) in potato strips, where the water contents drops from 77.25 to 30.51% after frying. This decrease of the water content is due to water evaporation from the heat of frying. Under the effect of heating, the water evaporates from the doughnuts and oil is subjected to endosmosis (Oroszvari et al., 2005). Indeed, frying is a result of dehydration under heat conditions in a hydrophobic environment resulting in a decrease of water content (Courtois et al., 2012).

The fat contents of the dough made with maize flour (DMM) or rice flour (DMR) were 12 and 13%, respectively. After frying, the fat contents in the doughnuts rose to 29.78 and 25.34% for the gas-fried (DMMgf) and crepe maker (DMRgf), respectively. Moreira et al. (1999) also found that the fat content of doughnuts was in the order of 20 - 25%. On the other hand, fat content of the mango doughnuts fried with the gas fryer (DMMgf, DMRgf) were slightly higher than these values. Other findings show that the oil absorbed in fried products increases with the quantity of water lost during frying (Rossell, 2001; Bouchon, 2009; Thanatuksorn et al., 2010; Galoburda et al., 2013). The endosmosis of oil is due to filling the spaces left by the evaporated water. This observation is confirmed in the present study because the samples having the highest fat content (29.78 and 25.34%) had the lowest moisture content (44.06 and 49.90%). However, the samples fried with crepe maker (DMMcm and DMRcm) had slightly elevated levels of fat (13.09 and 15.87%), respectively. It can be seen that the level of fat is higher in mango doughnuts obtained with the gas fryer than those obtained with the crepe maker, where the endosmosis of oil is limited. The

Table 2. Proximate composition of dough and doughnuts (% DM).

Samples (cods)	Moisture (%)	Titrable Acidity (%DM)	Total ash (%DM)	Fat (%DM)	Total sugar (%DM)	Proteins (% DM)	Energetic value (Kcal.100 g^{-1})
Dough							
Mango pulp + Maize flour + Egg (DMM)	68.68 ± 0.07^{a}	9.78 ± 0.00^{b}	1.15 ± 0.02^{a}	12.05 ± 0.04^{d}	61.99 ± 0.03^{a}	5.86 ± 0.13^{b}	357.86 ± 3.19^{d}
Mango pulp + Rice flour + Egg (DMR)	68.65 ± 0.01^{a}	10.48 ± 0.01^{a}	0.91 ± 0.01^{b}	13.12± 0.12^{c}	59.63^{c} ± 0.07^{b}	6.09 ± 0.02^{a}	366.44 ± 3.81^{c}
Doughnuts							
Mango pulp + Maize flour + Egg (DMMcm)	52.60± 0.04^{c}	4.62 ± 0.01^{d}	0.95 ± 0.05^{b}	13.09 ± 0.14^{c}	59.31 ± 0.05^{c}	5.53± 0.01^{d}	300.97 ± 3.16^{f}
Mango pulp + Maize flour + Egg (DMMgf)	44.06 ± 0.04^{e}	4.30 ± 0.00^{f}	0.85 ± 0.01^{c}	29.78 ± 0.15^{a}	40.37 ± 0.08^{f}	5.69± 0.02^{c}	422.26 ± 0.79^{b}
Mango pulp + Rice flour + Egg (DMRcm)	55.12 ±0.05^{b}	7.80 ± 0.00^{c}	0.84 ± 0.01^{c}	15.87 ± 0.05^{e}	58.85 ± 0.12^{d}	6.04 ± 0.07^{a}	328.21 ± 1.30^{e}
Mango pulp + Maize flour + Egg (DMRgf)	49.90 ± 0.03^{d}	4.38 ± 0.00^{e}	0.73 ± 0.03^{d}	25.34 ± 0.17^{b}	48.37 ± 0.04^{e}	5.96 ± 0.00^{a}	433.28 ± 6.96^{a}

Different letters a, b, c, d, e and f in the same row indicate statistically significant differences.

fat contents of the mango doughnuts fried with the crepe maker were relatively low. Total sugar content of the dough samples (DMM, DMR) were 59.63 and 62% respectively. After processing of dough into doughnuts (DMMcm, DMRcm, DMMgf, DMRgf), total sugars ranged from 40.37 to 58.85%. Sugar levels obtained were all significantly different (Table 2). The decrease in total sugar contents in the doughnut samples could be explained by caramelization of sugar and Maillard reactions which reduce sugars and amino acids during frying (Moyano et al., 2002). These reactions, which are responsible for the color, flavor and texture characteristics of the fried products, also produce compounds such as heterocyclic amines and acrylamides (Biego et al., 2009). Heterocyclic amines and acrylamides developed at temperatures between 100 and 200°C are suspected to be carcinogenic compounds (Friedman, 2003; Berlitz et al., 2004; Taubert et al., 2004; Pedreschi et al., 2004; Biego et al., 2009). However, deep frying at temperatures below 200°C may considerably limit their formation (Saguy and Dana, 2003). Since our doughnuts were fried at 155 and 135°C with a maximum time of 10 min, it could be assessed that the formation of these products would be limited.

The protein content of the dough samples ranged from 5.86 to 6.09% whereas that of the mango doughnuts ranged from 5.53 to 6.04%. A slight decrease in protein contents was observed in the doughnuts (DMMcm, DMMgf, DMRcm and DMRgf). Since the decrease in protein levels is not very significant, we could say that the frying temperature of the mango doughnut did not have a destructive effect on proteins or at least on total nitrogen. Nevertheless, protein digestibility may be affected by the process. Gonzalez (2007) reported that proteins are denatured into carboxylic groups under the effect of heat. It enters also in Maillard reactions with sugar to give new products such as acrylamide.

The average β carotene contents of the dough (DMM, DMR) ranged from 172.46 to 195.85 µg.100 g^{-1} DM, respectively (Table 3). Results show that β-carotene contents in the dough made from maize flour (DMM) was higher than those made from rice flour (DMR). β-carotene content in the mango doughnuts ranged from 85.49 to 110.32 µg.100 g^{-1} DM. The decrease in β-carotene content was observed after frying, and the mango doughnuts produced with the gas fryer had the lowest beta carotene level (85.49 and 90.91 µg.100 g^{-1}). Higher losses were recorded in mango doughnuts produced with the gas fryer (50.44 and 50.68%) compared with those produced with the crepe maker (37.43 and 43.68%). The decrease in the β carotene content observed in the mango doughnuts obtained with crepe maker and gas fryer was likely due to the isomerization reactions exposed by carotenoids during frying. These isomers then entered into complex reactions to form new products such as flavors (Villota and Hawkes, 1992; Belitz et al., 2004).

Conclusion

Mango pulp can be used to produce good quality doughnuts for human consumption. Appreciation of the doughnuts, as indicated by the panelists,

Table 3. Beta carotene contents and energetic value of mango doughnuts.

Samples (cods)	β-carotene (µg.100 g^{-1} DM)	β-carotene loss rate (%)
Dough		
Mango pulp + Maize flour (DMM)	195.85 ± 3.48[a]	-
Mango pulp + Rice flour (DMR)	172.46 ±1.30[b]	-
Doughnuts		
Mango pulp + Maize flour (DMMcm)	110.32± 5.07[c]	43.68
Mango pulp + Maize flour (DMMgf)	90.91 ± 17.81[d]	53.68
Mango pulp + Rice flour (DMRcm)	107.92 ± 4.59[c]	37.43
Mango pulp + Rice flour (DMRgf)	85.49 ± 3.21[d]	50.44

Different letters a, b, c, d, e and f in the same row indicate statistically significant differences.

suggests that they could be easily accepted by families, restaurants and street food vendors. The use of the crepe maker reduced the fat content of final products compared to frying in oil. Processing with the crepe maker also gave doughnuts with higher beta-carotene content. Adopting the formulation of mango doughnuts would help diversify mango consumption and improve growers'/processors' incomes. This product could be interesting for the food processing actors. This would not only reduce the post-harvest loss of mango, but also increase food and nutrition security in mango producing countries.

Abbreviations

DMM = dough consisting of mango pulp + maize flour +egg,
DMR = dough consisting of mango pulp + rice flour +egg,
DMMcm = Doughnuts (mango pulp + maize flour +egg) obtained by frying in the crepe maker
DMRcm = Doughnuts (mango pulp + rice flour +egg) obtained by frying in the crepe maker,
DMMgf = Doughnuts (mango pulp + maize flour +egg) obtained by frying in the gas fryer
DMRgf = Doughnuts (mango pulp + rice flour +egg) obtained by frying in the gas fryer

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Nutritional and sensory evaluation of African breadfruit-corn yoghurt

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Single extracts of African breadfruit (*Treculia africana var africana*) and sweet corn (*Golden cob F1*) were blended on 60:40 proportions to produce breadfruit-corn milk. The breadfruit-corn milk was fermented to obtain a yoghurt-like product (breadfruit-corn yoghurt), using inoculums drawn from activation batch of dried starter and previously made breadfruit-corn milk. The breadfruit-corn yoghurt was subjected to nutritional and sensorial evaluation using commercial cow milk yoghurt as a control. The breadfruit-corn yoghurt was significantly ($p<0.05$) higher in moisture, carbohydrate, calcium, potassium, magnesium, iron, zinc, vitamin B_2 and vitamin C. The commercial cow milk yoghurt was significantly ($p<0.05$) higher in protein, fat, ash, crude fibre, sodium, manganese, vitamins A, B_1 and B_3. Sensory scores show that the commercial milk yoghurt was significantly ($p<0.05$) higher in all the sensory attributes considered. In all, the breadfruit-corn yoghurt has acceptable nutritional and sensorial qualities which show it is a potential alternative to cow milk yoghurt from economic and health perspectives.

Key words: Yoghurt, lactic acid bacteria, nutritional, fermentation, breadfruit-corn yoghurt.

INTRODUCTION

Yoghurt is a Turkish name for fermented milk product. It originated from early nomadic herdsmen, especially from Asia, Southern and Eastern Europe (Olakunle, 2012). Milk, for thousands of years has been transformed through microbial fermentation into various food products with high nutritional value (Tamine and Robinson, 1999).

Yoghurt is made by adding a culture of acid forming bacteria to milk that is usually homogenized, pasteurized and fermented. Species of lactic acid bacteria (LAB) represent as potential microorganisms and have been widely applied in food fermentation worldwide. The presence of LAB in milk fermentation can be either spontaneous or inoculated starter culture, since milk is known as one of the natural habitats (Wouters et al.,

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2002; Delavenne et al., 2012). Although, under spontaneous fermentation, the growth of LAB cannot be predicted or controlled, but the procedure has been practiced and carried out traditionally for years (Mennane et al., 2007; Sharma et al., 2012).

Yoghurt is generally produced by lactic acid fermentation through the action of *Streptococus thermophilus* and *Lactobacillus bulgaricus*, and the viability and activity of yoghurt bacteria are of important commercial consideration so that they survive throughout shelf life, transit through acidic conditions in the stomach as well as enzymes and bile salts in the small intestine (Walia et al., 2013). The *S. thermophilus* and *L. bulgaricus* are inoculated simultaneously at 1:1 composition, for instance and remain present throughout the production of yoghurt, as well as in the final product. When both bacteria grow in association, the times for milk coagulation are faster than if either of them is grown separately. The *S. thermophilus* grow and, while they grow, they produce formic acid that in turn stimulates the growth of the *L. bulgaricus*. The activity of the latter on casein induces the presence of free amino acids, which in turn stimulates the growth of the former (Ginovert et al., 2002).

Industrial production of yoghurt has increasingly developed worldwide due to the nutritional benefit of milk constituents and live lactic acid bacteria (Birollo et al., 2000; Park et al., 2005). Due to the prohibitive cost of dairy milk and its products in developing countries, and avoidance of cow milk by vegetarians and people who are allergic to cow milk, enormous efforts are diverted towards making yoghurt from a variety of food resources (Kumar and Mishra, 2004; Lal et al., 2006). Yoghurt-like products have been developed from soymilk (Trindade et al., 2001; Olubimiwa et al., 2006), peanut milk (Isanga and Zhang, 2009), corn milk (Supavititpatana et al., 2010), tiger nut-coconut milk (Belewu et al., 2010), soy-corn milk (Olakunle, 2012; Kpodo et al., 2014a) and skim milk fortified non-dairy milk extracts (Elsamani et al., 2014; Kpodo et al., 2014b).

Yoghurt production from breadfruit-corn milk is envisaged on nutritional and health grounds, since a beverage blend from legume and cereal is considered a nutritional balance product (Olakunle, 2012). In addition, non-dairy yoghurt, such as soymilk based yoghurt, has been reported to offer several distinct health advantages over cow milk yoghurt to the consumer, such as reduced level of cholesterol, saturated fats and lactose (Lee et al., 1990).

MATERALS AND METHODS

Source of materials

The seeds of African breadfruit (*Treculia africana var africana*) were purchased from Oye Agu Market, Abagana, Njikoka L. G. A., Anambra State, Nigeria. Green field sweet corn (*Golden cob F1*) was purchased from Songhai Farm Initiative, Heneke, Ezeagu L.G.A., Enugu State, Nigeria.

Preparation of samples

The breadfruit seeds were washed in excess volume of water to remove extraneous materials and immature seeds, drained and parboiled in water at 95°C for 15 min with constant stirring. The parboiled seeds were drained, air dried and dehulled in a hand mill (Corona, Landers YCIA, South Africa) with teeth gap adjusted to approximately 15 mm to crack the hull without crushing the seeds, subsequently winnowed and washed to obtain clean seeds. The green field sweet corn was firstly husked, the silks removed and washed with water. The grains were separated from the cob using knife, cleaned to remove hairs and other extraneous materials.

The milk blending method of Udeozor (2012) was used. Approximately 2 kg of the clean breadfruit seeds were soaked in potable water for 6 h, with soak water changed every 2 h to avoid fermentation and to eliminate foul odour and greasy substances. At the end of the soaking, the seeds were repeatedly washed in potable water before wet-milling in a variable speed blender (SB-736, Sonic, Japan), with intermittent addition of distilled water. The slurry was filtered through double layer linen cloth, wet-milled and filtered repeatedly to final seeds to water ratio of 1:3 (w/v). The filtrate was boiled for 20 min with continuous stirring, re-filtered to obtain plain breadfruit milk. Approximately 2 kg of corn grains was soaked for 6 h and the soak water changed as before. The grains were repeatedly washed, wet-milled and filtered as before to a final grain to water ratio of 1:3 (w/v). The filtrate was boiled for 15 min, re-filtered to give plain corn milk. The breadfruit milk and corn milk were blended on 60:40 proportions (v/v) to obtain breadfruit-corn milk as shown in Figure 1.

The breadfruit-corn yoghurt was then produced using the method reported by Jimoh and Kolapo (2007) with slight modification. Vegan yoghurt starter culture could not be sourced locally as at the time of this study. A starter culture (Yogourmet, Canada) containing *S. thermophilus*, *L. bulgaricus* and *L. acidophilus* was used according to manufacturer specifications. However, using the free dried pack of this starter did not give expected result after the prescribed incubation period. Extending the fermentation duration and varying incubation temperature did not yield the desired coagulum. The product was however put in tight lid container and preserved in the refrigerator to serve as activation batch for subsequent productions. Exactly 2 L of plain breadfruit-corn milk was pasteurized at 88°C for 15 min and left to cool to 45°C. Approximately, 200 ml of inoculums from the activation batch was transferred aseptically into the 2 L milk. This was stirred with sterile spoon for even distribution, incubated at 45±2°C for about 8 h to obtain a product with acceptable gel strength. The set yoghurt was placed in the refrigerator for 3 h to stop fermentation. About 5% of sucrose, 0.02% of carboxyl methyl cellulose (CMC), preservatives (0.01% sodium benzoate and 0.01% potassium sorbate) and milk flavoring (to taste) were added to the coagulum, stirred to mix, filled into screw capped plastic bottles as in Figure 2. The products were stored in the refrigerator prior to analysis.

Commercial cow milk yoghurt

The commercial cow milk used in this study was obtained from a manufacturer in Nigeria to serve as a control for the breadfruit-corn yoghurt as in the characteristic shelf life study of corn milk yoghurt (Supavititpatana et al., 2010).

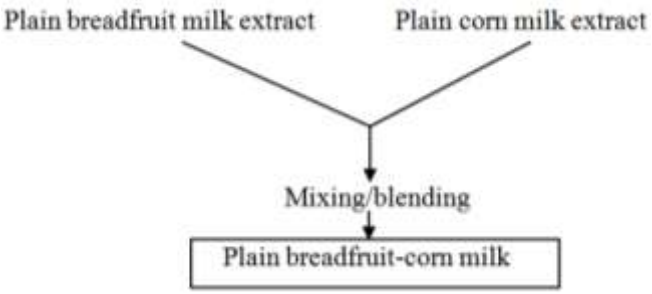

Figure 1. Flow chart for the production of plain breadfruit-corn milk

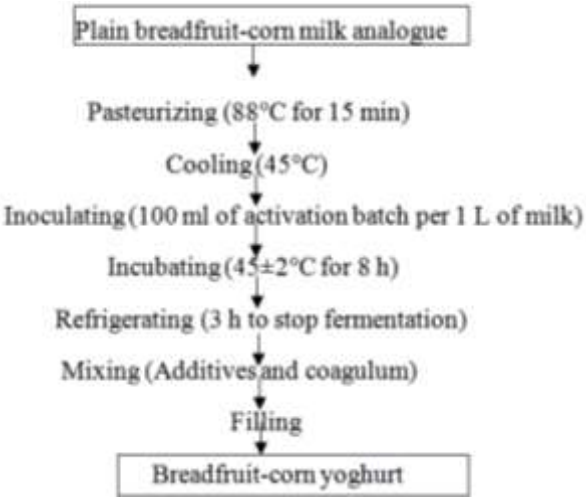

Figure 2. Flow chart for production of breadfruit-corn yoghurt.

Proximate analysis

The proximate composition of protein, fat, ash, fibre, moisture content and carbohydrate were determined according to the method of analysis described by the Association of Official and Analytical Chemists (AOAC, 2000).

Mineral content analysis

Mineral analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer (AAS) according to the method of APHA 1995 (American Public Health Association). Approximately 2 g of the sample was weighed into a digestion flask and 20 ml of the acid mixture (650 ml conc. HNO_3; 80 ml perchloric acid; 20 ml conc. H_2SO_4) was added.

The flask was heat until a clear digest was obtained. The digest was diluted with distilled water to the 100 ml mark. Appropriate dilutions were then made for each element.

Preparation of reference solution

A series of standard metal solution in the optimum concentration range were prepared. The reference solutions were prepared daily by diluting the single stock element solutions with water containing 1.5 ml concentrated nitric acid/liter. A calibration blank was prepared using all the reagents except for the metal stock solutions. Calibration curve for each metal was prepared by plotting the absorbance of standard versus their concentrations.

Vitamin content analysis

Determination of vitamin A

Vitamin A was determined by the calorimetric method of Kirk and Sawyer (1991). About 1 g of the sample and standard were mixed with 30 ml of absolute alcohol and 3 ml of 50% KOH solution was added to it and boiled gently for 30 min under reflux. After washing with distilled water, vitamin A was extracted with 150 ml of diethyl ether. The extract was evaporated to dryness at low temperature and then dissolved in 10 ml of isopropyl alcohol. 1 ml of standard vitamin A solution was prepared and that of the dissolved extract were transferred to separate cuvettes and their respective absorbance were read in a spectrophotometer at 325 nm with a reagent blank at zero.

$$\text{Concentration of vitamin A in sample} = \frac{\text{Abs of samples}}{\text{Abs of std}} \text{ x conc. of standard}$$

Determination of vitamins B_1 and B_2

Approximately 1 g of sample was weighed into a conical flask and dissolved with 100 ml of deionized water. This was shaken thoroughly and heated for 5 min and allowed to cool and then filtered. The filtrate was poured into cuvette and their respective wavelength for the vitamins set to read the absorbance using spectrophotometer.

Vitamin B_1 = 261 nm
Vitamin B_2 = 242 nm

$$\text{Concentration (mg/\%)} = \frac{\text{A X D.F volume of cuvetter (5)}}{\text{E}}$$

Where A = absorbance; DF = dilution factor; E = extinction coefficient = 25 for B_1 and B_2.

Determination of vitamin B_3

Approximately 5 g of sample was dissolved in 20 ml of anhydrous glacial acetic acid and was warmed slightly. About 5 ml of acetic anhydride was added and mixed. Two to three drops of crystal violet solution was added as indicator. 0.1 M perchloric acid was added to titrate to a greenish blue colour.

$$\text{Vitamin } B_3 = \frac{\text{titre value X } 0.012}{0.1}$$

Determination of vitamin C

This was determined by the titrimetric method (Kirk and Sawyer, 1991). Approximately 2 g sample was homogenized in 6% EDTA/TCA solution. The homogenate was filtered and used for

analysis. 20 ml of 30% KI solution was added to it and titrated against 0.1 M $CuSO_4$ solution. The end point was marked by a black coloration. A reagent blank was also titrated. Vitamin C content was calculated based on the relationship below:

1 ml of 0.1 mole $CuSO_4$ = 0.88 mg vitamin C

$$\text{Vitamin C} = \frac{100 \text{ x } 0.8 \text{ (titre - blank)}}{\text{Weight of sample}}$$

Sensory test

Two yoghurt samples coded BCY and CMY were presented in similar form to a 30 member sensory panel consisting of staff and students from a College of Agriculture community. They were requested to rate the yoghurts in terms of colour, texture, taste, aroma, mouth feel and overall acceptability on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely (Onwuka, 2005; Iwe, 2014). Each panelist was provided with enough privacy to avoid biased assessment.

Statistical analysis

Results were obtained in triplicates and the data collected were subjected to T-Test using SPSS Version 17 and differences between mean values were evaluated at $p<0.05$ using paired samples test.

RESULTS AND DISCUSSION

Proximate composition

The moisture content of breadfruit-corn yoghurt (BCY) was significantly ($p<0.05$) higher than the values of the commercial cow milk yoghurt (CMY) as shown in Table 1. The 85.7% moisture content of the BCY correlated with the 87.55% of corn milk yoghurt by Supavititpatana et al. (2010) and 89.08% of soy-corn yoghurt by Olakunle (2012). The lower moisture content of the CMY may be due to skimmed milk powder which thickens slurry and reduces moisture content. Elsamani et al. (2014) reported that increased addition of skimmed milk powder reduced the moisture content of peanut milk based yoghurt due to thickening effect. The lower moisture content of the commercial cow milk yoghurt is an advantage when shelf life is considered (Adeiye et al., 2013).

The protein content of the BCY of 4.58% was significantly ($p<0.05$) lower than the 4.89% of CMY, but higher than the 4.17% of corn milk yoghurt and 3.89% of the commercial cow milk yoghurt (Supavititpatana et al., 2010). The 4.58% of BCY was also higher than 4.30% of soy-corn yoghurt by Olakunle (2012). The higher protein content of the CMY might be due to the use of skimmed milk powder which has generally high protein value. Elsamani et al. (2014) reported that the protein content of peanut based yoghurt increased from 11.55 to 20.65% when fortified with skimmed milk powder. The fat content of BCY was significantly ($p<0.05$) lower than that of CMY. This might be attributed to the higher fat content of skimmed milk. Rehman et al. (2007) reported increased fat content of *Lathyrus sativus* milk fortified with 5% skimmed milk powder. Drying of milk during skimmed milk production is well known to concentrate the biochemical constituents of the powdered milk leading to significant increase in fat, protein and total solids of incorporated compound. The breadfruit-corn yoghurt may be classified as low fat yoghurt since it is slightly above 0.5% fat (Kosikowski, 1997). The low fat content of the BCY could reduce chances of rancidity while the higher fat content of CMY may easily contribute to the production of off flavor during storage.

Table 1. Proximate composition of yoghurt samples.

Parameter	BCY	CMY
Moisture (%)	85.70^{a}±0.49	77.84^{b}±0.31
Protein	4.58^{b}±0.03	4.89^{a}±0.02
Fat	0.58^{b}±0.04	1.17^{a}±0.02
Ash	2.14^{b}±0.16	9.33^{a}±0.30
Crude fibre	3.69^{b}±0.04	3.80^{a}±0.02
Carbohydrate	3.53^{a}±0.50	2.81^{b}±0.31

Means within a row followed by different superscripts are significantly ($p<0.05$) different. BCY = breadfruit-corn yoghurt, CMY = commercial milk yoghurt.

The ash content of CMY was significantly ($p<0.05$) higher than that of BCY, which might be attributed to use of skimmed milk powder. Increase in ash content with skimmed milk powder addition has been variously reported (Rehman et al., 2007; Trisnawati et al., 2013). Addition of corn has also been reported to increase ash content of yoghurt due to high mineral content of corn (Omueti and Ajomale, 2005; Olankunle, 2012). This conforms to the report of Odu et al. (2012) that high mineral content in products result in high ash content. Unlike CMY, the ash content of BCY was within the limit of <5% for milk beverages by Standard Organization of Nigeria (Adedokun et al., 2014). The crude fibre content of breadfruit-corn yoghurt was significantly ($p<0.05$) lower than that of the commercial cow milk yoghurt. Fortification of the CMY with corn starch, minerals and vitamins, as indicated on the label, may have contributed to the higher level of crude fibre. However, the 3.6% crude fibre of BCY and 3.8% 0f CMY were higher than the 3% minimum of the Codex Alimentarius Standards for dairies (Passmore and Eastwood, 1986). High crude fibre content of food could play a role in normal peristaltic movement of the intestine (Akinyele, 1983). The carbohydrate content of BCY was significantly ($p<0.05$) higher than that of CMY. The higher value of BCY may be due to substantial use of sweet corn in the milk blend.

Table 2. Mineral content of yoghurt samples.

Parameter	BCY	CMY
Sodium (ppm)	5.21^{b}±0.00	6.28^{a}±0.01
Calcium	15.47^{a}±0.03	13.76^{b}±0.06
Potassium	6.48^{a}±0.02	3.38^{b}±0.06
Magnesium	5.26^{a}±0.00	4.28^{b}±0.00
Manganese	0.01^{b}±0.00	0.02^{a}±0.01
Iron	0.03^{a}±0.00	0.02^{b}±0.00
Copper	0.00^{ns}±0.00	0.00^{ns}±0.00
Zinc	0.03^{a}±0.00	0.02^{b}±0.00

Means within a row followed by different superscripts are significantly ($p<0.05$) different. BCY = breadfruit-corn yoghurt, CMY=commercial milk yogh, ns = no significant value.

Table 3. Vitamin content of yoghurt samples.

Parameter	BCY	CMY
Vitamin A (mg/g)	39.05^{a}±0.00	56.51^{b}±0.44
Vitamin B_1 (mg%)	1.39^{b}±0.00	1.54^{a}±0.00
Vitamin B_2	2.01^{a}±0.00	1.06^{b}±0.00
Vitamin B_3	1.57^{b}±0.00	1.68^{a}±0.00
Vitamin C (mg/l)	36.28^{a}±0.03	30.80^{b}±0.01

Means within a row followed by different superscripts are significantly ($p<0.05$) different. BCY = breadfruit-corn yoghurt, CMY = commercial milk yoghurt.

Table 4. Sensory scores of yoghurt samples.

Attributes	BCY	CMY
Colour	7.66^{b}±0.41	8.13^{a}±0.40
Texture	6.90^{b}±0.74	7.83^{a}±0.56
Taste	6.90^{b}±0.73	7.66^{a}±0.69
Aroma	6.96^{b}±0.72	7.56^{a}±0.70
Overall acceptability	6.53^{b}±0.81	7.20^{a}±0.56

Means within a row followed by different superscripts are significantly ($p<0.05$) different. BCY = Breadfruit-corn yoghurt, CMY = commercial milk yoghurt.

Addition of corn in the production of soy-corn yoghurt was similarly reported to have increased the carbohydrate content of soy yoghurt (Olakunle, 2012). Cereals are generally known to be good source of carbohydrate.

Mineral content

The BCY was significantly ($p<0.05$) higher than CMY in calcium, potassium, magnesium, iron and zinc, but significantly ($p<0.05$) lower in sodium and manganese as shown in Table 2. It is expected that nutrient value of yoghurt will depend largely on the milk from which it was fermented. The higher values of breadfruit-corn yoghurt in most of the minerals may be due to their fair distribution in legumes and cereals (Onweluzo and Odume, 2007). Yoghurt is a rich source of calcium and good provider of magnesium, potassium and phosphorus, and other minerals such as iron, zinc, iodine, chloride and selenium are also found in yoghurt (Miller, 2000). The absence of copper in BCY and CMY might be due to the low value in the milk which was probably utilized during fermentation. It has been reported that copper could be used as a potential additive to inhibit the post acidification of yoghurt (Han et al., 2011), hence its inadequacy in the first instance might have led to the sudden depletion. The higher iron content of the breadfruit-corn yoghurt is understandable since dairy milk is known to be deficient in iron (Passmore and Eastwood, 1986).

Vitamin content

The breadfruit-corn yoghurt was significantly ($p<0.05$) higher in vitamin B_2 and C than the commercial cow milk yoghurt, but significantly ($p<0.05$) lower in vitamins A, B_1 and B_3, as shown in Table 3. The appreciable value of vitamin A (a fat soluble vitamin) in the BCY might be due to the yellow sweet corn which was partly used in milk production, since the yellow pigments (carotenoids) of yellow corn is a precursor of vitamin A. The higher vitamin C content of BCY is expected since vitamin C is synthesized primarily in plants. The presence of vitamin C in the CMY can be attributed to the fortification of the product with corn starch and minerals. The difference in values of B vitamins may be due to their levels in the milks that were fermented. The vitamins content of yoghurt is variable depending on the type of yoghurt and method of production, but remains fairly similar to the milk for the majority of vitamins (Kosikowski, 1997). Cow milk yoghurts are good providers of the B vitamins as reported by Miller et al. (2000).

Sensory scores

It is shown in Table 4 that the commercial cow milk yoghurt was significantly ($p<0.05$) higher than the breadfruit-corn yoghurt in all the attributes considered. The lower colour score of BCY might be due to the yellow pigments (carotenoids) of the yellow sweet corn. Olakunle (2012) reported low colour score of soy-corn milk which was attributed to the yellow colour of xanthophylls pigments (carotenoids) of yellow corn. This however contradicts the report of Lestiyani et al. (2014) where the pigments conferred better colour. The higher taste score of CMY may be due to the difference in

composition of milk that was fermented, and the added ingredients. In addition, the higher fat content of CMY might have contributed to the higher taste score. Fat has been reported to promote mouth feel (FAO/WHO, 1993), which might have impacted positively on the taste of the commercial milk yoghurt. The panelists may have preferred the texture of the commercial cow milk yoghurt to the breadfruit-corn yoghurt due to difference in gel consistency. The structural arrangement of the gel network determines the textural characteristics of coagulated dairy product and is affected by factors such as composition and manufacturing processes (Rawson and Marshall, 1997). Non-dairy yoghurts are known for lower water holding capacity which leads to high syneresis and poor texture (Akalin et al., 2012). It has also been reported that total solids and fat levels in the milk, heat treatment of the milk prior to inoculation, homogenization, presence of stabilizers and incubation conditions will affect the body of the final product (Kumar and Mishra, 2004), and these may have contributed to the better texture of the CMY.

Aroma of yoghurt is supported by various compounds, in which lactic acid represent the major contributor, and other aroma compounds. The most common lactic acid bacteria cultures used in yoghurts manufacture *S. thermophilus* and *L. bulgaricus* act in association and synergistically to provide volatile metabolites that determine the flavor of yoghurt, and acetaldehyde and diacetyl were reported to be essential aroma compounds of typical yoghurt (Tamine and Robinson, 1999; Walstra et al., 1999). The higher aroma score of CMY might be due to different amino acids as well as organic acids which produce more lactic and aromatic compounds (Routrary and Mishra, 2011). The CMY had higher overall acceptability than the BCY, which is expected considering that it had excelled in all other attributes evaluated. However, the mean sensory scores of BCY were similar to the values reported by Zhanhi and Jideani (2012) for non-dairy yoghurts. Elsamani et al. (2014) also reported better sensory results for peanut yoghurt samples fortified with skimmed milk during maturation. Furthermore, the CMY was fortified with flavor, minerals and vitamins supplement in addition to being derived from reconstituted skimmed milk. It is also possible that familiarity of the panelists with cow milk yoghurt may have influenced the higher sensory scores of CMY, hence its higher overall acceptability. However, the sensory scores of BCY were within the commercially acceptable range (4-9 scores) recommended for yoghurts by the Karl Ruther nine point scheme (Tamine and Robinson, 1999).

Conclusion

The study has shown that breadfruit-corn milk can be fermented into a yoghurt-like product of good nutritional and sensorial quality. The non-dairy yoghurt was comparable to the cow milk yoghurt in virtually all the parameters evaluated. Given the nutritional balance of legume-cereal beverage, the breadfruit-corn yoghurt has the potentials as dairy yoghurt substitute from economic and health point of view.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Impact of electric voltages on the emulsification capabilities of okra seed protein-rich extract

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A portion of okra seed protein-rich extract (PRE) prepared with NaCl solution (5 g/L) was hydrolyzed at 110°C for 5 h (1 atm. pressure). The PRE (sample A), hydrolyzed PRE-B, whole okra seed flour-C and gelatin-D were tested for emulsification capacity (EMC) and emulsion stability (ES). The emulsions were prepared and tested in (i) normal environmental condition (o/w and w/o), (ii) current carrying beaker-CB, (iii) Ohmic heating beaker-OB. The tests were carried out at zero to 240 V. The results showed that at 200 V, the EMC were 85.71, 80.50, 88.23, 85.31, 94.71, 94.70, 90.68, and 83.3% for A_{CB}, A_{OB}, B_{CB}, B_{OB}, C_{CB}, C_{OB}, D_{CB}, and D_{OB}, respectively. The respective ES are 23, 31, 25, 43, 98, 61, 98, and 65%. At 200 V, okra product C_{CB} had the highest EMS and ES (94 and 98%, respectively). At 95% oil (w/o) emulsion, EMC for PRE and gelatin were 6.0 and 1.9%, respectively. At 5% oil (o/w) emulsion, the corresponding EMS and ES is 84 and 94%. Hydrolyzed okra seed PRE-C_{CB} is possibly a hydrophilic emulsifier, combining high (94%) EMC with high (98%) ES.

Key words: Okra seed, protein-rich extract, hydrolysis, emulsification, electric field.

INTRODUCTION

The amino acid composition of okra seed was found to be similar to that of soybean, yet the protein efficiency ratio (PER) was higher for okra seed (Karakoltsidis et al., 1975; Martin et al., 2006). These researchers also showed that the PER of okra seed flour, heated at 130°C for 3 h was not different from non-heated flour.

According to Vickie and Elizabeth (2008), the best emulsifiers are proteins, which uncoil or denature and adsorb at the interface and interact to form a stable interfacial film. Proteins tend to uncoil such that their hydrophobic sections are oriented in oil and hydrophilic sections are oriented in water. Hence, a series of loops, trains and tails may be envisioned at the interface. This confers emulsification capabilities on proteins. Vegetable

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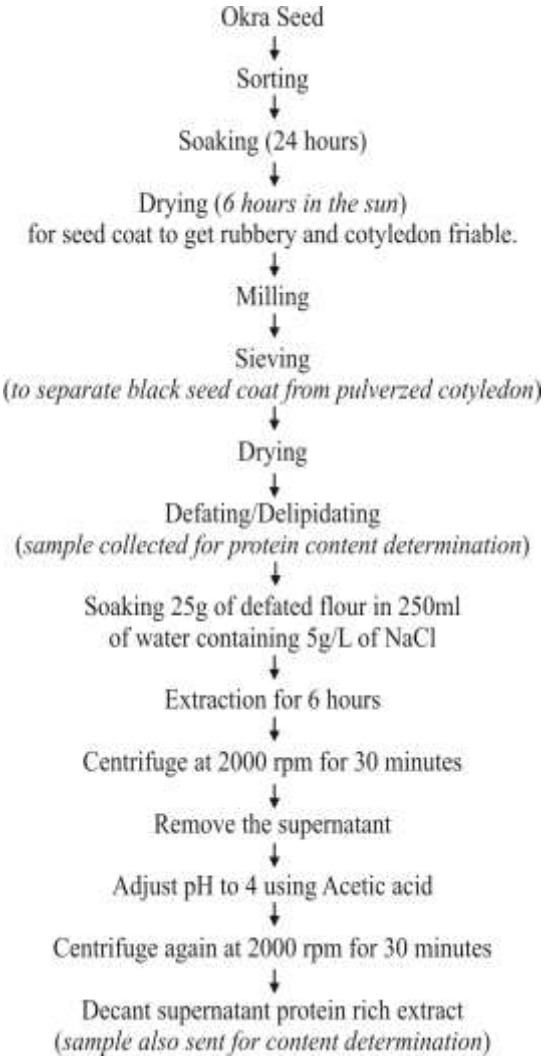

Figure 1. Production of PRE (Gilles, 2002).

proteins are commonly used as emulsifiers in food processing, perhaps due to the high molecular weights, which enables them to stabilize the emulsion, by elevation of the systems' viscosity when gelled (Vickie, 2008). Okra seed protein, with all its quality attributes can attract more utility to the crop, if the seed protein can be fashioned out as a major emulsifier in the food industry. Makers of cakes particularly at homes, may want to avoid much of egg yolk where there is need to avoid cholesterol in the meal. A vegetable protein from okra with appreciable emulsification capabilities will be helpful in such situations.

The objectives of this work are to obtain protein-rich extract (PRE) from okra seed, hydrolyze the PRE and employ the PRE, hydrolyzed PRE and whole okra seed flour in the production of emulsions at normal environmental conditions as well as under the influence of electricity. Gelatin is included as a standard.

The aim is to record particularly, the positive impacts of electric voltages on the emulsification capabilities of okra seed products measures that can increase the usefulness of okra.

MATERIALS AND METHODS

Preparation of PRE

Okra seed was soaked in water for 24 h, allowed to drain for 8 h before milling using an attrition mill. The hull was then sieved out using 0.2 mm sieve. Oil from the whole okra seed flour was extracted using hexane at 45°C. Three successive extractions were done. The oil-free flour (100 g) was added into 1 L of NaCl solution (5 g/L).

The mixture was stirred for 15 min. Extraction was allowed to go on for 6 h. The solution was then centrifuged at 2000 rpm for 30 min. The pH of the supernatant was adjusted to 4.0 with acetic buffer tablet. After 15 min of stirring, the supernatant was centrifuged at 2000 rpm for 30 min. The solid residue-PRE was dried in a cabinet dryer at 60°C (Figure 1).

Hydrolysis of protein rich okra seed extract

The slurry of the PRE was prepared by weighing 10 g of the extract into 250 ml beaker; 100 ml of distilled water was added and mixed properly with a glass stirrer, until the PRE was completely suspended in the water. 5M HCl (200 ml) was added to the mixture and the pH was monitored until it dropped to 2. The acid was used as catalyst in hydrolyzing the protein. The hydrolysis was completed in an autoclave by the use of steam at temperature of 121°C for 5 h. At the end, the sample was mixed with 20 ml of 3M NaOH, increasing the pH of the hydrolyzate to 6 (Gilles, 2006; Balami, 2004).

Determination of emulsification capacities (EMC)

Emulsions were prepared with each of these as emulsifiers-whole okra seed flour, PRE, hydrolyzed PRE and gelatin. Each of these (2 g) was mixed in 100 ml of distilled water and 10 ml of dried groundnut oil and homogenized for 5 min using a PROLABO homogenizer (silver model L2R) at 2500 rpm. The emulsion was then poured into graduated centrifugal tube and centrifuged at the speed of 2500 rpm for 15 min.

EMC (%) is given by:

$$\frac{\text{Length of emulsified layer}}{\text{Length of whole content of tube}} \times \frac{100}{1}$$

One of the factors that affect the EMC of proteins according to Riken (2002) is the extent of conformational arrangement at the interface of oil and water, an attribute of solubility of the protein. For this reason, a sample of the PRE was hydrolyzed at pH 2 for 5 h using an autoclave at 1 atm. EMC of the hydrolyzed sample was assayed alongside others as described earlier (Balsam, 1994).

Conformational change can also be brought about by ionization, presence of charges and charged particles (Balsam, 1994). Hence, the research design varied conditions of emulsification. Emulsions were prepared: (1) in an Ohmic heating beaker-OB (Figure 3) and (2) in a current carrying or conducting beaker-CB (Figure 2). Ohmic

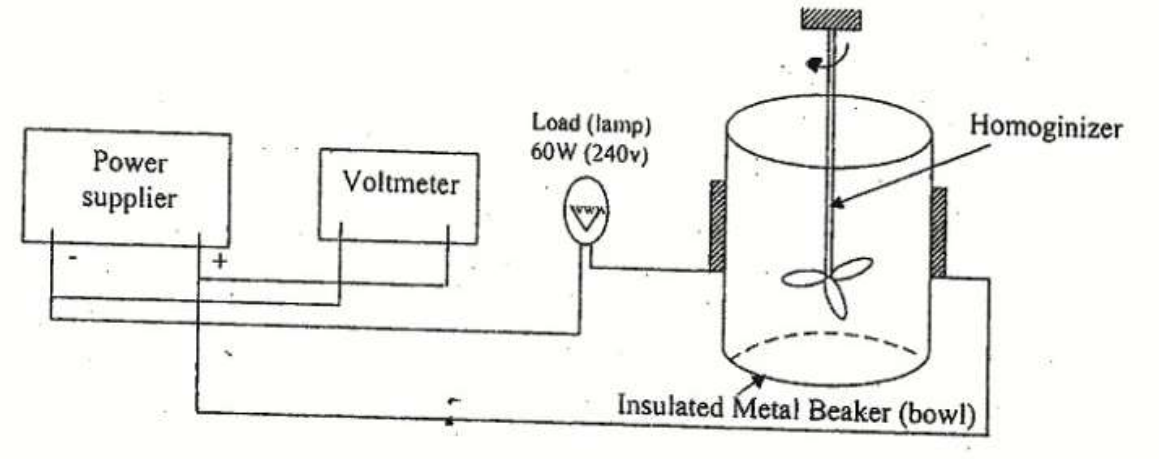

Figure 2. Diagram illustrating the emulsification of samples in a current carrying conductor in an electric field.

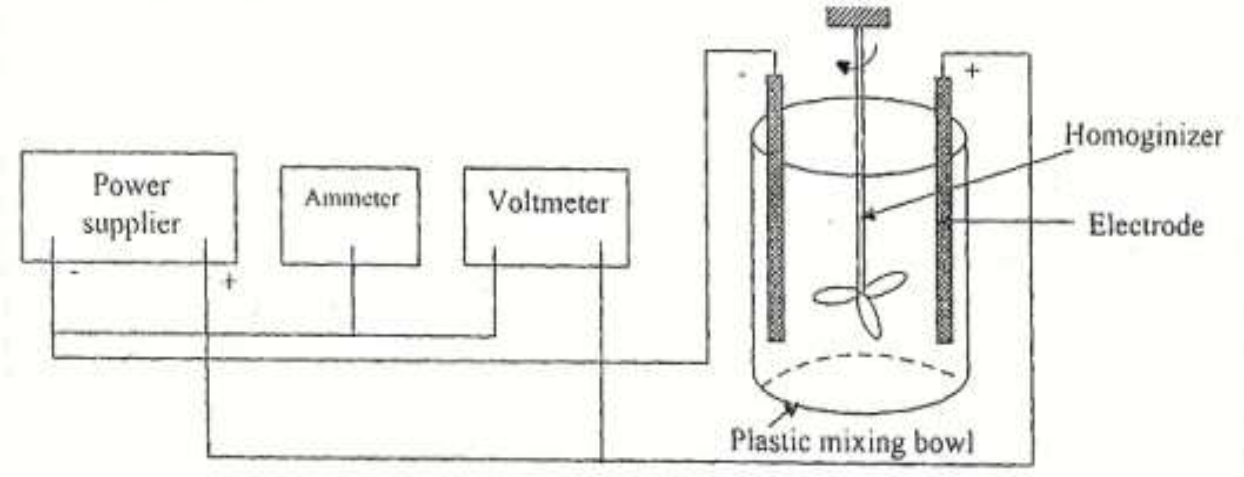

Figure 3. Diagram illustrating the emulsification of samples in an Ohmic heating beaker.

heating beaker permits the flow of free ions to the poles while a current carrying conductor allows the flow of electrons or electricity through the walls of the reaction beaker (Figure 2). Finally, emulsions were prepared with oil concentration of between 5 and 95%, at normal atmospheric conditions, using PRE (in one batch) and gelatin (in another). The EMC were measured and compared.

Emulsion stability (ES)

After reading off and calculating the EMC, the marked tubes, containing the centrifuged samples were stored in racks and kept on the shelf for 5 days. ES (%) was calculated as (Balami, 2004; Gilles, 2006):

Height of remaining emulsified layer / Height of the whole column × 100

RESULTS AND DISCUSSION

EMC of okra seed products at different voltages of electricity

There is significant difference in EMC among samples both of current carrying beaker (CB) and Ohmic heating beaker (OB) at zero voltage. The hydrolyzed PRE (94.7%) is significantly higher than the rest. It is higher than gelatin (84.85%), a common food emulsifier which in this study served as a control (Cole, 2000). Changes in particle size should be a major consequence of conversion of the whole okra seed into PRE and subsequently to hydrolyzed PRE. The larger the protein molecule, particularly the globular protein, the smaller the

Table 1. Emulsification capacities (%) at different voltages of electricity in CB and OB.

Sample	Emulsification capacities (%)					
	0	200	210	220	230	240
A_{CB}	79.14^{a}	85.71^{b}	88.51^{e}	$87.^{94f}$	84.09^{c}	85.23^{c}
A_{OB}	79.14^{a}	80.50^{c}	81.01^{f}	81.21^{c}	82.42^{c}	83.33^{c}
B_{CB}	89.24^{a}	88.23^{b}	88.0^{e}	85.36^{f}	82.94^{c}	80.55^{c}
B_{CB}	89.24^{a}	85.31^{b}	80.12^{f}	78.03^{c}	78.03^{c}	78.02^{c}
C_{OB}	94.74^{b}	94.65^{d}	94.71^{g}	95.56^{g}	95.76^{b}	96.19^{d}
C_{CB}	94.74^{b}	94.71^{d}	94.70^{g}	94.70^{g}	94.51^{b}	88.76^{d}
D_{OB}	84.85^{a}	89.46_{b}	90.68^{g}	94.68^{g}	94.80^{b}	95.70^{d}
D_{CB}	84.85^{a}	84.61^{c}	83.31^{f}	83.01^{c}	82.91^{c}	82.88^{c}

A: Whole okra flour; B: protein rich extract; C: hydrolyzed protein rich extract; D: gelatin; CB: current carrying beaker; OB: Ohmic heating beaker; Sample on same column with same subscripts are not significantly different ($p \leq 0.05$)

solubility. The increase in EMC, for PRE, between 0 and 240 V is 96.19 to 94.74%. The highest increase was exhibited by gelatin (95.0 to 84.85). PRE under increasing voltage, showed rather decreasing EMC.

The impact of increasing voltages (200 to 230) for the hydrolyzed PRE, is increased EMC (94.65 to 95.76) for CB and decreased EMC for OB (94.71 to 94.51)

EMC in a current carrying conductor-CB, for all the samples, kept increasing as the voltage increased. The only exception to this pattern was the PRE whose EMC though second highest at zero voltage (89.24%) decreased to 80.55 at 240 V (Table 1). During the preparation of the PRE, the seeds were crushed, soaked, subjected to extremes of pH with salts that possibly affected ionic positions. These predisposed the protein molecules to denaturation which from the account of workers like Gilles (2006) could expose more surfaces of the protein structure, enhancing their EMC. When these protein molecules were subjected to hydrolysis, as with sample C, the exposure could even be enhanced, increasing further the EMC (Table 1).

Stability (%) of emulsions prepared at varying voltages in current carrying and Ohmic heating beakers

The emulsification stability at 0 V or normal conditions was 22, 23, and 36%, for whole okra seed flour, PRE, and hydrolyzed PRE, respectively. It was a consistent improvement though marginal. That of gelatin at the same conditions was 45%. Micheal (1990) explained that there is a positive correlation between protein solubility and emulsion capacity/stability. Non dissolved protein contributes very little to emulsification. Protein must dissolve and migrate to the interface, before their surface properties could come into play. The denatured and hydrolyzed protein molecules dissolve more readily and provide better coating for the dispersed phase, resulting in enhanced ES (Fennema, 2003).

At higher voltages, the samples generally showed increased ES. At 200 V, the percent emulsion stability of sample A (whole okra seed flour), was 25 at CB and 31 at OB. These are significantly different from that of PRE sample B (43% in Ohmic heating beaker). In current carrying beaker, sample B had ES of 25%. Sample C (hydrolyzed PRE) had a significantly higher score (98%) of ES as compared to the other okra seed products at 200 V. Under the same condition, gelatin also scored 98% ES.

For the emulsions prepared at 210, 220, and 230 V, the ES scores for PRE sample B (in current carrying beaker-CB) were, respectively 43, 46, and 50%. Under the same conditions, gelatin scored 98, 98, and 98%, respectively. In Ohmic heating beaker-OB, the scores are, respectively 43, 65, and 75%. For gelatin, the corresponding scores are 65, 75 and 80%. Ionic emulsifiers produce emulsions having a dispersed phase that exhibit particle charge. Proteins particularly the hydrophilic portions are ionic and can introduce particle charge and conductivity to emulsions. Under such conditions, solubility and therefore emulsion capacity and stability could be enhanced. These are likely to be the reasons for the increasing stability of emulsions produced in Ohmic heating and current carrying beakers (Balsam, 1994).

The ES for the hydrolyzed PRE was significantly higher than those of other samples in the experiments performed in a current carrying beaker (conductor). At 200 V for example, while the emulsions prepared with samples A and B had 23 and 25%, respectively that of sample C (hydrolyzed PRE) had 98%. This is quite remarkable judging from the fact that at 0 V, the same sample C made emulsion of only 36% stability. The interactions of the hydrophilic and hydrophobic groups

Table 2. Emulsion stability (%) of emulsions prepared at different voltage of electricity (in CB and OB).

Sample	Emulsion stability (%)					
	0	200	210	220	230	240
A_{CB}	22^{a}	23^{a}	24^{a}	26^{a}	26^{a}	25^{a}
A_{OB}	22^{a}	31^{a}	42^{b}	50^{b}	58^{b}	70^{c}
B_{CB}	23^{a}	25^{a}	43^{b}	46^{b}	50^{b}	52^{b}
B_{OB}	23^{a}	43^{b}	65^{b}	75^{c}	83^{c}	87^{c}
C_{CB}	36^{a}	98^{c}	98^{c}	98^{c}	98^{c}	98^{c}
C_{OB}	36^{a}	61^{b}	67^{b}	75^{c}	80^{c}	85^{c}
D_{CB}	45^{b}	98	98^{c}	98^{c}	98^{c}	98^{c}
D_{OB}	40^{b}	65^{b}	75^{c}	80^{c}	81^{c}	90^{c}

A: Whole okra flour; B: protein rich extract; C: hydrolyzed protein rich extract; D: gelatin; CB: current carrying beaker; OB: Ohmic heating beaker; Sample on same column with same subscripts are not significantly different ($p \leq 0.05$).

Table 3. Comparing okra seed PRE and galatin as emulsifiers (o/w and w/o).

Dispersed phase	Okra seed-PRE (EMC)		Gelatin (EMC)	
Conc. (%)	w/o	o/w	w/o	o/w
5	6.0^{a}	84.0^{a}	1.90^{a}	94.9^{a}
10	7.3	81.32^{a}	10.90^{c}	86.4^{a}
15	13.3^{a}	77.0^{a}	19.0^{b}	83.9^{a}
20	16.0^{b}	73.0^{a}	24.2^{b}	80.5^{a}
30	20.0^{b}	72.7^{b}	10.0^{c}	79.4^{b}

w/o: Water in oil emulsion; o/w: oil in water emulsion; PRE: protein-rich extract; EMC: emulsification capacity. Figures on same column with same subscripts are not significantly different ($p \leq 0.05$)

are likely to be quite higher for sample C as compared to A and B. The stability was relatively higher for both samples B and C as compared to A. For emulsion production done at Ohmic heating beakers as compared to those prepared in current carrying beaker, the stability 62% is significantly lower than 98% which sample C had (Table 3). Figure 4 shows okra product- hydrolyzed okra seed PRE (sample C) prepared at 200 V, in a current carrying beaker-CB. It had an EMC of 94% and ES of 98%, a combination that was only attempted by gelatin at the same conditions. EMC and ES for sample C remained almost the same at 210, 220, 230, and 240 V (Tables 1 and 2 and Figure 4).

Okra seed PRE in O/W and W/O emulsions

The results of comparative analysis of PRE and gelatin as emulsifier at both 95% oil level (water in oil) and 95% water level (oil in water) situations are shown in Table 3. EMC for both okra seed extract and gelatin were higher at lower oil levels, decreasing steadily with increasing concentration of oil. Balsam (1994) stipulated that this could be a pointer to the fact that okra PRE is a hydrophilic emulsifier. At lower levels of water content (5%), that is, 95% oil content, okra PRE performed better than gelatin. The same happened at 20% water. Maybe due to multiple structural nature of vegetable proteins (particularly after denaturation and other forms of alterations that took place during extraction), the PRE might have more than one structural forms, some of which might be more lipophilic as compared to gelatin.

The dispersed phase in the water in oil (W/O) emulsion is water. At 5% water level, the EMC for PRE is 6 and 1.9 for gelatin. At 10 and 20% oil levels, it is 7.3 and 16.0, and 10.9 and 24.2, respectively for PRE and gelatin. The oil in water version was significantly different. At 10 and 20% oil levels, the EMC (%) for PRE and gelatin were respectively 81.3, 73.0, 86.4, and 80.5. This is an indication to the fact that okra seed PRE just like gelatin are hydrophilic emulsifying agents (Micheal, 1990). This means that the hydrophilic lipophilic balance might be in

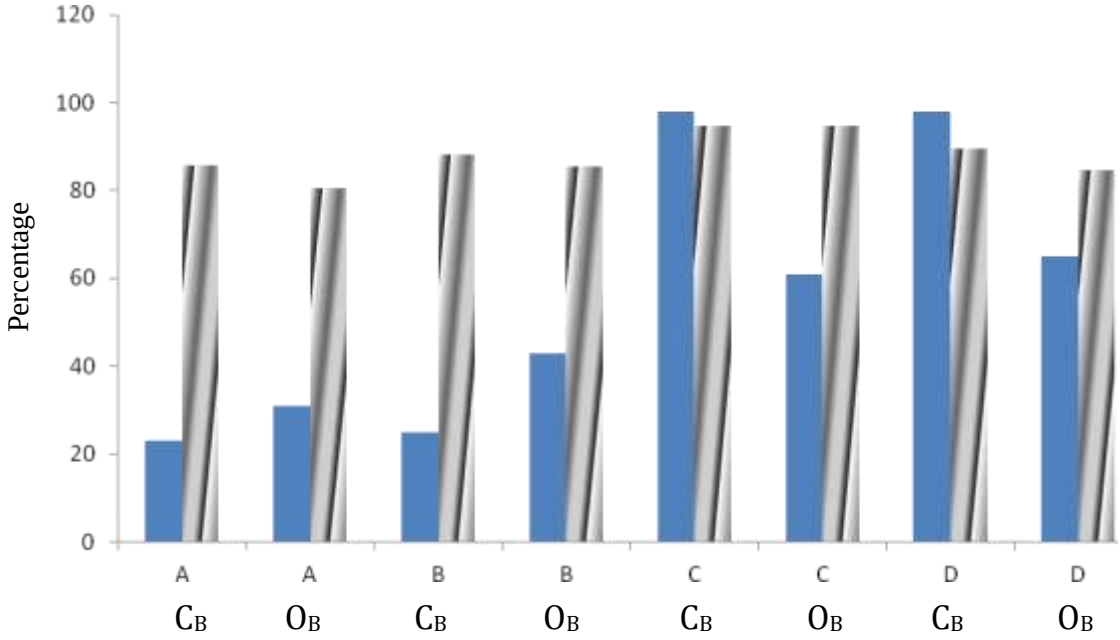

Figure 4. Emulsification capacity and Stability of emulsions (made at 200v). Striped column: emulsification capacity (%); Blue column: emulsion stability (%). CB: Current carrying beaker; OB: Ohmic heating beaker; A: whole okra seed flour; B: protein rich extract (PRE); C: hydrolyzed PRE.

the range of 11 to 12. They are more effective in the preparation of oil in water emulsions like kola cream soups stews, etc.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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Quality of porridge from sub-Saharan Africa evaluated using instrumental techniques and descriptive sensory lexicon - Part 1: Thick (stiff) porridge

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The sensory attributes of thick porridges made from different composite flours in neutral, citric acid or sodium bicarbonate media was identified using instrumental methods and modified quantitative descriptive analysis. The results showed that composite flours with high cassava concentrations had lower pasting temperatures but higher peak, breakdown, final and setback viscosities than the cereal-rich flours. The onset pasting temperatures of alkali-treated slurries were higher ($p < 0.05$) than for the neutral- or acid-treated slurries. Acid-treated slurries had higher ($p < 0.05$) peak viscosities than neutral- or alkali-treated slurries. Acid-treated slurries had higher ($p < 0.05$) breakdown viscosities as compared to the neutral slurries. The toughness and work of shear of thick porridge ranged between 0.21 - 0.58 kg and 0.83 - 5.95 kg·mm, respectively. Thick porridge cooked in alkaline media was significantly darker ($p < 0.05$) than that made in neutral or acid media. Principal component analysis identified four major principal components (PCs) that accounted for 87.6% of the total variance in the sensory attribute data. The principal component scores indicated that the location of each porridge along each of the four scales corresponded with attributes associated with sodium bicarbonate aroma and taste (PC1); cassava aroma and hardness (PC2); colour of thick porridge (PC3); and finger millet/sorghum aroma (PC4). Thick porridges targeting specific consumer groups in sub-Saharan Africa can be developed by appropriate choice of flours and pH thereby forming the basis for commercial production of thick porridges for different population categories in sub-Saharan Africa with diverse sensory expectations of the product.

Key words: Colour, texture, thick porridge, quantitative descriptive analysis.

INTRODUCTION

Thick porridge (also known as stiff porridge) is an important source of calories for millions of people in sub-Saharan Africa. It is also recommended as a functional food for the management of certain non-communicable

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diseases such as type II diabetes (Eli-Cophie et al., 2016; Mlotha et al., 2016). Thick porridge is prepared from straight (that is, unblended) or composite flours of tropical cereals such as finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and maize (*Zea mays*); and roots crops such as cassava (*Manihot esculenta*) (Wanjala et al., 2016; Murty and Kumar, 1995). The porridge is prepared by adding flour to boiling water (20-30% w/v) in increments while vigorously stirring, until it forms a thick, homogenous and well-gelatinized mass devoid of lumps (Murty and Kumar, 1995; Taylor and Emmambux, 2008).

Thick porridge is cooked in neutral, acidic or alkaline media. Neutral thick porridge, which is cooked in water, is known as *ugali* in Kenya, Uganda and Tanzania; *nsima* in Zambia and Malawi; *mafo* in Somalia; *sadza* in Zimbabwe; *mosokwane* (*bogobe*) in Botswana; *tuwo* in Nigeria; *tuo* in Ghana; *boule* in Mauritania and Chad; *bita* in Niger; and *pap* in South Africa (Murty and Kumar, 1995; Anyango et al., 2011). Acidic thick porridge is made by cooking flour in water containing lemon or tamarind pulp, and is known as *tô* in Burkina Faso and Mali and *kunun tsamiya* in Nigeria (Murty and Kumar, 1995; Taylor and Emmambux, 2008). Acidic thick porridge can also be made from spontaneously fermented slurry, and includes *umqo* and *umpokoqo* (or *phuthu*) in South Africa, *motogo wa ting* (*ting* or *bogobe*) in Botswana, *aceda* in Sudan, *dalaki* in Nigeria and *nsima* in Malawi (Mlotha et al., 2016; Murty and Kumar, 1995). Alkaline thick porridge, such as *tô* in Mali, is made by cooking the flour with wood or peanut hull ash extract or potash (Murty and Kumar, 1995; Da et al., 1982; Scheuring et al., 1982).

The sensory character of thick porridge is dependent on the botanical origin of the raw materials and the processing conditions (Anyango et al., 2011; Kebakile, 2008). The most important sensory qualities of thick porridge are a thick and firm texture, non-stickiness and good keeping quality (Murty and Kumar, 1995; Mukuru et al., 1982; Obilana, 1982). Starch, which is the main constituent of thick porridge, has the most influence on its texture. Starch gelatinization gives thick porridge a firm, cohesive and non-sticky texture, which is evaluated by the tactile and kinesthetic senses during moulding in the hand and mastication in the mouth (Onyango, 2014; Bolade et al., 2009; Aboubacar et al., 2006). The pH of thick porridge may also affect its texture. Da et al. (1982) found that thick porridge made in alkali medium was stickier than that made in acid media.

The taste of thick porridge is influenced by its pH. Thick porridge prepared from native unmodified flour has a starchy taste and slightly burnt aroma, whereas acidic thick porridge has a sour taste (Wanjala et al., 2016). Although there is limited published information that describes the characteristic taste or aroma of alkaline-treated porridge, Hou and Kruk (1998) described alkaline-treated noodles as having an ‘alkaline flavour.’

Nonetheless, in most cases, the taste of thick porridge is masked by the side-dishes consumed with it and consequently is not as important as other sensory properties (Murty and Kumar, 1995). Scheuring et al. (1982) noted that taste was the least significant sensory property of alkaline thick sorghum porridge, and consumers tended to judge the porridge quality on the basis of its colour and texture rather than taste.

The colour of thick porridge ranges from white through yellow to dark brown because it is prepared from various combinations of white-coloured cassava, maize and sorghum; and coloured maize, sorghum and millets (Wanjala et al., 2016). The pH of the slurry used to prepare thick porridge may also affect its colour. Thick porridge made in acid medium is lighter in colour than that made in alkaline media (Da et al., 1982, Scheuring et al., 1982). A variation in the expected colour of the product can cause consumers to reject the product even if it is nutritionally superior. Studies conducted in Kenya and South Africa show that consumers prefer thick porridge prepared from white maize rather than yellow maize or the nutritionally superior biofortified yellow maize (De Groote and Kimenju, 2012; Khumalo et al., 2011).

The sensory quality factors of foods that influence consumers’ choices and preferences are measured using instrumental or sensory techniques. Instrumental methods are appropriate where product evaluations are repetitive, fatiguing and dangerous (Kilcast, 2013). However, consumer enjoyment of foods is determined by a wide range of responses from the senses that cannot be fully mimicked by instruments (Kilcast, 2013). In view of some of the limitations of instrumental techniques of evaluating sensory properties of foods, analytical sensory methods such as Quantitative Descriptive Analysis (QDA) that uses trained panellists instead of instruments have been developed. The QDA method gives objective assessment of the sensory properties of foods because panellists are trained to measure specific attributes of a product in a reproducible manner in order to obtain a quantitative product profile that is amenable to statistical analyses (Chapman et al., 2001). The results of QDA are commonly analysed using principal component analysis (PCA), which reduces the set of dependent variables (that is, attributes) to a smaller set of underlying variables (that is, factors) based on patterns of correlation among the original variables (Lawless and Heymann, 2010). The objective of the current study is to use instrumental techniques and modified QDA to evaluate the impact of pH and type of composite flour on the sensory quality of thick porridge. The choice of composite flours used in the current study was derived from the results of a field study done in western Kenya in 2016 (Wanjala et al., 2016).

MATERIALS AND METHODS

Preparation of composite flours and slurries

Maize (*Z. mays*) was purchased from a local market in Kisumu

County, Kenya. Finger millet (*E. coracana* (L) Geartn.) "P224" and sorghum (*S. bicolor* (L.) Moench "IESV 24029-SH" were donated by ICRISAT (Alupe Research Station, Busia, Kenya). The grains were cleaned to remove dirt and foreign matter and milled in a hammer mill fitted with 800 µm sieve to obtain whole-milled flours. Mould-fermented cassava flour (*M. esculenta* Crantz) was purchased in Busia County, Kenya.

Five types of composite flours (cassava-sorghum, 20:80; cassava-sorghum, 85:15; cassava-finger millet, 20:80; cassava-finger millet, 85:15; and cassava-maize, 20:80) were prepared, packed in moisture-proof zip-lock polythene bags and stored at 10°C prior to use. Neutral slurries (pH range: 6.08 - 6.35) were prepared by mixing the composite flours with distilled water. Food-grade anhydrous citric acid (2 g/1,000 ml) was used to prepare acidic slurries (pH range: 3.83 - 4.22). Food-grade bicarbonate of soda (sodium bicarbonate; 8 g/1,000 ml) was used to prepare alkaline slurries (pH range: 7.31 - 7.74).

Pasting properties of composite flours

The pasting properties of the composite flours were measured using a Brabender Viscograph-E (Brabender GmbH and Co. KG, Duisburg, Germany) at 85 rpm and 700 cmg torque. Neutral, acidic or alkaline slurries made up of 40 g flour (adjusted to 14% moisture content) and 420 ml distilled water was added into the Viscograph-E canister. The canister was put in the Viscograph-E heating chamber and the mixing spindles attached. The slurry was heated from 30°C and the temperature increased at 1.5°C/min up to 93°C. The temperature of the slurry was held at 93°C for 15 min before it was decreased at 1.5°C/min up to 30°C and subsequently held at this temperature for 15 min. The resistance to stirring was recorded as viscosity in Brabender Units (BU). The pasting temperature (°C), peak viscosity, time to peak viscosity (min), breakdown viscosity (peak viscosity minus trough viscosity) and setback viscosity (cold paste viscosity minus trough viscosity) were determined from the viscograph.

Objective evaluation of the texture of thick porridge

Thick porridge was made from the composite flours (240 g) and 600 ml water, citric acid or sodium bicarbonate solutions. The water or chemical solution was brought to boil in a stainless steel cooking pan before adding 70% of the flour and heating continued without any intervention until boiling resumed. The rest of the flour was added and the paste gently mixed with the aid of a flat wooden cooking stick (ladle) for 5 min until a homogenous fully hydrated paste devoid of lumps was obtained. The cooking pan was covered and further heated for 5 min while intermittently kneading. The porridge was transferred to a clean wooden surface and shaped into a cylinder. A piece measuring 6 cm diameter and 3.5 cm high was punched out from the porridge using a biscuit cutter. Edible vegetable oil was applied on the inner surface of the biscuit cutter to facilitate easy removal of the thick porridge. The oil was also applied on the surface of the test sample to prevent dehydration. The test sample was incubated in a laboratory incubator (Memmert GmbH + Co. KG, Schwabach, Germany) at 25°C for 2 h to allow for temperature equilibration. The texture of the test sample was evaluated using a TA-XT*plus* Texture Analyzer (Stable Micro Systems, Surrey, UK) equipped with a 50 kg load cell and an extended craft knife probe (A/ECB). Measurement was made at the following conditions: height of the blades from the base of the plate: 40 mm; test speed: 5 mm/s; post-test speed: 5 mm/s; target mode: distance; distance travelled: 19 mm; trigger type: button. The force (N) versus time (s) required by the probe to compress the test porridge was recorded. The toughness (kg) and work of shear (kg·mm) of the thick porridge were calculated using EXPONENT Texture Analysis software version 6.1.5.0 (Stable Micro Systems, Surrey, UK).

Objective evaluation of the colour of thick porridge

Thick porridges were prepared as described above and subsequently dried in a laboratory incubator (Memmert GmbH + Co. KG, Schwabach, Germany) at 70°C to about 10% moisture content. The dried thick porridge was milled using a MRK hummer mill (Mitamura Riken Kogyo Inc., Tokyo, Japan). A Konica Minolta Chroma Meter CR-200 (Minolta Co. Ltd., Osaka, Japan) was used to evaluate the colour of the dehydrated thick porridge flour. Each flour sample (20 g) was put in a clean Petri dish and covered. The equipment was calibrated using the standard white tile provided with the equipment. CIE-LAB-System colour values of light (L* = 100) to dark (L* = 0); red (+a*) to green (-a*); and yellow (+b*) to blue (-b*) were recorded for each sample.

Descriptive sensory evaluation of thick porridge

Thick porridges were prepared as described above using 320 g flour and 400 ml water or chemical solution. After cooking, the thick porridge was cooled to 30ºC and served in white plastic plates. Eight students from local universities were recruited to undertake descriptive sensory evaluation of the thick porridges. They were given a consent form to sign, listing ingredients in the products and possible allergens. The study was done in a well-ventilated laboratory at 25±1ºC. Since sensory booths were not available, the panellists were spaced 2 m apart to avoid interaction. The panellists were trained for 10 sessions. The first five sessions consisted of attribute generation, whereby the panellists listed all sensory attributes present in the porridges. The panel generated 18 descriptive terms (Table 1). The next five sessions involved identifying references (Table 1) that fit the sensory attributes of thick porridge and rating them on 100 mm unstructured line scales for intensity. The panellists rinsed their mouth with mineral water before testing each sample and in between the tests. Samples were given randomized three-digit codes and served monadically in random order with a 5 min break between each sample evaluation. All attributes of a specific sample were evaluated before the next sample was served. Panel sessions were repeated until all samples were scored in triplicate.

Experimental design and statistical analysis

The instrumental experiments were set-up as a 5×3 factorial combination in a randomized complete block design. The treatment combinations consisted of five types of composite flours at three pH levels (neutral, acidic and alkaline). Each treatment was conducted in triplicate and the results reported as mean ± standard deviation. The data were analysed using a two-way factorial analysis and further analysis done using a one-way factorial analysis. The sensory evaluation data was analysed using PCA in a covariance matrix with the product in rows and the mean panellists and replication scores for the 18 sensory attributes in columns. All data were analysed with Minitab Release 14 (Minitab Inc., Pennsylvania, USA).

RESULTS AND DISCUSSION

Pasting properties of composite flours

The pasting properties of the composite flours in neutral, acidic or alkaline media are presented in Table 2.

Table 1. Descriptive sensory lexicon developed by the sensory panel to evaluate the quality of thick porridge.

Attribute	Description	Reference and rating scale
Appearance		
Colour	Perception of colour ranging from white to dark brown	Cassava starch (10% w/v) stirred in hot water = 0 (white) [a]Baker's dark compound chocolate = 10 (dark brown)
White specks	Quantity of white specks on the surface of porridge	0 = No white specks 10 = Many white specks
Brown and dark specks	Quantity of brown and dark specks on the surface of porridge	Cassava starch (30% w/v) stirred in hot water = 0 (no dark specks) [b]Indian hemp hair and scalp treatment oil = 7 (many dark specks)
Gloss	Perception of a shiny appearance on the surface of porridge	[c]Brookside farm fresh milk (fat content 3%) = 0 (not glossy) Pure glycerin for cosmetic application = 10 (very glossy)
Aroma		
Cassava aroma	Aroma characteristic of cassava flour in hot water	Cassava flour (30% w/v) stirred in hot water = 10 (very intense)
Finger millet aroma	Aroma characteristic of finger millet flour in hot water	Whole-milled finger millet flour (30% w/v) stirred in hot water = 10 (very intense)
Maize aroma	Aroma characteristic of maize flour in hot water	Whole-milled maize flour (30% w/v) stirred in hot water = 10 (very intense)
Sorghum aroma	Aroma characteristic of sorghum flour in hot water	Whole-milled sorghum flour (30% w/v) stirred in hot water = 10 (very intense)
Sodium carbonate aroma	Aroma characteristic of sodium carbonate cooked in starch slurry	0 = No characteristic smell 10 = intense characteristic smell
Taste		
Sour taste	Intensity of sour taste associated with fermented milk	[c]Brookside farm fresh milk (fat content 3%) = 0 (not sour) [d]Bio yoghurt natural (fat content 3%) = 5 Whole-milled maize porridge (10% w/v) cooked in citric acid solution 1% w/v = 10
Soapy taste	Intensity of taste associated with soap in water	No soapy taste = 0 Soapy taste = 10
Texture		
Hardness	Force required to compress porridge between the thumb and index finger	Cassava porridge (28% w/v) = 0 (soft) Maize porridge (28% w/v) = 10 (hard)
Adhesiveness	Degree to which porridge particles remain sticking on the hand after rolling a piece of it between the fingers and palm of the hand into a ball	0 = Not adhesive 10 = Very adhesive
Gumminess	Degree of mastication required before the food disintegrates and is ready for swallowing	Maize porridge (28% w/v) = 0 (mealy, 5 chews before swallowing) Cassava porridge (28% w/v) = 10 (gummy, 10 chews before swallowing)
Coarseness	Degree to which particles are perceived in the mouth during mastication	Honey = 0 (not perceived) Fresh pressed, unsieved carrot juice = 10

Table 1. Contd.

After swallow		
Sour aftertaste	Perception of lingering sourness in the mouth after mastication and swallowing	0 = No sour aftertaste 10= Strong sour aftertaste
Soapy aftertaste	Perception of lingering saltiness in the mouth after mastication and swallowing	0 = No soapy aftertaste 10= Strong soapy aftertaste
Residual particles	Amount of material left between teeth after mastication and swallowing	Water melon = 0 (no residual particles) Fresh pressed, unsieved carrot juice = 10 (many residual particles)

[a]PT Gandum Mas Kencana, Tangerang, Indonesia; [b]Dynamix Trading Ltd., London , Britain; [c]Brookside Dairy Ltd., Ruiru, Kenya; [d]Bio Food Products Ltd., Nairobi, Kenya.

Cassava-rich slurries tended to have lower pasting temperatures but higher peak, breakdown, final and setback viscosities than cereal-rich slurries. The different pasting behaviours of the composite flours reflected the influence of the predominant flour in the mixtures. Swelling of starch granules and the attainment of peak viscosity is largely associated with the amylopectin fraction of starch, whereas amylose-lipid complexes inhibit granule swelling and decrease the peak, breakdown and final viscosities of flours (Morrison et al., 1993; Tester and Morrison, 1990; Blazek and Copeland, 2008). Thus, the high content of branched-chain amylopectin polymers and low lipid content in cassava flour as compared to cereal flours (Breuninger et al., 2009) enable it to swell more readily and acquire higher peak, breakdown, final and setback viscosities.

Two-factor analysis of variance showed that the interaction effect between the type of composite flour and pH was significant ($p < 0.05$) for pasting temperature (°C), peak viscosity (BU), time to peak viscosity (min), breakdown viscosity (BU), final viscosity (BU) and setback viscosity (BU). The simple main effects of pH on the pasting properties of the composite flours showed that the onset pasting temperatures of alkali-treated slurries were higher ($p < 0.05$) than for the neutral- or acid-treated slurries. These results are in agreement with those of Karim et al. (2008) and Cai et al. (2014). Karim et al. (2008) postulated that sodium hydroxide increases the pasting temperature of starch through diffusion of sodium ions into the starch granules and subsequent stabilisation of the granule through electrostatic interactions between sodium ions and the hydroxyl groups of starch. Alkali-treated cassava-sorghum (20:80) and cassava-maize (20:80) slurries had significantly lower ($p < 0.05$) peak viscosity as compared to the neutral slurries. Alkali treatment significantly decreased ($p < 0.05$) the setback viscosity of cassava-sorghum (20:80) and cassava-maize (20:80) slurries as compared to the neutral slurries. Alkali attacks the amorphous regions of starch thereby increasing leaching of amylose polymers and facilitating depolymerization of starch, which results in decreased peak, breakdown, setback and final viscosities (Karim et al., 2008; Nadiha et al., 2010; Wang and Copeland, 2012; Israkarn et al., 2014).

The pasting temperature of cassava-sorghum (20:80) and cassava-sorghum (85:15) slurries treated with citric acid were significantly lower ($p < 0.05$) than those of neutral slurries. Acid-treated slurries had significantly higher ($p < 0.05$) peak viscosities than neutral- or alkali-treated slurries.

In addition, the acid-treated slurries had significantly higher ($p < 0.05$) breakdown viscosities than the neutral slurries. The effect of organic acids on the rheological properties of starch is dependent on the degree of pH adjustment. Hirashima et al. (2005) reported that when the pH of corn starch is lowered to 3.6 using citric acid, leaching of amylose and amylopectin polymers increases resulting in higher paste viscosity. By contrast, pH values lower than 3.5 promotes hydrolysis of amylose and amylopectin polymers resulting to decreased paste viscosity (Hirashima et al., 2005). The final viscosities of cassava-finger millet (85:15) and cassava-maize (20:80) slurries significantly increased ($p < 0.05$) after treatment with citric acid. These results partially agree with those of Hirashima et al. (2004, 2012) who noted that organic acids accelerate retrogradation of starch gels by promoting faster re-association of shorter chains.

Objective evaluation of the texture of thick porridge

The toughness and work of shear of thick porridge made from the composite flours in neutral, acidic or alkaline media ranged between 0.21 - 0.58 kg and 0.83 - 5.95 kg·mm, respectively (Table 3). Two-factor analysis of variance showed that the

Table 2. Pasting properties of composite flours segregated by pH.

Treatment (pH)	PT (°C)	PV (BU)	Time PV (min)	BV (BU)	FV (BU)	SV (BU)
Cassava-sorghum (20:80)						
Neutral[1] (6.35)	84.1±0.6^{b}	282±8	43.6±0.4^{a}	7±6^{a}	450±18^{b}	221±25^{b}
Citric acid[2] (3.83)	80.2±0.1^{a}	313±1	42.7±0.0^{a}	97±4^{b}	423±2^{b}	232±1^{b}
Sodium bicarbonate[3] (7.74)	91.2±0.1^{c}	294±13	56.6±0.4^{b}	0±0^{a}	218±21^{a}	-64±9^{a}
Cassava-sorghum (85:15)						
Neutral (6.17)	68.9±0.4^{b}	607±16^{a}	43.9±0.1^{ab}	93±5^{a}	830±51^{ab}	347±40
Citric acid (4.01)	67.0±0.1^{a}	761±5^{c}	43.1±0.4^{a}	307±1^{b}	728±9^{a}	314±4
Sodium bicarbonate (7.66)	81.4±0.3^{c}	663±1^{b}	44.5±0.2^{b}	110±11^{a}	867±14^{b}	368±0
Cassava-finger millet (20:80)						
Neutral (6.23)	77.4±1.7	365±3^{a}	43.7±0.0	44±9	496±18^{ab}	183±24
Citric acid (4.22)	79.2±0.1	381±1^{b}	43.3±0.1	78±1	532±1^{a}	233±1
Sodium bicarbonate (7.55)	79.3±0.9	361±3^{a}	44.2±0.7	49±17	480±5^{b}	174±11
Cassava-finger millet (85:15)						
Neutral (6.22)	68.2±0.3^{a}	552±4^{a}	43.2±0.0	121±6^{a}	728±13^{a}	314±17
Citric acid (3.85)	67.3±0.1^{a}	744±0^{b}	43.6±0.1	247±0^{b}	815±1^{b}	352±0
Sodium bicarbonate (7.38)	72.3±0.1^{b}	722±11^{b}	40.8±1.5	263±1^{c}	695±14^{a}	335±7
Cassava-maize (20:80)						
Neutral (6.08)	88.5±0.2^{a}	82±4^{b}	54.8±0.8^{c}	0±0^{a}	149±0^{b}	81±5^{b}
Citric acid (4.07)	88.5±0.1^{a}	135±0^{c}	49.4±0.3^{b}	9±0^{b}	205±1^{c}	117±1^{c}
Sodium bicarbonate (7.31)	93.2±0.1^{b}	26±0^{a}	42.7±0.1^{a}	16±2^{c}	13±2^{a}	2±0^{a}

[1]Neutral slurry (10% w/v) prepared using distilled water; [2]Acidic slurry (10% w/v) prepared using anhydrous citric acid in distilled water (2 g/1000 ml); [3]Alkaline slurry (10% w/v) prepared using sodium bicarbonate in distilled water (8 g/1000 ml). PT – pasting temperature; PV – peak viscosity; Time PV – time to peak viscosity; BV – breakdown viscosity; FV – final viscosity, SV – setback viscosity, BU – Brabender Units. Values having superscripts of the same letter in the same column for each type of composite flour are not significantly different at $p < 0.05$. Data sets without superscript letters for each type of composite flour are not significantly different at $p < 0.05$.

interaction effect between the type of composite flour and pH was significant ($p < 0.05$) for toughness (kg) and work of shear (kg·mm) of the thick porridges. The simple main effect of pH had a significant effect ($p < 0.05$) on the toughness of all thick porridges, whereas work of shear was significant ($p < 0.05$) for thick cassava-finger millet (85:15) and cassava-maize (20:80) porridges only (Table 3). The relative proportion of cassava versus cereal flours in the composite flours has a major influence on the texture of thick porridge.

Unblended cassava flour is unsuitable for making thick porridge because it gives a gummy product that is difficult to knead in the hand and masticate. Cereals on the other hand, give very firm and cohesive thick porridges. However, when cassava is mixed with cereal flours in appropriate ratios, cassava flour decreases the firmness and cohesiveness of thick porridge, whereas cereal flours decrease its gumminess (Wanjala et al., 2016). It is difficult to compare our data with previous published studies on the texture of thick porridge because of different sample preparation and measurement techniques (Onyango, 2014; Anyango et al., 2011). Therefore, it is necessary to develop standard methods for evaluating the texture of thick porridge.

Objective evaluation of the colour of thick porridge

The degree of lightness, redness and yellowness of thick porridges cooked in neutral, acidic or alkaline media are shown in Table 3. Irrespective of the pH, cassava-maize (20:80) porridges were the least dark (that is, had the highest L* values), least red (that is, had the lowest a* values) and most yellow (i.e. had the highest b* values). The intense yellow colour of cassava-maize porridge treated with sodium bicarbonate can be attributed to the reaction of the alkali with colourless flavonoids in white maize kernels (Morris et al., 2000). A similar reaction is responsible for the characteristic yellow colour of noodles made from wheat flour treated with sodium hydroxide (Hou and Kruk, 1998). Yao et al. (2006) suggested that the yellow colour that develops when wheat dough is treated with sodium hydroxide and when making pretzels is not due to flavonoids in the flour, but is rather caused

Table 3. Texture and colour of thick porridges segregated by pH.

Treatment (pH)	Toughness (kg)	Work of shear (kg·mm)	Colour		
			L*	a*	b*
Cassava-sorghum (20:80)					
Neutral[1] (6.35)	0.41±0.02^{ab}	3.15±0.12	57.4±0.5^{b}	7.7±0.1^{b}	9.8±0.3^{b}
Citric acid[2] (3.83)	0.49±0.10^{b}	3.06±1.44	57.9±0.5^{b}	7.7±0.1^{b}	10.7±0.5^{b}
Sodium bicarbonate[3] (7.74)	0.34±0.02^{a}	1.94±0.25	50.2±0.5^{a}	6.3±0.1^{a}	6.2±0.2^{a}
Cassava-sorghum (85:15)					
Neutral (6.17)	0.33±0.04^{a}	2.79±0.61	68.0±0.9^{b}	5.2±0.2^{a}	11.5±0.2^{a}
Citric acid (4.01)	0.38±0.03^{ab}	2.33±0.37	66.5±0.6^{b}	6.7±0.1^{b}	13.5±0.4^{b}
Sodium bicarbonate (7.66)	0.40±0.04^{b}	3.02±0.99	60.0±0.4^{a}	7.8±0.2^{c}	11.2±0.2^{a}
Cassava-finger millet (20:80)					
Neutral (6.23)	0.28±0.04^{a}	2.50±0.72	55.6±0.7^{b}	5.8±0.1^{b}	8.6±0.2^{a}
Citric acid (4.22)	0.43±0.05^{b}	3.27±0.89	61.0±0.1^{c}	7.0±0.2^{c}	10.7±0.1^{b}
Sodium bicarbonate (7.55)	0.41±0.02^{b}	2.88±0.46	52.1±0.6^{a}	5.1±0.2^{a}	7.9±0.7^{a}
Cassava-finger millet (85:15)					
Neutral (6.22)	0.34±0.07^{b}	2.92±0.75^{b}	67.8±1.5^{b}	4.4±0.1^{a}	14.1±0.3
Citric acid (3.85)	0.21±0.04^{a}	1.09±0.38^{a}	68.8±1.0^{b}	4.3±0.3^{a}	13.6±0.2
Sodium bicarbonate (7.38)	0.58±0.05^{c}	5.95±0.86^{c}	63.2±0.7^{a}	5.9±0.2^{b}	13.7±0.4
Cassava-maize (20:80)					
Neutral (6.08)	0.20±0.02^{a}	1.84±0.19^{b}	78.6±0.6^{b}	2.3±0.3^{a}	19.9±0.8^{b}
Citric acid (4.07)	0.22±0.01^{a}	0.83±0.24^{a}	80.5±0.0^{c}	2.3±0.1^{a}	17.7±0.6^{a}
Sodium bicarbonate (7.31)	0.32±0.04^{b}	2.12±0.92^{b}	67.7±0.2^{a}	3.4±0.2^{b}	21.9±0.5^{c}

L*: lightness; a*: redness; b*: yellowness; [1]Neutral slurry (10% w/v) prepared using distilled water; [2]Acidic slurry (10% w/v) prepared using anhydrous citric acid in distilled water (2 g/1000 ml); [3]Alkaline slurry (10% w/v) prepared using sodium bicarbonate in distilled water (8 g/1000 ml). Values having superscripts of the same letter in the same column for each type of composite flour are not significantly different at $p < 0.05$. Data sets without superscript letters for each type of composite flours are not significantly different at $p < 0.05$.

by the reaction within or between the starch and protein hydrolysis derivatives.

Two-factor analysis of variance showed that the interaction effect between the type of composite flour and pH was significant ($p < 0.05$) for lightness, redness and yellowness of the thick porridges. The simple main effect of pH was significant ($p < 0.05$) for lightness, redness and yellowness of all thick porridges except yellowness of cassava-finger millet (85:15) porridge. Thick porridge cooked in sodium bicarbonate media was significantly darker ($p < 0.05$) than that made in neutral or acid media for all samples. The colour of pigmented grains is associated with the presence of phenolic acids in the pericarp (Kobue-Lekalake, 2008; Liu et al., 2010). The phenolic pigments in coloured grains stain thick porridge with a dark colour during cooking (Kebakile, 2008;

Anyango et al., 2011). In addition, non-enzymatic browning from Maillard-type reaction products that develop during heating also contributes to the dark colour of thick porridge (Martins et al., 2001; Pathare et al., 2013). The dark colour of thick porridges cooked in sodium bicarbonate solution could also be attributed to the radical-mediated reaction of the phenolic compounds in these cereals with sodium bicarbonate to form highly rearranged and oxidatively-coupled products (Beta et al., 2000).

Descriptive sensory evaluation of thick porridge

Modified QDA was used to describe the sensory attributes of thick porridges made from composite flours in neutral, acidic or alkaline media. The panellists identified 18 sensory attributes in the thick porridges. The data was analysed using PCA in order to identify the number of fundamentally different sensory properties of the thick porridges. Principal component analysis identified three major principal components (PCs) that accounted for 87.6% of the variance in the sensory attribute data (Table 4). These PCs were used to explain the relationships between the variables. Loadings with absolute values greater than 0.449 (marked with an

Table 4. Principal component factor loadings for sensory attributes of thick porridge.

Attribute	PC1	PC2	PC3	PC4
Colour	-0.237	-0.095	-0.621*	0.168
White specks	0.107	-0.059	0.199	0.041
Dark specks	0.018	-0.214	-0.140	-0.379
Gloss	0.006	-0.348	0.118	-0.095
Cassava aroma	0.229	-0.454*	0.193	0.121
Finger millet aroma	0.074	-0.004	-0.399	-0.595*
Maize aroma	0.186	0.383	0.376	-0.106
Sorghum aroma	0.085	0.083	-0.302	0.626*
Sodium bicarbonate aroma	-0.656*	0.035	0.181	-0.050
Sour taste	0.227	0.038	0.038	-0.033
Soapy taste	-0.527*	0.024	0.147	-0.040
Hardness	-0.013	0.449*	0.029	0.086
Adhesiveness	0.079	-0.002	-0.120	-0.047
Gumminess	-0.072	-0.338	0.156	0.101
Coarseness	0.039	0.329	-0.088	-0.131
Sour aftertaste	0.102	0.004	0.025	-0.019
Soapy aftertaste	-0.215	0.001	0.058	-0.010
Residual particles	0.062	0.182	-0.067	-0.063
Variance (%)	35.5	25.6	17.3	9.2
Cumulative variance (%)	35.5	61.0	78.4	87.6

*Loadings with absolute values greater than 0.449.

asterisk) represented a strong influence on the thick porridges and implied that the PC was related to those variables. The first PC accounted for 35.5% of the variance and distinguished alkali-treated thick porridges from acid-treated or neutral thick porridges (Figure 1a). Alkali-treated thick porridges were located on the left side of the PC plot, whereas acid-treated and neutral thick porridges were on the right side (Figure 1a). The loading plot shows the mutual relations among the variables (Figure 1b). The alkali-treated thick porridges were notable for their sodium bicarbonate aroma (loading value -0.656) and soapy taste (loading value -0.527) (Figure 1b).

The second PC accounted for 25.6% of the variance in the sensory attribute data (Table 4). It distinguished the thick porridges on the basis of cassava aroma (loading value -0.454) and hardness (loading value 0.449). Thick porridges located on the upper part of the PC plot had low cassava and high cereal concentrations, whereas those in the lower part of the PC plot had low cereal and high cassava concentrations (Figure 1a). The thick cassava-rich porridges had a stronger cassava aroma and were less firm than their cereal-rich counterparts. In addition, thick cassava-rich porridges had a glossy appearance and gummy texture while their cereal-rich counterparts had a coarse mouth-feel (Figure 1b). Cassava is normally mixed with cereal flours when making thick porridge in order to decrease the perception of coarse particles in the mouth caused by cereals (Wanjala et al., 2016). The coarse mouthfeel of thick cereal porridges is due to the lignocellulosic layers, large particles and insoluble fibre (Heiniö, 2009). Kebakile (2008) found that firmness of sorghum porridge is affected by the amount of coarse endosperm particles. Coarse particles absorb water slowly and thereby restrict swelling of starch granules, resulting in a high proportion of non-ruptured gelatinised starch granules that reinforce the porridge matrix (Kebakile, 2008). Kebakile (2008) also reported that corneous sorghum varieties with high protein content give firmer porridges due to the presence of a hard and less water-permeable protein-starch matrix in the endosperm meal particles.

The third PC accounted for 17.3% of the variance in the sensory attribute data (Table 4). This PC was associated with the colour (loading value -0.621) of the raw materials (white maize and cassava versus dark coloured finger millet or sorghum) and the colour developed when the composite flours were cooked in neutral, acidic or alkaline media. These findings were in agreement with the instrumental colour results reported in the instrumental analysis of colour (Table 3).

The fourth PC accounted for 9.2% of the variance in the sensory attribute data (Table 4). This PC was associated with a large negative loading value for finger millet aroma (-0.595) and a large positive loading value for sorghum aroma (0.626). Variables located close to

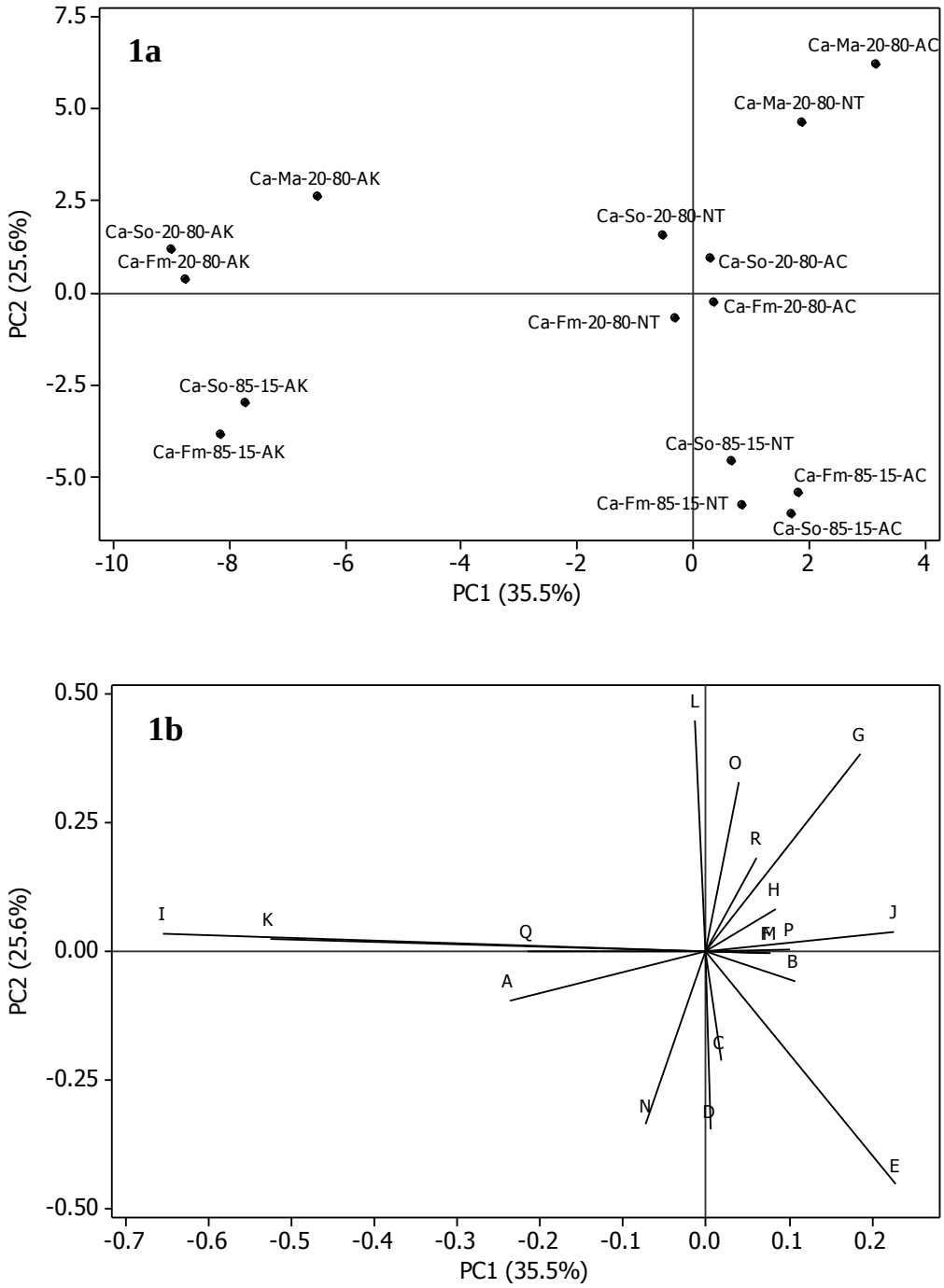

Figure 1. Principal component analysis of thick porridge. (a) Plot of the first two principal component scores of composite flours used to prepare thick porridge (b) Plot of the first two principal component loading vectors of sensory attributes of thick porridge. Ca: cassava; So: sorghum; Fm: finger millet; Ma: maize; AC: acid; AK: alkali; NT: neutral. The numbers refer to the ratios of the flours used to prepare the composite flours. A: colour; B: white specks; C: dark specks; D: Gloss; E: cassava aroma; F: finger millet aroma; G: maize aroma; H: sorghum aroma; I: sodium bicarbonate aroma; J: sour taste; K: soapy taste: L: hardness; M: adhesiveness; N: gumminess; O: coarseness; P: sour aftertaste; Q: soapy aftertaste; R: residual particles.

each other on the loading plot are positively correlated, whereas variables located opposite each other are negatively correlated (Destefanis et al., 2000). Thus, the locations of the loading values for sorghum and finger millet aroma imply that the aroma of the grains are located far apart in the PC space and are caused by different

chemical constituents.

Small loadings (that is, values close to zero) are also a source of valuable information in the interpretation of PCA data because they indicate that the PC is not related to those variables (Lawless and Heymann, 2010). Thus, the low loading value across all PCs for adhesiveness, sour aftertaste and perception of residual particles in the mouth after swallowing (Table 4) indicate that these were insignificant sensory attributes of thick porridge. Well-prepared thick porridge should have a firm texture and not exhibit adhesiveness when it is kneaded in the hand (Onyango, 2014; Murty and Kumar, 1995). The sour aftertaste of thick porridge treated with citric acid may have been an insignificant sensory property because of the low content of citric acid in the porridge. Nonetheless, in normal circumstances thick porridge is consumed with side-dishes and hence flavour is a minor sensory attribute because it is masked by the flavour of the accompanying food (Murty and Kumar, 1995). The perception of residual particles in the mouth after swallowing thick porridge was an insignificant sensory attribute possibly because of the dense mealy texture of thick porridge and its high moisture content.

Conclusion

The diversity of thick porridges consumed in sub-Saharan Africa can be differentiated using instrumental and sensory techniques in order to identify important sensory attributes. Pasting properties of the slurries, and the texture and colour of the porridges were affected by the pH. Aroma, hardness and colour were identified as the major sensory attributes of thick porridges. Thus, thick porridges targeting specific consumer groups in sub-Saharan Africa can be developed by appropriate choice of flours and pH. These findings can form the basis for commercial production of thick porridges for different population categories in sub-Saharan Africa with diverse sensory expectations of the product.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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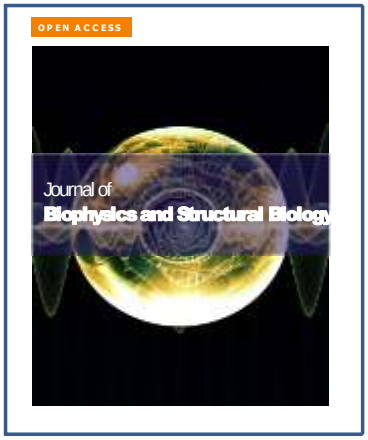

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