

irrespective of age or social status.

Nigeria is a leading producer of sweet potato in Africa with an estimated production of 3.3 metric tonnes per year, and second in the world, next to China (FAOSTAT, 2012). The sweet potato root possesses a variety of chemical compounds which are relevant to the use of sweet potato as a food, from the viewpoint of nutrition, quality or processing. Approximately 80-90% of the dry matter of the storage roots is composed of carbohydrates consisting of starch, sugars and lesser amounts of pectins, hemicelluloses and cellulose. This composition influences quality factors such as taste, texture, firmness and mouthfeel (Woolfe, 1992). Sweet potato has a low glycaemic index, indicating low digestibility of the starch despite its high carbohydrate content (ILSI, 2008). Sweet potato contains functional components such as polyphenolics, anthocyanins, fibre and carotenoids which serve physiological functions such as anti-oxidation, anti-diabetes, anti-hypertension (Yoshimoto, 2010).

The production and nutritional potentials identified with the sweet potato crop are still underexploited in Africa, especially in Nigeria (Akoroda and Egeonu, 2009). Development of products such as crisps, from sweet potato could be a way of expanding utilization among consumers. However, in spite of the potentials of sweet potato crisps as a nutritious snack food, several problems related to quality of the finished product need to be addressed. As reviewed by Akpapuman and Abiante (1991), problems identified were darkening of the surface of the chips after peeling which intensified with deep-fat frying, as well as lack or loss of crispness following deep-fat frying. A review by Woolfe (1992) also identified fac-

tors such as excessive browning during frying which resulted in discoloration of the chips, oiliness, chip hardness and lack of crispness. These problems have also been associated with fried potatoes, and this had led earlier researchers to employ various pre-treatment conditions to improve the quality of the fried products. For instance, Rani & Chauhan (1995) blanched potato slices in a boiling solution of potassium metabisulphite (0.05%) for 3 min to prevent browning. Potato slices were washed and dried on paper towel before frying to get rid of free starches on the surface (Sahin, 2000). Sweet potato slices were dipped into a solution of varying concentrations of sodium chloride, citric acid and potassium metabisulphite for 10 mins for varying purposes such as prevention of enzymatic browning, provision of an acidic medium and as an antioxidant and thereby improve the quality of the fried chips (Singh *et al.*, 2003). The reports by the various authors were based on either the use of one pre-treatment or compared the effect of a few chemicals. Comparing the effect of different forms of pretreatment on the same product is expected to assist in selecting an appropriate condition that will give a product with specific desired attributes such as low oil and moisture contents as well as acceptable crispness. Therefore, the objective of this study was to evaluate the effect of some pre-frying treatments on the composition and sensory attributes of sweet potato crisps.

## MATERIALS AND METHODS

### *Sweet potato roots*

Sweet potato roots were purchased from Mile 12 market in Lagos, Lagos State. The oval-shaped roots were of medium size with yellow skin and cream-coloured flesh.

**Production of sweet potato crisps**

The roots were thoroughly washed under running potable water and peeled manually with a stainless steel kitchen knife. The peeled roots were sliced into discs of 1.2 mm thickness using a plantain slicer (Model No. 714.216 Mother's Choice, Houston, Texas). The slices were divided into five batches. Five different pre-treatment conditions were used; (i) blanched at 93 °C for 2 min, (ii) blanched at 93 °C for 2 min in 1% (w/v) NaCl, (iii) dipped in 1% (w/v) ascorbic acid for 2 min, (iv) dried at 80 °C for 15 min in a cabinet dryer, and (v) untreated sample served as control. Each batch was subjected to a pretreatment. The batches that involved dipping in solution were drained and surface dried on paper towel before frying. Each of the pretreated batch (100 g) of sweet potato slices were fried in a 2.5 L capacity deep-fat fryer (Model: Platinum PL-DF-2.5L, China) at 170 °C for 3 min. Pure refined, bleached and deodorized vegetable oil (King's brand) from Malaysia was used as the frying medium. The oil was preheated to the frying temperature prior to frying. The fried crisps were drained in a sieve and thereafter spread on layers of paper towel to absorb excess oil. The sweet potato crisps were allowed to air cool to room temperature (30 ±2 °C) and then packaged in high density polyethylene bags (0.06 mm) to prevent moisture loss before quality analysis.

**Compositional Analysis**

Moisture content of sweet potato crisps was determined by the oven-drying AOAC Method 934.01, procedure 4.1.03, (AOAC, 2000). Crude protein was determined by using Kjeldahl technique (AOAC Method 955.04, 2.4.03) for determination of the total nitrogen in the sample followed by multiplication of the nitrogen value by a 6.25

(AOAC, 2000). Oil content was determined as the crude fat using Method 920.39, 4.5.01 (AOAC, 2000). Ash was determined by Method 900.02 (AOAC, 2000). Reducing sugar was determined by the Lane-Eynon method, by titration in the presence of methylene blue (AOAC Method 923.09, 14<sup>th</sup> Ed.) Vitamin C was determined by the 2,6-Dichlorophenolindophenol titration method (AOAC Method 967.21, 45.1.14).

**Sensory analysis**

The sweet potato crisps were subjected to product test by a 10-member semi-trained panel. The panellists assessed the colour, taste, flavour and crispness using the 'difference from control' test on a scale of 0 = 'no difference' to 4 = 'extreme difference' (Watts *et al.*, 1989). Overall acceptability test was also conducted by using an in-house consumer panel comprising of 30 untrained undergraduate students who were regular consumers of sweet potato, using a '9-point hedonic scale' (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely) (Watts *et al.*, 1989).

**Statistical Analysis**

Data generated from compositional and sensory analysis were subjected to an 'Analysis of variance' test to determine if significant differences ( $p < 0.05$ ) exist among the samples as a result of the pretreatment. Duncan's multiple range test was used to separate means where differences existed. Pearson's correlation coefficient was computed to determine significant ( $p < 0.05$ ) relationship between composition and sensory attributes of sweet potato crisps. Statistical packages used were Microsoft Excel and SPSS Version 17.0 (SPSS Inc., Chicago, IL, USA).

## RESULTS AND DISCUSSION

Composition of sweet potato crisps varied significantly with pretreatment ( $p < 0.05$ ) (Table 1). The moisture content of the crisps ranged between 1.13 and 4.93%. Values of composition of sweet potato crisps is limited in literature, however, Singh *et al.* (2003) reported a range of 7.32-14.21% for moisture content of sweet potato crisps produced from slices of 1.5 mm thickness, frying temperature of 165-185 °C, frying

time of 20-60 sec and different chemical pretreatments. The low values reported in the present study could be as a result of the lower slice thickness as well as the differences in frying conditions and pretreatment. Moisture content of 23.50-52.67 % was reported for French fries from five cultivars of sweet potato (Odenigbo *et al.*, 2012) while sweet potato chips pre-dried at 70 °C and varying drying times of 0-165 min had moisture values of 13.63-69.52% (Akpapunam and Abiante, 1991).

**Table 1: Composition of sweet potato crisps as influenced by pretreatment**

Pretreatment	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Reducing Sugar (%)	Vitamin C (mg/100g)
1	2.74c	0.43b	20.87b	1.30d	2.61a	22.42a
2	4.93d	0.97d	31.68d	0.42b	2.67a	22.77b
3	4.93d	0.90d	32.00e	0.18a	3.07b	27.98d
4	2.12b	0.60c	21.83c	0.90c	3.30c	27.87c
5	1.13a	0.31a	18.50a	2.10e	3.07b	35.25e

Values are means of two replicates. Values followed by the same alphabet within a column are not significantly different from one another ( $p > 0.05$ ). 1- Control (No pretreatment); 2- Blanched at 93 °C for 2 min; 3- Blanched at 93 °C for 2 min in 1% (w/v) NaCl; 4- Dipped in 1% w/v Ascorbic acid for 2 min; 5- Dried at 80 °C for 2min.

Low moisture content is expected to be an advantage towards crispiness and increased shelf stability of the fried product. Drying pretreatment gave crisps with the least moisture content while blanching gave the highest values. There was no significant difference in moisture content between blanching with or without NaCl solution.

The protein content of the sweet potato crisps ranged between 0.31 and 0.97%. A similar trend to that of moisture content was observed, with drying and blanching

pretreatments giving the lowest and highest values respectively. Also, there was no significant difference in the protein content of the crisps blanched with or without NaCl solution. French-fried sweet potato chips had protein values of 2.88-7.74% (Odenigbo *et al.*, 2012). Sweet potato root is normally not a major source of protein; however the use of protein-enriched varieties as currently developed (ILSI, 2008) could improve the protein content of products such as crisps.

The fat content of the sweet potato crisps

ranged from 18.50 to 32.00%. These values were within the range of 22.74 and 35.63% (Rani and Chauhan, 1995) but lower than 35.77-39.44% (Kita, 2002) for potato crisps. The values were however higher than 2.57-22.22% for sweet potato crisps (Singh *et al.*, 2003). Drying pretreatment gave the lowest value while blanching gave the highest values. Also, the use of NaCl solution for blanching resulted in a significantly higher value ( $p < 0.05$ ) of fat in the crisps. It has been reported that blanching, which increases moisture content, can increase undesirable oiliness of chips, and that the problem is made worse by the use of low dry matter cultivars and very thin slices (Woolfe, 1992). Although the dry matter content of the cultivar used in this study was not determined, the high fat content of the resulting crisps may be due to the thin slices used, amongst other factors including type of oil. For instance, Rani and Chauhan (1995) studied the effect of intermittent frying and frying medium on quality of sweet potato chips (crisps) and reported that quantity of fat absorbed did not vary much due to intermittent frying, but the frying medium altered the fat absorption by the chips with samples fried in refined groundnut oil exhibiting higher fat absorption than those fried in refined soya bean oil. Deep-fat frying involves the transfer of heat from the surrounding oil to the interior of a food product. In addition to heat transfer, mass transfer takes place, and is characterized by the movement of oil into the product, and movement of water in the form of vapour from the product into the oil (Singh *et al.*, 2003). Fat values reported by Odenigbo *et al.* (2012) for sweet potato French fries were 6.90-15.54%. According to Lamberg *et al.* (1990), fat uptake during deep fat frying of potato strips (French fries) was affected by pretreatment and frying time. The highest

fat content was observed for blanched undried potato strips. Strips blanched and dried with dry air 2% RH, showed the lowest fat uptake. The authors suggested that the surface moisture content seemed to be the limiting factor whereby increased surface moisture content resulted in an increased fat uptake (Lamberg *et al.*, 1990). This observation is supported by the lowest fat content found with pre-dried sweet potato crisps in this study.

The ash content of the sweet potato crisps ranged between 0.18-2.10%. Blanched samples had the lowest values while dried samples had the highest value. Ash content of 2.07-3.42% was reported for sweet potato French fries (Odenigbo *et al.*, 2012).

There was a significant difference ( $p < 0.05$ ) between the reducing sugar content of sweet potato crisps blanched with and without NaCl. Crisps that were not pretreated had the lowest reducing sugar (2.61%) while samples dipped in ascorbic acid had the highest value of 3.30%. Akpapunam and Abiante (1991) reported a total sugar and reducing sugar contents of 6.88-7.10% and 0.496-0.514% respectively for sweet potato chips as a result of differences in drying times before frying. The authors emphasized that although blanching in water and  $\text{NaHSO}_3$  did not cause significant losses in both the total and reducing sugar of the chips, they were significantly affected by dehydrating time. In the present study, blanched samples had higher reducing sugar content than untreated samples, with samples blanched in NaCl particularly significant ( $p < 0.05$ ).

Sweet potato crisps produced from drying pretreatment had the highest Vitamin C content (35.25 mg/100g) while samples without pretreatment had the lowest (22.42 mg/100g). Sweet potato chips pre-dried at

different times contained 9.67-38.11 mg/100g ascorbic acid (Akpapunam and Abiante, 1991), with the values decreasing gradually with increase in drying time. The authors further reported that blanching in water and in NaHSO<sub>3</sub> caused significant losses in ascorbic acid content of the chips. This is contrary to the result in the present study in which blanched samples showed higher ascorbic acid values than untreated samples. In addition samples blanched in NaCl solution showed significantly higher (p<0.05) ascorbic acid content than blanching without NaCl.

The influence of pretreatment on sensory attributes of sweet potato crisps is shown in Table 2. The untreated sample was not

scored because it served as the control, while the treated samples were scored against it. Only crisps pretreated by drying showed significant difference (p<0.05) in colour compared to the untreated. The use of NaCl for blanching not only resulted in significant difference (p<0.05) in taste, but had the highest difference from control score among all the sensory attributes. Although crisps dipped in ascorbic acid and the dried samples were not significantly different (p>0.05) in taste compared to untreated ones, each of these samples were significantly different (p<0.05) from the blanched crisps.

**Table 2: Difference from control scores for sweet potato crisps as influenced by pretreatment**

Sensory attributes	Pretreatments				
	1	2	3	4	5
Colour	ns	3.40b	3.37b	3.27b	2.13a
Taste	ns	3.77ab	3.83b	3.17a	3.27ab
Flavour	ns	3.77a	3.27ab	3.67b	2.83b
Crispness	ns	3.50a	3.63b	3.40b	2.70b

**Values are means of two replicates. Values followed by the same alphabet along a row are not significantly different from one another (p > 0.05). 1- Control (No pretreatment); 2- Blanched at 93 °C for 2 min; 3- Blanched at 93 °C for 2 min in 1% (w/v) NaCl; 4- Dipped in 1% w/v ascorbic acid for 2 min; 5- Dried at 80 °C for 2 min. ns-'not scored' since it served as control**

The flavour of sweet potato crisps dipped in ascorbic acid and those dried were not significantly different (p>0.05) from untreated crisps, however each of these samples showed significant difference from crisps that were blanched irrespective of

blanching condition. The crispness of fried sweet potato was affected by blanching without NaCl only as indicated by the significant difference (p<0.05). All the other pretreatments did not result in significant difference in crispness compared to the control. Al-

though it was expected that drying would result in a significant difference in crispness, however this was not the case, although the difference from control was not as much as the other pretreatments as indicated by the lower score.

Generally, drying resulted in a moderate difference (2.13-2.83) in colour, flavour and crispness compared to the untreated while the other pretreatments showed an extreme difference (3.17-3.83) in all the attributes. Only the taste of dried crisps showed appreciable difference from control (3.27). Sweet potato crisps from all the pretreatments were generally acceptable (6.53-7.60), however crisps produced by drying before frying was the most acceptable (7.60) (Fig.1).

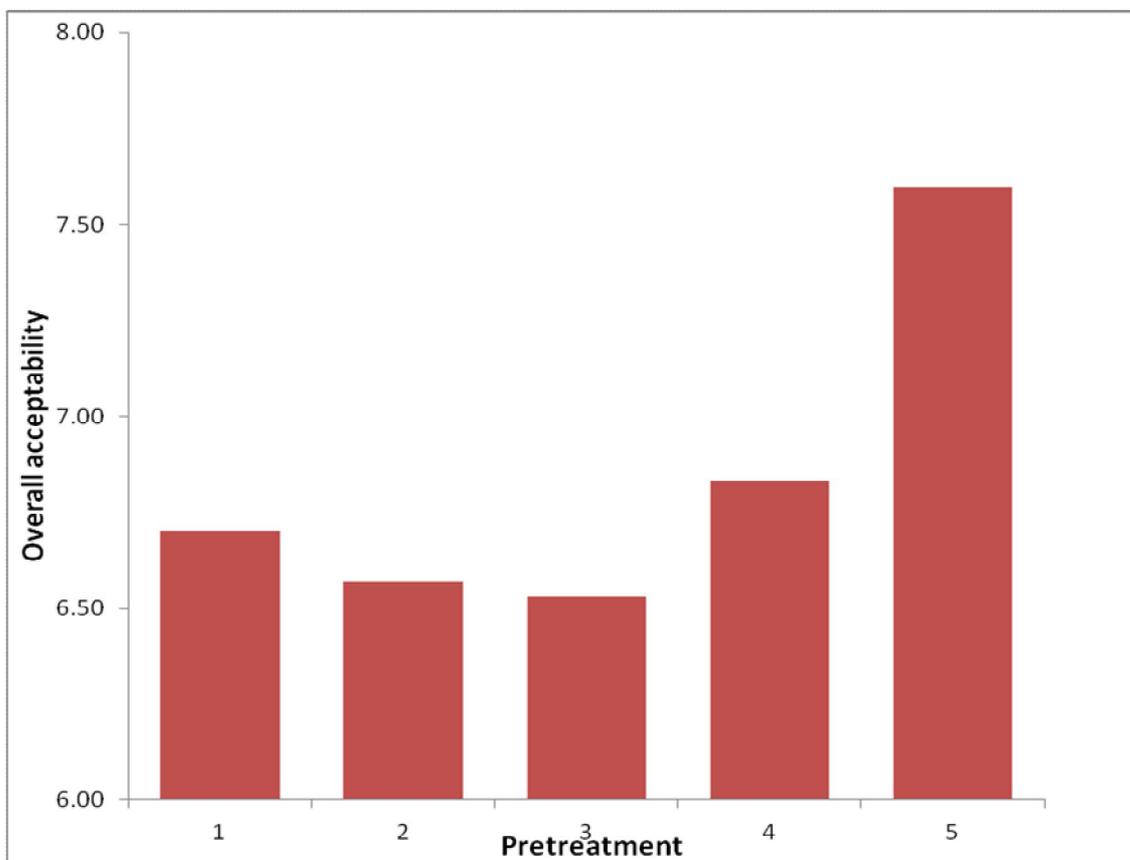
Table 3 shows the correlation coefficient between composition of the sweet potato crisps and consumer acceptability. There was no significant correlation ( $p > 0.05$ ) between composition and individual sensory attributes except between protein and col-

our ( $r = 0.68$ ,  $p < 0.05$ ). All the components except reducing sugar showed significant correlations ( $p < 0.05$ ) with acceptability. The correlations between ash, vitamin C content and acceptability ( $r = 0.85-0.90$ ) were positive and significant at  $p < 0.01$ , while the correlations between moisture, protein and fat were significant ( $p < 0.05$ ) but negative. This indicates that the higher the ash and vitamin C content, the higher the acceptability. However, the lower the moisture, protein and fat content, the higher the acceptability. Rodriguez-Saona and Wrolstad (1997) reported that reducing sugars, ascorbic acid, phenolic acids and glutamine were highly correlated with potato chip colour. The authors however suggested that reducing sugar alone, particularly at less than 60 mg/100g does not explain or predict colour quality. According to Kita (2002), the crisp texture of potato crisps depended on the content of starch in the tubers as well as nitrogen substances and non-starch polysaccharides. The author further reported that among the non-starch polysaccharides, protopectins had the most important influence on crisp texture.

**Table 3: Correlation coefficient between composition and sensory properties of sweet potato crisps**

	Colour	Taste	Flavour	Crispness	Overall acceptability
Moisture	0.42	0.31	0.23	0.33	-0.83**
Protein	0.68*	0.55	0.55	0.59	-0.76*
Fat	0.60	0.52	0.46	0.53	-0.73*
Ash	-0.56	-0.36	-0.39	-0.46	0.90**
Reducing sugar	0.54	0.53	0.57	0.59	0.32
Vitamin C	0.20	0.42	0.32	0.34	0.85**

\*Correlation is significant at  $< 0.05$ , \*\* Correlation is significant at  $< 0.01$



1- Control (No pretreatment); 2- Blanched at 93 °C for 2 min; 3- Blanched at 93 °C for 2 min in 1% (w/v)

NaCl; 4- Dipped in 1% w/v ascorbic acid for 2 min; 5- Dried at 80 °C for 2 min.

Figure 1: Overall acceptability of sweet potato crisps as influenced by pretreatment

## CONCLUSIONS

Drying pretreatment gave sweet potato crisps with the least moisture and fat contents while blanching gave the highest values. The use of NaCl solution for blanching resulted in a significantly higher value of fat in the crisps. Crisps produced by drying before frying was the most acceptable, although crisps from all the pretreatments were generally acceptable. The lower the moisture, protein and fat content, the higher the acceptability. There is a need to

establish compositional standards of oil and moisture for sweet potato crisps, so as to serve as reference for quality control purposes in commercial production.

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