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# Effect of frying temperature and time on composition and sensory quality of sweet potato crisps

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## Abstract
Fried products have been found to be among the sweet potato products that are not only capable of increasing the utilization of sweet potato in Nigeria, but also have high commercial potential. It is important to establish frying conditions for use by emerging small to medium scale processors that will ensure production of acceptable quality of sweet potato crisps. This study was conducted to determine the effect of frying temperature and frying time on the composition and sensory properties of sweet potato crisps. Sweet potato crisps from yellow-fleshed roots were produced at frying temperatures of 150-180 ºC and frying periods of 3-12 min. The proximate composition and sensory properties of the crisps were determined. The range of composition was moisture content (0.49-3.83 %), protein (0.10-1.42 %), fat (19.11-28.59 %), crude fibre (0.44-1.99 %), ash (2.00-4.50 %) and carbohydrate (62.17-74.92 %). The moisture, protein, fat, crude fibre, ash and carbohydrate content were significantly affected ($p<0.001$) by the individual and combined effects of frying temperature and frying time. Crisps produced at 150-170 ºC at 3-8 min were generally acceptable, although the sample with the highest overall acceptability score was produced at 170 °C/8 min. The taste, colour, flavour, crispness and overall acceptability were significantly affected ($p<0.001$) by the individual and combined effects of frying temperature and frying time. The contribution of each of the sensory attributes to the overall acceptability scores was significant ($p<0.01$), and in the order of taste ($r=0.93$)>flavour ($r=0.90$)>colour ($r=0.89$)>crispness ($r=0.78$).

**Key words**: sweet potato, crisps, frying, food quality

## Introduction
Sweet potato (*Ipomoea batatas* [L.] Lam) is the seventh most important food crop and next to cassava among the root and tuber crops grown in the world (Lebot, 2009). Sweet potato is not only a good source of carbohydrates, fibre and many micronutrients but also the orange-fleshed varieties are especially rich in beta-carotene, the precursor to vitamin A (Woolfe, 1992). 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 production and nutritional potentials identified with the sweet potato crop are still underexploited in Nigeria (Akoroda and Egeonu, 2009).

Fried products have been found to be among the sweet potato products that are not only capable of increasing the utilization of sweet potato, but also have high commercial potential (Onumah et al 2012). A recent study was conducted in Nigeria to generate evidence on the desirability and feasibility of investing in development of sweet potato value chains for fresh root marketing and processed products in the major producing areas and markets. The report indicated that the fresh root market shows the greatest prospects for rapid growth in the short to medium term; particularly because it services a growing number of street-food vendors, selling fried sweet potato chips targeting school children and urban workers. The authors further emphasized that the other top two value chains with good prospects for uptake of sweet potato are the emerging sweet potato crisps industry and marketing of sweet potato fries by the fast food outlets (Onumah et al 2012).

Frying of foods is one of the most common processing techniques throughout the world. Deep-fat frying is an established process of food preparation worldwide. It is a simultaneous heat and mass transfer process where moisture leaves the food in the form of vapour bubbles, while oil is absorbed simultaneously (Luiping et al 2005). This method of food processing results in modification of the physical, chemical and sensory characteristics of the food (Patterson et al 2004). While extensive work has been reported on deep frying of potatoes (Gamble et al, 1987, Sahin, 2000, Krokida et al 2001, Kita 2002, Pedreschi et al 2005), studies on deep frying of sweet potato to produce crisps is limited (Singh et al 2003, Ali et al, 2012). Potatoes are fried following either the French fry model or the crisp (or chip) model. The former has a significant internal volume, external surface and good crust differentiation, while the latter is without a significant internal volume but with a large external surface area, similar to an all-crust, no-centre product (Blumethal 1991). One major commercial advantage of crisps over French-fries is its potential longer shelf stability. Crust formation is one of the most palatable characteristics of fried foods and it is closely linked to fat penetration. It is a complex process, in which many factors are involved, such as temperature of the heated fat, length of frying time, method used (household or industrial deep-fryers), food weight/frying-fat volume and surface-area/volume ratios, some food characteristic and the fat source (Guillaumin 1988).

Moisture and oil content, as well as colour and texture are important quality attributes of fried sweet potato products (Singh et al 2003, Brigatto Fontes et al 2011). The limited literature available on these products have shown that these quality attributes are influenced by frying conditions such as frying temperature, duration of frying, slice thickness and oil type among other factors. Sahin (2000) studied the effects of frying time and temperature on the colour kinetics of French-fried potatoes during frying; the author developed a multiple regression equation for total colour change as a function of time and temperature. The equation showed that increase in time and temperature increased total colour change. In the light of global trend to consume healthy products with low calories, Brigatto Fontes et al 2011 developed optimized conditions for processing of sweet potato chips in different oil types. The conditions for palm oil were 160 °C for 3 min 30 sec for chips with moisture content of 7.43% and oil content of 14.46%, while that for palm stearin were the same time, but at 180 °C for chips with moisture content 3.47% and oil content of 13.1%. Singh et al 2003 also developed models capable of predicting the quality of sweet potato chips (crisps) using response surface methodology as an optimization tool; the model had optimum conditions of 174.7 °C as frying temperature, 26 s as frying time and varying concentrations of a mixture of chemical salts. These conditions and in particular the very short frying time may not be feasible for the budding micro to small scale producers of sweet potato crisps in Nigeria considering the limited sophistication of equipment. The use of a mixture of chemicals and safety concerns by consumers may also not allow for easy adoption of such models as developed. Therefore it is important to establish simple and more realistic frying conditions for use by potential small scale processors while ensuring acceptable quality of sweet potato crisps. Hence, the objective of this study was to determine the effect of frying temperature and frying time on the composition and sensory properties of sweet potato crisps.

## Materials and Methods

Yellow-fleshed sweet potato roots were bought from Ketu market in Lagos. 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 blanched in 1% w/v NaCl for 2 min, drained and fried in refined, bleached and deodorized vegetable oil (Turkey brand, Malaysia) using a deep fat fryer (Model: Platinum PL-DF-2.5L, China). Frying was done at four different temperatures (150, 160, 170 and 180 ºC) and at four different times (3, 5, 8 and 12 min). 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). Crude fibre was determined as the acid –detergent fibre using procedure 4.6.03, method 973.18 of the AOAC.

1.0 g of flour made from the sweet potato crisps was refluxed with an acid-detergent solution; the residue was washed successively with water followed by acetone. The residue was dried at 105 ºC in a hot air oven, cooled in a dessicator and weighed (AOAC, 2000). Total carbohydrate was calculated by difference according to James (1995).

**Sensory evaluation**

A 10-member semi-trained panel evaluated the sweet potato crisps for attributes of taste, colour, flavor and crispness 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). A total of 16 samples were evaluated. The coded samples were presented to the panelists in batches of eight. Overall acceptability test was also conducted by an in-house consumer panel comprising of 30 untrained undergraduate students who were regular consumers of sweet potato, using the same scale (Lyon et al 1992).

**Statistical analysis**

The compositional and sensory data are presented as means of duplicate analysis. The data were subjected to descriptive analysis and the minimum, maximum, mean, and standard deviation were computed. One-way 'analysis of variance' (ANOVA) test was conducted to determine if the samples were significantly different ($p<0.05$) from one another. Least Significant Difference (LSD) and Duncan Multiple Range Test (DMRT) were employed as post hoc tests to separate the means were significant difference existed. A multivariate General Linear Model (GLM) analysis was performed to determine the individual and interactive effects of the treatments (frying temperature and time) on the attributes measured. Significant effects were established at $p<0.05$, 0.01 and 0.001 levels. Pearson's correlation coefficient was computed to determine significant ($p<0.05$) relationship between composition and sensory attributes of sweet potato crisps. The correlation between individual sensory attributes and overall consumer acceptability was also calculated in order to determine the attributes that were important to consumers. Statistical packages used were Microsoft Excel and SPSS Version 16.0 (SPSS Inc., Chicago, IL, USA).

## Results and Discussion

**Composition of sweet potato crisps.** Table 1 shows the composition of sweet potato crisps as influenced by frying temperature and time. The samples were significantly different ($p<0.05$) from one another. The moisture content ranged from 0.49 to 3.83%. These values were lower than the values reported by Singh et al (2003). The authors reported values of 7.32-14.21% for sweet potato crisps produced from slices of 1.5 mm thickness, frying temperature of 165-185 °C and frying time of 20-60 sec and different chemical pretreatments. The large differences in moisture content may be due to the different frying conditions used in each study. Low moisture content is expected to enhance shelf stability of the fried product. Moisture content of the crisps decreased with increase in frying time at each of the frying temperatures. One of the characteristics of a frying process, is the movement of water in the form of vapour from the product into the oil (Lui-ping et al 2005).

The sweet potato crisps had protein content of between 0.10 and 1.42%. The values decreased with increase in frying time at each of the frying temperatures. Protein values of sweet potato crisps are limited in literature; however, Odenigbo et al (2012) reported values of 2.88-7.74% for French-fried sweet potato chips. 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 fried products is an important quality factor from the perspective of health and storage considerations (Gunstone 2008, Brigatto Fontes et al 2011). The range of fat content for sweet potato crisps was 19.11-28.59%. These values were higher than reported by Singh et al (2003). They were also higher than the optimum values reported by Brigatto Fontes et al (2011). This may be due to the initial moisture content of the sweet potato slices which was neither determined in the present study, nor reported in the studies cited. It may also be due to the different pre-frying treatments used in the various studies. For instance, high initial moisture content and blanching have been reported to contribute to increased oil absorption in fried sweet potato crisps (Woolfe, 1992). Movement of oil into the product is a characteristic of frying processes (Singh et al 2003). According to deMan (1999), lower frying temperature and longer frying time results in higher oil uptake. The author however stated further that oil absorption depends on conditions of frying and the nature and size of the food. In the present study, at each frying temperature, the fat content of the sweet potato crisps reduced with increase in frying time. This may be due to the thin slices and crispy nature of

the fried product which has been described by Blumethal (1991) as, a product without a significant internal volume but with a large external surface area, similar to an all-crust, no-centre product. It may be explained further that the limited internal volume of the food product does not allow for absorption and/or retention of oil.

The crude fibre of the sweet potato crisps followed the same trend as that of the moisture, protein and fat contents. The values which ranged from 0.44-1.99% decreased with an increase in frying time at each frying temperature. Sweet potato is a rich source of soluble fibre (Woolfe 1992, Yoshimoto 2010). The ash content is a measure of the mineral content of foods. The sweet potato crisps had ash contents of between 2.00 and 4.50%. The ash content increased with increase in frying time at each frying temperature. Odenigbo et al (2012) reported ash content of 2.07-3.42 for sweet potato French fries.

Sweet potato is a major source of carbohydrate and hence energy. The carbohydrate content of the sweet potato crisps ranged from 62.17 to 74.97%; hence sweet potato crisps could be marketed as an energy-providing snack. The trend of carbohydrate content was similar to that of ash, with an increase in carbohydrate content as the frying time increased for each frying temperature. The moisture, protein, fat, crude fibre, ash and carbohydrate content were significantly affected ($p<0.001$) by the individual and combined effects of frying temperature and frying time (Table 1). This indicates that the frying temperature and time are important factors affecting the compositional quality of sweet potato crisps.

Table 2 shows the scores for the sensory attributes of sweet potato crisps as influenced by frying temperature and frying time. The crisps were significantly different ($p<0.05$) in attribute scores. Crisps fried at 150 °C for 5 min had the highest score for taste while the lowest score was for crisps fried at 180 °C for 12 min. Sweet potato crisps fried at 150, 160 and 170 °C showed a similar trend in taste with the values initially increasing from 3 to 5 min, and thereafter reduced through 8 min to 12 min. At 180 °C, the score for taste reduced as the frying time increased. Sweet potato crisps fried at 150 °C for 3 min had the highest score for colour, while the lowest score was for crisps fried for 12 min at 180 °C. Generally at each frying temperature, there was a decrease in taste and colour scores with increase in frying time. An equation developed by Sahin (2000) indicated that increase in time and temperature increased total colour change. In view of the important contribution of colour to overall acceptability of sweet potato crisps as established in this study, there may be a need for further studies to correlate sensory colour scores to data from instrumental measurements. The output will be useful for quality control during commercial production of sweet potato crisps.

The highest score for flavour of sweet potato crisps was obtained at 180 °C for 3 min while the lowest was at the same temperature but a frying time of 12 min. Cripsness is an important texture attribute valued by consumers of potato crisps. Crisps fried at 160 °C for 12 min had the highest score for crispness. For all the frying temperatures except at 180 °C, crispness increased with increase in frying time. Generally, sweet potato crisps fried at 150-180 °C and 3-5 min had higher scores for taste, colour and flavour while temperatures of 150-160 °C for 8-12 min favoured crispness. On the other hand, crisps fried at 180 °C for 8-12 min were poorly rated for all the attributes including crispness. The sample with the highest overall acceptability score was produced at 170 °C/8 min (Figure 1). Sweet potato crisps produced at 150-170 °C for 3-12 min and at 180 °C for 3-5 min were generally acceptable while crisps produced at 180 °C for 8-12 min were poorly accepted. The taste, colour, flavour, crispness and overall acceptability were significantly affected ($p<0.001$) by the individual and combined effects of frying temperature and frying time (Table 2). This indicates that frying temperature and time are important factors affecting the sensory quality of sweet potato crisps.

Table 1: Composition of sweet potato crisps as affected by frying temperature and time

| Temperature (°C) | Time (min) | Moisture (%) | Protein (%) | Fat (%) | Crude fibre (%) | Ash (%) | Carbohydrate (%) |
|---|---|---|---|---|---|---|---|
| 150 | 3 | 3.83m | 1.42l | 28.59gh | 1.99j | 2.00a | 62.17a |
| | 5 | 2.46i | 1.40l | 27.90g | 1.45h | 2.95b | 63.84b |
| | 8 | 1.64g | 1.36k | 23.89d | 1.21g | 3.70e | 68.20e |
| | 12 | 1.50f | 1.27j | 22.63c | 0.93e | 3.84fg | 69.83fg |
| 160 | 3 | 3.71l | 1.30j | 27.94h | 1.50i | 2.96b | 62.59a |
| | 5 | 2.94j | 1.11i | 26.94f | 1.42h | 2.97b | 64.62c |
| | 8 | 1.54f | 1.06h | 23.70d | 0.77c | 3.75ef | 69.18f |
| | 12 | 1.29e | 0.90g | 22.53c | 0.94e | 3.85gh | 70.49gh |
| 170 | 3 | 3.11k | 0.70f | 25.23e | 1.21g | 3.00c | 66.75d |
| | 5 | 0.85d | 0.50d | 23.94d | 1.10f | 3.20d | 70.41g |
| | 8 | 0.59b | 0.30b | 23.47d | 0.44a | 3.97h | 71.23gh |
| | 12 | 0.56b | 0.50d | 22.48c | 0.85d | 3.99h | 71.62hi |
| 180 | 3 | 2.28h | 0.60c | 23.70d | 0.49b | 3.05c | 69.88fg |
| | 5 | 0.80c | 0.40c | 22.02c | 1.09f | 3.75ef | 71.94i |
| | 8 | 0.58b | 0.30b | 20.64b | 0.43a | 3.99h | 74.06j |
| | 12 | 0.49a | 0.10a | 19.11a | 0.83d | 4.50i | 74.97k |
| Min | | 0.49 | 0.10 | 19.11 | 0.43 | 2.00 | 62.17 |
| Max | | 3.83 | 1.42 | 28.59 | 1.99 | 4.50 | 74.97 |
| Mean | | 1.76 | 0.84 | 24.11 | 1.05 | 3.48 | 68.76 |
| SD | | 1.13 | 0.44 | 2.76 | 0.42 | 0.60 | 3.94 |
| LSD | | 0.14 | 0.02 | 0.01 | 0.01 | 0.01 | 0.08 |
| Effects | | | | | | | |
| FTp | | *** | *** | *** | *** | *** | *** |
| FTm | | *** | *** | *** | *** | *** | *** |
| FTp x FTm | | *** | *** | *** | *** | *** | *** |

Values are mean of two determinations, SD-standard deviation, LSD-least significant difference
Values followed by different alphabets are significantly different ($p<0.05$)
FTp-frying temperature, FTm-frying time
***significant effect at $p<0.001$

Table 2: Sensory scores of sweet potato crisps as affected by frying temperature and time

| Temperature (°C) | Time (min) | Taste | Colour | Flavour | Crispness |
|---|---|---|---|---|---|
| 150 | 3 | 8.00k | 8.40m | 7.63j | 6.50e |
| | 5 | 8.27o | 8.13k | 8.23n | 7.30i |
| | 8 | 7.57h | 7.23f | 7.83m | 7.73l |
| | 12 | 6.43c | 6.33d | 6.67d | 8.00m |
| 160 | 3 | 8.20n | 8.13k | 7.80l | 5.53c |
| | 5 | 7.83i | 7.47h | 7.23h | 6.60f |
| | 8 | 7.03f | 6.37d | 6.77cf | 7.37j |
| | 12 | 6.67d | 5.93c | 6.27c | 8.43n |
| 170 | 3 | 8.13l | 8.43n | 8.23n | 6.33d |
| | 5 | 7.83j | 7.73j | 7.67k | 7.40jk |
| | 8 | 7.07g | 7.27g | 6.87g | 7.10g |
| | 12 | 6.70e | 6.43e | 6.70e | 7.27h |
| 180 | 3 | 8.10m | 8.23l | 8.30o | 7.43k |
| | 5 | 7.80i | 7.57i | 7.57i | 7.40j |
| | 8 | 3.47b | 3.53b | 3.53b | 4.43b |
| | 12 | 1.33a | 1.93a | 1.93a | 2.37a |
| Min | | 1.33 | 1.93 | 1.93 | 2.37 |
| Max | | 8.27 | 8.43 | 8.30 | 8.43 |
| Mean | | 6.78 | 6.83 | 6.71 | 6.64 |
| SD | | 1.88 | 1.71 | 1.48 | 2.05 |
| LSD | | 0.00 | 0.01 | 0.01 | 0.02 |
| Effects | | | | | |
| FTp | | *** | *** | *** | *** |
| FTm | | *** | *** | *** | *** |
| FTp x FTm | | *** | *** | *** | *** |

Values are mean of two determinations, SD-standard deviation, LSD-least significant difference
Values followed by different alphabets are significantly different ($p<0.05$)
FTp-frying temperature, FTm-frying time
***significant effect at $p<0.001$

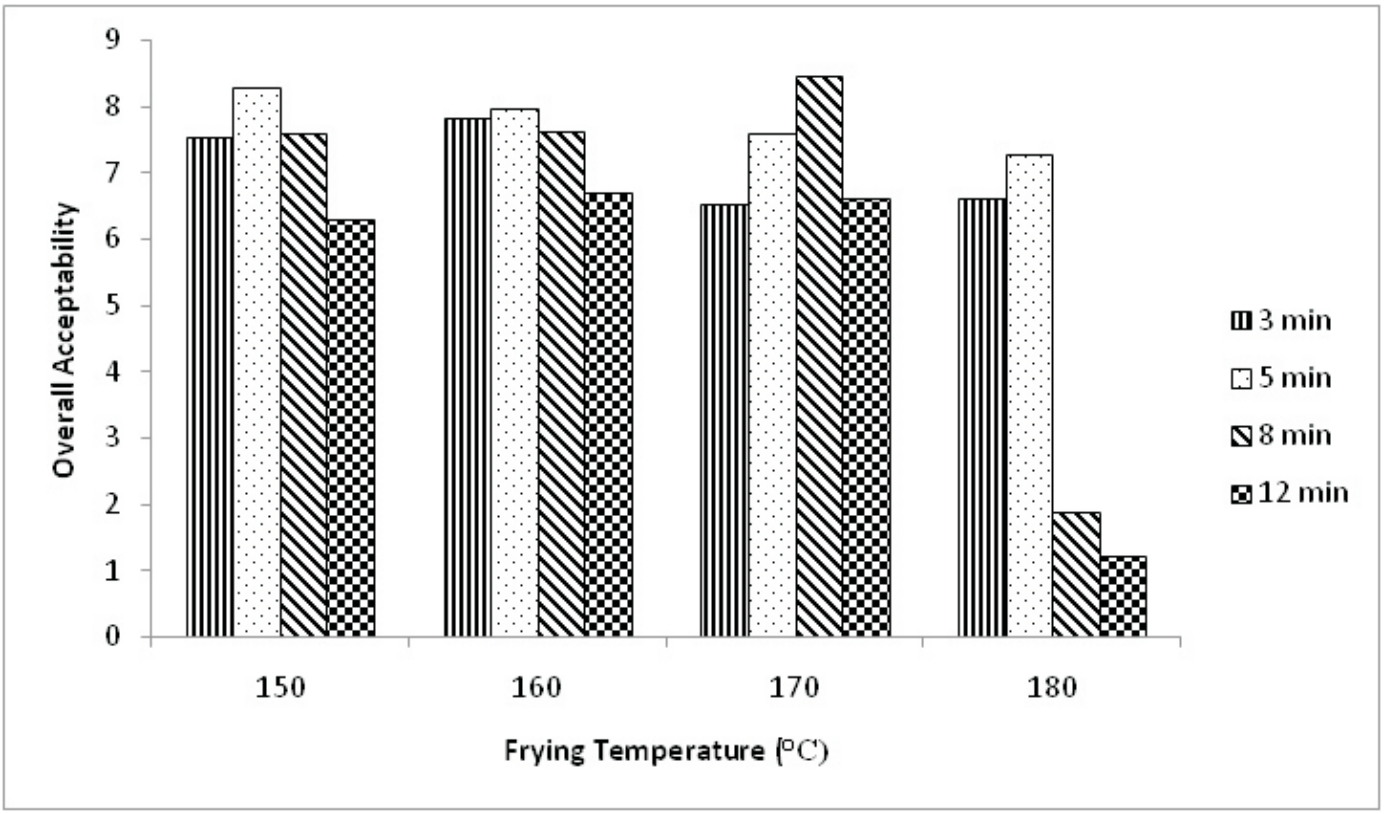


Figure 1: Overall acceptability of sweet potato crisps as affected by frying temperature and frying time

Table 3 shows the correlation coefficient between composition of sweet potato crisps and sensory attributes. Taste and colour of sweet potato crisps were significantly affected ($p<0.01$) by moisture, protein, fat, crude fibre, ash and carbohydrate; however the correlation coefficients were relatively low ($r<0.77$). Flavour was significantly affected ($p<0.01$) by moisture, protein and fat. According to Ihekeronye and Ngoddy 1985, proteins can contribute to the colour and flavour of foods by participating in Maillard and other browning reactions; this may explain the significant correlations between protein and the colour and flavour of sweet potato crisps. Maillard is a nonenzymic browning reaction, which causes the decomposition of certain amino acids (the building blocks of proteins), in the presence of reducing sugars. This reaction leads to the formation of brown pigments, or melanoidins, which are not well defined and may result in numerous flavour and odour compounds (deMan 1999).

Overall acceptability was significantly affected by protein, fat, ash and carbohydrate at $p<0.01$, and affected by moisture and crude fibre at $p<0.05$. The higher the moisture, protein, fat and crude fibre content, the higher the acceptability of the sweet potato crisps. On the other hand, a lower ash and carbohydrate content favoured acceptability. Several factors determine the quality and hence acceptability of a food. Similarly, quality standard of foods may be set by processors and consumers. Although relatively high moisture and fat content of sweet potato crisps contributed significantly to taste, colour, flavour and overall acceptability, this may not favour the processor with respect to storage due to fat hydrolysis and rancidity. Also, a high fat content may not be acceptable to the consumer on health considerations. It is therefore important to establish a range limit for these important components for quality control in the commercial production of sweet potato crisps. Overall acceptability was significantly affected ($p<0.01$) by each of the sensory attributes; this is an indication that all the sensory attributes of sweet potato crisps were important to the consumers. The contribution of each of the sensory attributes to the overall acceptability scores was in the order of taste ($r=0.93$)>flavour ($r=0.90$)>colour ($r=0.89$)>crispness ($r=0.78$).

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

| | Taste | Colour | Flavour | Crispness | Overall acceptability |
|---|---|---|---|---|---|
| Moisture | 0.57** | 0.62** | 0.55** | 0.07 | 0.42* |
| Protein | 0.57** | 0.54** | 0.56** | 0.44* | 0.57** |
| Fat | 0.74** | 0.76** | 0.67** | 0.26 | 0.69** |
| Crude fibre | 0.46** | 0.48** | 0.43* | 0.07 | 0.42* |
| Ash | -0.68** | -0.74** | -0.66 | -0.22 | -0.53** |
| Carbohydrate | -0.69** | -0.71** | -0.66 | -0.23 | -0.63** |

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

## Conclusion

This study has established further that frying temperature and time are important factors affecting the compositional and sensory quality of sweet potato crisps. Although frying temperature of 170 °C and frying time of 8 min produced the most acceptable sweet potato crisps by consumers, the fat content was relatively high. Taste, flavour and colour attributes contributed more to the overall acceptability score of the samples than crispness. There is need for further studies that will take into consideration various quality factors of sweet potato crisps from the processing, storage and consumer perspective. This is important in order to establish standard ranges for composition and sensory attributes that will be useful as quality indicators during small to medium scale production of sweet potato crisps.

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