

# The Use of Shea Butter in the Production of Fried Plantain (*Musa AAB*) Chips and Its Effect on the Product's Quality Attributes

Mathew K. Bolade<sup>1</sup>✉, Mohammed A. Usman<sup>2</sup>, Paul O. Ogungbemi<sup>1</sup>

<sup>1</sup>Department of Food Science and Technology, Federal University of Technology, Akure, Ondo State, Nigeria

<sup>2</sup>Department of Food Science and Technology, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria

**Abstract:** This study investigated the possible use of shea butter for fried plantain chips production as well as comparative assessment of their quality characteristics. Mature green plantain was peeled and chipped followed by deep-frying using three different vegetable oils (shea butter, soybean oil and palm oil) individually. The respective fried plantain chips were then evaluated for their quality attributes. The fat content of fried plantain chips from shea butter (FPC-Shea) was 19.79% while that from FPC-Soy (plantain chips from soybean oil) and FPC-Palm (plantain chips from palm oil) were 18.47 and 20.04%, respectively. The protein, ash, crude fibre and carbohydrate contents of FPC-Shea were 5.22, 2.62, 3.54 and 69.33%, respectively while those of FPC-Soy and FPC-Palm ranged from 3.84 – 4.77, 2.36 – 2.54, 3.41 – 3.64 and 69.01 – 71.92%, respectively. The browning index (BI), oiliness index and *in vitro* starch digestibility of FPC-Shea were 103.71, 28.14 cm<sup>2</sup> and 42.38 mg/g, respectively while those of FPC-Soy and FPC-Palm ranged from 108.34 – 111.94, 24.45 – 36.31 cm<sup>2</sup>, and 34.54 – 37.27 mg/g, respectively. The organoleptic assessment revealed that FPC-Shea was rated the highest in terms of colour and crispness while FPC-Soy was rated the highest in terms of taste, aroma, hand greasiness and overall acceptability. The FPC-Palm was rated the lowest in terms of all sensory parameters. The overall acceptability of FPC-Shea was lower than that of FPC-Soy but still processed high potentiality. The storability study revealed that the fried plantain chips from all vegetable oil sources could not last beyond seven days due to the level of thiobarbituric acid reactive substance (TBARS) exceeding a threshold level of 1.1 mg MDA/kg. The type of packaging material used (transparent polyethylene material) might have played a critical role in this relatively short storage life of the fried plantain chips.

**Keywords:** Plantain Chips, Shea Butter, Soybean Oil, Palm Oil, Frying

## Introduction

The consumption of snacks in both developed and developing countries is now a common trend in the eating habits of people while convenient ready-to-eat (RTE) snacks with exciting sensory and textural properties are in high demand (Brennan *et al.*, 2013). Snack foods are essentially described as sweet or savoury foods usually consumed to provide light sustenance in a quick and convenient manner (IFIS, 2009). The type of available raw materials and culture of the people in a particular locality usually influence the category of snacks that can be found in such environment. Some commonly encountered snacks, particularly in Nigeria, include chin-chin, doughnuts, meat pies, and biscuits from wheat flour; fried chips from sweet potato, potato or unripe

plantain and fried snacks from maize or cowpea paste, among others.

The production of fried plantain chips as a snack is an age-long commercial practice in Nigeria. Fried chips are best prepared from plantain at 'harvest-stage-greenness' and this product is traditionally called 'ipekere'. The fried chips obtained from 'more-yellow-than-green' stage are referred to as 'dodo' which is less common as a snack. Mba *et al.* (2015) had observed that the stage of ripeness of plantain could affect the quality characteristics of its chips as well as physical properties of plantain fingers and flour prepared from it. The frying of plantain chips at green stage is by the use of deep-frying method. It is a process of immersing food pieces in hot vegetable

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Mathew K. Bolade (Correspondence)



mkbolade@futa.edu.ng



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oil or fat at relatively high temperature (150 – 190°C) (Moyano and Pedreschi, 2006).

Deep-frying of food materials usually involves the use of different types of oil ranging from soybean oil, cottonseed oil, sunflower oil, rice bran oil, and palm oil, among others (Alireza *et al.*, 2010). Shea butter is another category of cooking fat but is not currently being used in the commercial production of plantain chips particularly in Nigeria. Shea butter is usually processed from the seed of shea tree (*Vitellaria paradoxa* Gaertn) and its utilization cuts across both food and non-food applications. The food applications include its usage as primary cooking fat in some rural areas of African savanna zone (Honfo *et al.*, 2014), baking fat and as margarine in confectionery and chocolate industry in Europe and Asia (Akhter *et al.*, 2008). Some communities in the northern part of Oyo State, Nigeria, are reputed for using shea butter in the preparation of their household vegetable soups. The non-food applications of shea butter include its use as illuminant in rural areas of African savanna zone (Honfo *et al.*, 2014), in soap making, cosmetics and traditional medicine (Maranz *et al.*, 2004; Okullo *et al.*, 2004). The high demand of shea butter by international cosmetic industries has been attributed to its anti-inflammatory and anti-oxidant properties due to its high concentration of unsaponifiable compounds such as triterpenes, tocopherol, phenols, and sterols (Alander, 2004; Maranz and Wiesman, 2004).

In order to further diversity the utilization of shea butter in food application, there is the need to investigate its food frying potential particularly in commercial fried plantain production, and this is the general objective of this study.

## Materials and Methods

### Sources of materials

The vegetable oils used for this study are commercial palm oil, soybean oil and shea butter, respectively obtained from Bodija neighbourhood market, Ibadan, Nigeria. The mature green plantain (*Musa AAB*) was obtained from the Teaching and Research Farm, Federal University of Technology, Akure, Nigeria.

### Production of fried plantain chips

Each finger of the mature green plantain was first washed and then peeled manually followed by slicing into fine discs of 4±0.1 mm thickness using a locally-fabricated slicer. The plantain chips (in circular shape) were slightly sprinkled with salt at 0.01% concentration (1:100, weight/weight; salt/plantain disc) and this was followed by actual deep-frying using each oil type (palm oil/soybean oil/shea butter) respectively. About four litres of each oil type was poured into a cleaned bench-top, temperature-

controlled fryer (model no: D24527DZ, Délonghi Inc., USA). The plantain discs were then poured into pre-heated vegetable oil at 180±2°C and allowed to fry for 5 min coupled with periodic turning. After frying, the fryer basket was removed and well shaken to remove adhering oil and then poured into a stainless steel sieve for proper draining and cooling at ambient temperature (29±2°C). After cooling, the fried plantain discs/chips were packaged in transparent high density polyethylene material and then kept at ambient temperature (29±2°C).

### Storage study on the fried plantain chips

The fried plantain chips obtained from each of the vegetable oil and packaged in transparent polyethylene materials at 100 g/package were separately kept at ambient temperature (29±2°C) in an aerated storage chamber for 28 days. Fried plantain chips from different vegetable oils (shea butter, soybean oil and palm oil) represented individual set to give a total of 3 different sets. Samples were taken from each set periodically at 0, 7, 14, 21, and 28 days for assessment of deterioration. The parameters for evaluation were free fatty acid and thiobarbituric acid reactive substance (TBARS) as indicators for degree of deterioration.

### Determination of proximate composition of raw and fried plantain chips

The raw and fried plantain chips were analyzed for moisture content, ash, crude protein, and crude fibre by the AOAC (2012) method. Moisture content of the samples was determined by air oven method at 105°C until a constant weight was obtained. The crude protein of the sample was determined using micro-Kjeldahl method. Crude fat was determined by Soxhlet extraction method using petroleum ether as extracting solvent. The ash content was determined using a muffle furnace set at 550°C for 4 hours until a constant weight of ash was obtained. Crude fibre was determined using the method of Saura-Calixto *et al.* (1983). Carbohydrate was determined by difference.

### Determination of colour characteristics of fried plantain chips

The colour of fried plantain chips from each vegetable oil type was evaluated by measuring  $L^*$  (brightness; 100 =white, 0 = black),  $a^*$  (+, red; -, green) and  $b^*$  (+, yellow; -, blue) parameters by means of a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA). The instrument was first standardized ( $L^*=94.11$ ,  $a^*=0.97$ ,  $b^*=-2.62$ ) with a white photocopying paper (80 g/m<sup>2</sup>) (McGuire, 1992).

The browning index (BI) of the fried chips was calculated from the  $L^*$ ,  $a^*$ ,  $b^*$  tristimulus scale and used to describe the brown colour characteristics of the sample (Maskan, 2001):

$$\text{Browning Index (BI)} = \frac{[100(x-0.31)]}{0.17} \dots\dots \text{Eq. (1)}$$

where,

$$x = \frac{(a*+1.75L*)}{(5.645L*+a*-3.012b*)}$$

#### Evaluation of oiliness index of fried plantain chips

The oiliness index of the fried plantain chips was determined using the method of Bolade *et al.* (2017) with modification. Fried plantain chips from each oil type were evaluated for their index of oiliness by placing a circular-shaped fried chip at the centre of a large white filter paper (18 cm in diameter) which was also placed on a flat, non-absorbent platform. The central point of the sample was noted when placed on the paper while the fried chip sample was left to stay on the filter paper for 2 h after which the circular spread of the oil absorbed by the filter was measured. The index of oiliness in the fried chip sample was taken as the total circular area (cm<sup>2</sup>) occupied by the oil absorbed from the sample on the filter paper. The experiment was carried out in triplicates while the average total circular area occupied by the absorbed oil was taken as the actual index of oiliness (cm<sup>2</sup>) of the sample. This evaluation assumed a circular movement of the absorbed oil.

Calculation:

Index of oiliness (cm<sup>2</sup>) = Total circular area occupied by the absorbed oil

$$\begin{aligned} &= \pi R^2 - \pi r^2 \\ &= \pi(R^2 - r^2) \dots\dots\dots \text{Eq. (2)} \end{aligned}$$

where:

R = outer radius of circular distance travelled by the absorbed oil (cm)

r = radius of the fried chip under investigation (cm)

π = constant factor (3.142)

#### Evaluation of *in vitro* starch digestibility of fried plantain chips

The *in vitro* starch hydrolysis rate of fried plantain chips from each oil type was determined according to Goni *et al.* (1997). One gramme (1 g) of the blended chips was incubated with 0.2 ml of pepsin in 10 ml distilled water and 0.005 g of α-amylase was added at 37 °C in a shaking water bath. Exactly 0.1 ml sample was taken from the flask every 30 min from 0 h to 3 h and boiled for 15 min to inactivate the enzyme. Sodium acetate buffer (1 ml 0.4M, pH 4.75) was added and the residual starch digested to glucose by adding 30 ml amyloglucosidase and incubating at 60 °C for 45 min. Glucose concentration was determined by adding 200 ml of dinitrosalicylic acid colour reagent. The reaction mixtures was stopped by placing the tubes in a water bath at 100 °C for 5 min and then cooled to room temperature. The reaction mixture was then diluted by adding 5 ml of distilled water and the mixture was centrifuged at 1200 x g. The supernatant was collected and the absorbance

measured at 540 nm using spectrophotometer. The extent of hydrolysis was expressed as the percentage of starch hydrolyzed to glucose (glucose equivalent) at different incubation times. A 50 mg sample of glucose was used as the standard.

#### Sensory quality rating of fried plantain chips

Fried plantain chips prepared from each oil type were evaluated for their sensory qualities and general acceptability. A scoring test was used which was designed to determine which of the products was most preferred. A 45-member untrained taste panel was requested to carry out the rating of the fried chips. The panelists were all familiar with the food product while they were also instructed on the use of sensory evaluation procedures. The presentation of the samples to the panellist was done at ambient temperature (29±2°C). Each of the panelists was asked to rate the samples on the basis of colour, taste, crispiness, aroma and overall acceptability using a nine-point hedonic scale (i.e. 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The scores from the rating were subsequently subjected to analysis of variance (ANOVA) and the means separated using Duncan Multiple Range test (IFT, 1981; Lawless and Heymann, 2010).

#### Determination of free fatty acid value in fried plantain chips under storage

The free fatty acid value was determined according to the method of Qian and Pike (2010). Five grammes of ground sample of fried plantain chips from each oil type were respectively measured into a 250 mL conical flask followed by the addition of 25 mL of 95% ethanol and 3 drops of phenolphthalein indicator. The mixture was heated in a shaking water bath for 5 minutes. While hot, it was titrated against 0.1 N KOH until pink colour appeared. Vigorous shaking was done when approaching the end point to ensure thorough mixing. The volume of 0.1 N KOH consumed by an acid was recorded. The free fatty acid value was calculated as follows:

$$\text{Free fatty acid (as oleic)} = \frac{V \times N \times 282}{W} \dots\dots\dots \text{Eq. (3)}$$

where:

FFA = Percent free fatty acid (g/100 g), expressed as oleic acid

V = Volume of NaOH titrant (ml)

N = Normality of NaOH titrant (mol/1,000 ml)

282 = Molecular weight of oleic acid (g/mol)

W = Sample mass (g)

#### Evaluation of thiobarbituric acid-reactive substance (TBARS) content in the fried plantain chips under storage

The thiobarbituric acid-reactive substance (TBARS) content of fried plantain chips under storage was determined using the method of Witte *et al.* (1970) with modification. Ten grammes of ground sample of

fried plantain chips from each oil type were respectively measured into a 100-mL beaker followed by the addition of 20 mL of 10% trichloroacetic acid (TCA). The mixture was subjected to magnetic stirring for 3 min after which the mixture was cooled to 4°C. The cooled mixture was then transferred into a centrifuge (Eltek centrifuge, MP 400R, Electrocraft, India) where centrifugation was done at 600 rpm for 5 min. After centrifugation, the supernatant was filtered through Whatman #1 filter paper. One millilitre of filtrate was combined with 1 mL of a 0.02 M aqueous 2-thiobarbituric acid solution (TBA), heated in a boiling water bath for 20 min together with a blank containing 1 mL of a TCA/water mix (1:1) and 1 mL of TBA reagent and subsequently cooled under running tap water. The samples were analysed in triplicate and the results were expressed as milligramme malondialdehyde per kg sample (mg MDA/kg sample) using a standard curve that covered the concentration range of 1 to 10 mM 1,1,3,3-tetramethoxypropane. The absorbance was measured at 532 nm with a spectrophotometer (Unicam Limited, Cambridge, UK) against a blank that contained all the reagents, but no fried chip sample.

#### Statistical analysis

All determinations carried out were done in triplicates. A mean value and standard deviation were calculated in each case. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at  $p < 0.05$  using Statistical Package for Social Scientists (SPSS) software, version 16.0.

#### Results and Discussion

##### Comparative proximate composition of fried plantain chips produced from different vegetable oils

The proximate composition of fried plantain chips produced from shea butter, soybean oil and palm oil respectively, is presented in Table 1. The moisture content of unfried plantain chips (raw) was 52.91% while that of the fried chips ranged between 4.13 and 4.92% with no significant difference at  $p < 0.05$ . The drastic loss of water by the chips during deep-fat frying was expected because the high temperature of frying ( $180 \pm 2^\circ\text{C}$ ) was bound to cause heat and mass transfer within the chips. An earlier observation had stated that at high temperature of frying, evaporation of water did occur at the external layers of the food product by way of moving into the surrounding oil (Sulaeman *et al.*, 2001). Some of the frying oil could also be absorbed by the frying chips thereby replacing part of the water (Mellema, 2003).

The fat content of the chips increased from the initial 1.91% (unfried plantain chips) to a range of 18.47 – 20.04% (fried chips). The chips fried with soybean

oil had the lowest fat content while that fried with palm oil had the highest value. The result had revealed that the type of oil used for deep-frying could influence the extent of oil absorption by the food product. Fillion and Henry (1998) had observed that the amount of oil uptake by a food material during frying is dependent on such factors as frying process technique (deep or shallow frying), type and quality of frying oil, and the characteristics of the food material being fried. Similarly, Makinson *et al.* (1987) had observed that plant food materials with initially high moisture and low fat contents have high tendency to absorb more oil during frying, and plantain chips are no exemptions in this regard.

The protein content of raw plantain chips was 4.13% (dry weight basis) while that of the fried chips ranged between 3.84 and 5.22% with significant differences at  $p < 0.05$ . The fried chips from shea butter exhibited the highest protein content while that from soybean oil exhibited the lowest value even lower than that of the raw chips. The reduction in the protein content of fried chips from refined soybean oil (FPC-Soy) may be attributed to the high temperature ( $180 \pm 2^\circ\text{C}$ ) of frying which might have caused protein denaturation (Bouchon and Aguilera, 2001) as well as causing some amino acids to form heterocyclic flavouring compounds (Pokorny, 1989). However, the higher protein content as observed in FPC-Shea and FPC-Palm respectively may be due to the unrefined nature of the frying oil which might have enhanced the overall protein content of the fried chips. Bup *et al.* (2011) had observed that the protein content of shea butter was found to be as high as 8.91% (dry weight basis) depending on the method of butter extraction.

The ash content of the fried chips was generally observed to be higher than that of the raw chips; ranging between 2.36 and 2.62% (dry weight basis) while that of the raw chips was 2.14%. The increase in the ash content of the fried chips may be attributed to seeming concentration of the ash content during frying operation. Ash essentially refers to the inorganic residue remaining after ignition of organic matter (Marshall, 2010). Therefore, at high temperature of frying ( $180 \pm 2^\circ\text{C}$ ), the inorganic residue would remain intact rather than being destroyed. The crude fibre of the fried chips was generally observed to be lower than that of the raw chips. The fried chips gave a range of 3.41 – 3.64% (dry weight basis) while that of the raw chips was 4.11%. The crude fibre is essentially a measure of the quantity of indigestible components (cellulose, lignin, pentosans) of a food material (BeMiller, 2010). Therefore, the high temperature of frying might have caused the reduction in these indigestible components.



The carbohydrate content of raw plantain chips was 87.71% (dry weight basis) while those of the fried chips generally had lower values (69.01 – 71.92%) with significant differences at  $p \leq 0.05$ . The reduction in the carbohydrate content of the fried plantain chips may be attributed to possible starch gelatinization at high temperature of frying coupled with some reducing sugars in the plantain chips taking part in the Maillard reaction for brown colour formation (Bordin *et al.*, 2013).

#### **Colour characteristics, oiliness index and *in vitro* starch digestibility of fried plantain chips as influenced by different frying vegetable oils**

The colour characteristics of fried plantain chips are shown in Table 2. The lightness index ( $L^*$ ) of raw plantain chips was 71.32 while that of fried chips ranged between 40.25 and 48.58, with significant differences at  $p \leq 0.05$ . The browning index (BI) of raw plantain chips was 59.82 while those of fried plantain chips ranged between 103.71 and 111.94, with significant differences at  $p \leq 0.05$ . Fried plantain chips from palm oil exhibited the highest browning index while that from shea butter had the lowest value. The implication of this observation is that the type of vegetable oil used in deep-frying could have influence on the degree of brown colouration in fried products. The brown colouration of the fried plantain chips may be attributed to a combination of caramelization of sugars in the plantain chips and possible Maillard reaction involving sugars and amino groups present within the frying medium (Krokida *et al.*, 2001; Ikoko and Kuri, 2007).

The oiliness index of the fried plantain chips ranged between 24.45 and 36.31 $cm^2$ , with significant differences at  $p \leq 0.05$  (Table 2). The oiliness index is regarded as a measure of quantity of oil capable of migrating from the product into its surrounding environment such as when it is being handled by a consumer (Bolade, 2018). The implication of this result is that the product with the highest oiliness index (FPC-Palm) would exhibit the greatest level of 'greasiness' when it is handled by a consumer.

The *in vitro* starch digestibility of the fried plantain chips is also presented in Table 2. The *in vitro* starch digestibility of FPC-Shea, FPC-Soy and FPC-Palm were 42.38, 34.54 and 37.27 mg/g, respectively. The implication of highest value of *in vitro* starch digestibility as observed in FPC-Shea is that it has greatest possibility of increasing glucose release into the blood stream of the consumer, which is disadvantageous to diabetic patients (Zia-Ul-Haq *et al.*, 2007). One of the factors that could contribute to variability in starch digestibility is the extent of gelatinization during high-temperature frying (Chung *et al.*, 2006) while the types of frying oil used, as

observed in this study, may also be a factor influencing such starch digestibility.

#### **Organoleptic quality characteristics and storage stability of fried plantain chips as influenced by types of frying oils**

The sensory quality rating of fried plantain chips produced from different vegetable oils is presented in Table 3. Fried plantain chips obtained from shea butter (FPC-Shea) was observed to be rated the highest in terms of colour and crispness while fried plantain chips obtained from soybean oil (FPC-Soy) was rated the highest in terms of taste, aroma, hand greasiness and overall acceptability. The FPC-Shea was rated the second-best followed by FPC-Palm in terms of overall acceptability. The implication of this observation is that shea butter could similarly be used for frying plantain chips as its acceptability is relatively high.

Figure 1 shows the changes in free fatty acid (FFA) values of fried plantain chips under storage. The FFA values of freshly produced fried plantain chips were 0.16 g/100g (FPC-Soy), 0.23 g/100g (FPC-Shea), and 0.29 g/100g (FPC-Palm). The initial FFA found in freshly produced fried product may be regarded as a function of the extent of chemical reactions that occur during the frying stage. Chung *et al.* (2004) had observed that when food is subjected to frying in heated oil, the water-steam-oxygen interactions will initiate certain chemical reactions in the oil and food. Such chemical reactions include hydrolysis, oxidation and polymerization of the oil (Kim *et al.*, 1999; Houhoula *et al.*, 2003; Choe and Min, 2007). As the storage period increased, the FFA values of the fried plantain chips were also increasing. Choe and Min (2007) had observed that storage under sunlight is a predisposing factor in the drastic increase of FFA. Fried plantain chips from palm oil were observed to exhibit highest FFA (1.54 g/100g) at the end of 28-day storage period. However, it has been recommended that the level of FFA in freshly produced vegetable oil should be 0.05 – 0.08% (Stevenson *et al.*, 1984) while the maximum FFA level in vegetable oil intended for re-use in frying should be 2.0 – 2.5% (Dobarganes and Marquez-Ruiz, 1998). It was similarly observed that higher value of FFA in fried products could be attributed to the breakdown of the esters, bound in triglycerides, which is more common in oils containing short chain or medium chain fatty acids such as palmitic acid (Choe and Min, 2007). The significance of FFA content is that it is a measure of the extent to which hydrolytic rancidity has occurred in a food product and it is also used extensively as a general indication of the condition and edibility of fried products or vegetable oils (Gheisari, 2011).

Figure 2 represents the changes in thiobarbituric acid reactive substance (TBARS) content of fried plantain chips during storage. The TBARS contents in freshly produced FPC-Shea, FPC-Soy and FPC-Palm were 0.68, 0.47 and 0.94 mg MDA/kg. As the storage duration increased, the TBARS values were also observed to increase in the fried plantain chips under storage up to a maximum of 3.59 mg MDA/kg in FPC-Shea, 3.13 mg MDA/kg in FPC-Soy, and 3.88 mg MDA/kg in FPC-Palm. The implication of this observation is that the TBARS values in the fried plantain chips at the end of a 28-day storage period were relatively high. The maximum allowable TBARS content in food products, particularly in frozen sardines, has been put at 1.1 mg MDA/kg sample (Guillen-Sans and Guzman-Chozas, 1998). This threshold limit for TBARS implies that none of the packaged fried plantain chips, under storage, could satisfy this limit beyond seven days of storage. The type of packaging material used in this instance (transparent polyethylene) might have played a role in the relatively short storage life. The TBARS is essentially a measure of the extent of oxidative rancidity in the termination phase of lipid oxidation (Gomes *et al.*, 2003). The TBARS evaluation is regarded to measure the breakdown products of unsaturated fatty acid oxidation particularly in the termination phase of lipid oxidation while such breakdown products include aldehydes, 2-enals, and 2-dienals (Gheisari, 2011).

### Conclusion

The study has revealed that the use of shea butter for the production of fried plantain chips is highly possible. The proximate compositions of fried plantain chips from shea butter, soybean oil and palm oil were comparable; the browning index of FPC-Shea was not totally deviated from that of FPC-Soy; while its oiliness index was intermediate between that of FPC-Soy and FPC-Palm. The sensory quality of fried plantain chips revealed that the FPC-Shea was rated the second-best after FPC-Soy in terms of overall acceptability while the storage life of all the classes of fried chips could not go beyond seven days as thiobarbituric acid reactive substance (TBARS) level of 1.1 mg MDA/kg was exceeded.

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**Table 1:** Proximate composition of fried plantain chips produced from different vegetable oils (dry weight basis).

Sample source	Proximate composition (g/100g) <sup>1</sup>					
	Moisture content	Fat	Protein	Ash	Crude fibre	Carbohydrate
FPC-Shea	4.71±0.22 <sup>b</sup>	19.29±0.76 <sup>ab</sup>	5.22±0.12 <sup>a</sup>	2.62±0.18 <sup>a</sup>	3.54±0.14 <sup>b</sup>	69.33±1.14 <sup>c</sup>
FPC-Soy	4.92±0.35 <sup>b</sup>	18.47±0.61 <sup>bc</sup>	3.84±0.07 <sup>cd</sup>	2.36±0.17 <sup>ab</sup>	3.41±0.26 <sup>b</sup>	71.92±1.21 <sup>b</sup>
FPC-Palm	4.13±0.52 <sup>b</sup>	20.04±0.84 <sup>a</sup>	4.77±0.11 <sup>b</sup>	2.54±0.11 <sup>a</sup>	3.64±0.28 <sup>b</sup>	69.01±1.28 <sup>c</sup>
UPC-Raw	52.91±1.48 <sup>a</sup>	1.91±0.31 <sup>d</sup>	4.13±0.54 <sup>c</sup>	2.14±0.09 <sup>bc</sup>	4.11±0.33 <sup>a</sup>	87.71±1.19 <sup>a</sup>

<sup>1</sup>Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at p<0.05.

FPC-Shea = Fried plantain chips produced from shea butter.

FPC-Soy= Fried plantain chips produced from soybean oil.

FPC-Palm= Fried plantain chips produced from palm oil.

UPC-Raw= Unfried plantain chips.

**Table 2:** Colour characteristics, oiliness index and *in vitro* starch digestibility of fried plantain chips produced from different vegetable oils.

Sample source	L*	a*	b*	Browning index (BI)	Oiliness index (cm <sup>2</sup> )	<i>In vitro</i> starch digestibility (mg/g)
FPC-Shea	48.58±1.21 <sup>b</sup>	11.41±0.56 <sup>b</sup>	29.01±0.73 <sup>a</sup>	103.71±1.11 <sup>c</sup>	28.14±0.51 <sup>b</sup>	42.38±0.39 <sup>a</sup>
FPC-Soy	44.36±1.04 <sup>c</sup>	9.01±0.81 <sup>c</sup>	27.92±0.32 <sup>b</sup>	108.34±0.88 <sup>b</sup>	24.45±0.74 <sup>c</sup>	34.54±0.66 <sup>c</sup>
FPC-Palm	40.25±1.35 <sup>d</sup>	15.04±0.42 <sup>a</sup>	23.69±0.44 <sup>c</sup>	111.94±1.05 <sup>a</sup>	36.31±0.86 <sup>a</sup>	37.27±0.43 <sup>b</sup>
UPC-Raw	71.32±1.77 <sup>a</sup>	5.63±0.67 <sup>d</sup>	29.43±0.66 <sup>a</sup>	59.82±0.65 <sup>d</sup>	NCO <sup>2</sup>	NCO

<sup>1</sup>Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at p<0.05.

FPC-Shea = Fried plantain chips produced from shea butter.

FPC-Soy= Fried plantain chips produced from soybean oil.

FPC-Palm= Fried plantain chips produced from palm oil.

UPC-Raw= Unfried plantain chips.

<sup>2</sup>NCO= Not carried out.

**Table 3:** Sensory quality rating of fried plantain chips produced from different vegetable oils.

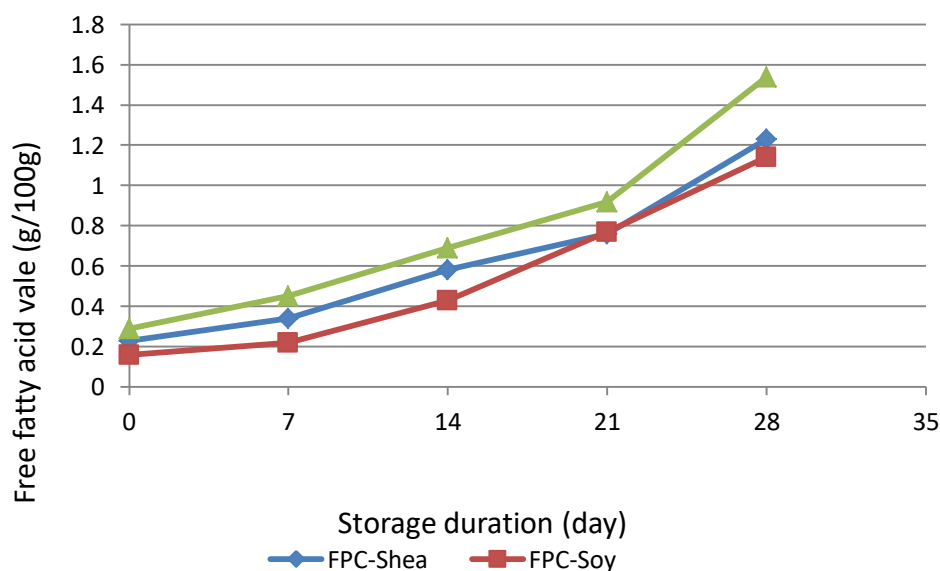
Sample source	Sensory factor <sup>1</sup>					
	Colour	Taste	Aroma	Crispness	Hand 'greasiness'	Overall Acceptability
FPC-Shea	7.9 <sup>a</sup>	7.3 <sup>b</sup>	7.2 <sup>c</sup>	8.3 <sup>a</sup>	6.9 <sup>b</sup>	7.9 <sup>b</sup>
FPC-Soy	7.7 <sup>a</sup>	8.1 <sup>a</sup>	8.3 <sup>a</sup>	7.9 <sup>b</sup>	7.5 <sup>a</sup>	8.3 <sup>a</sup>
FPC-Palm	6.1 <sup>b</sup>	7.1 <sup>b</sup>	7.7 <sup>b</sup>	6.3 <sup>c</sup>	5.9 <sup>c</sup>	6.9 <sup>c</sup>

<sup>1</sup>Results are mean values from 45 panelists. Mean value within the same column having the same letter are not significantly different at p< 0.05.

FPC-Shea = Fried plantain chips produced from shea butter.

FPC-Soy= Fried plantain chips produced from soybean oil.

FPC-Palm= Fried plantain chips produced from palm oil.



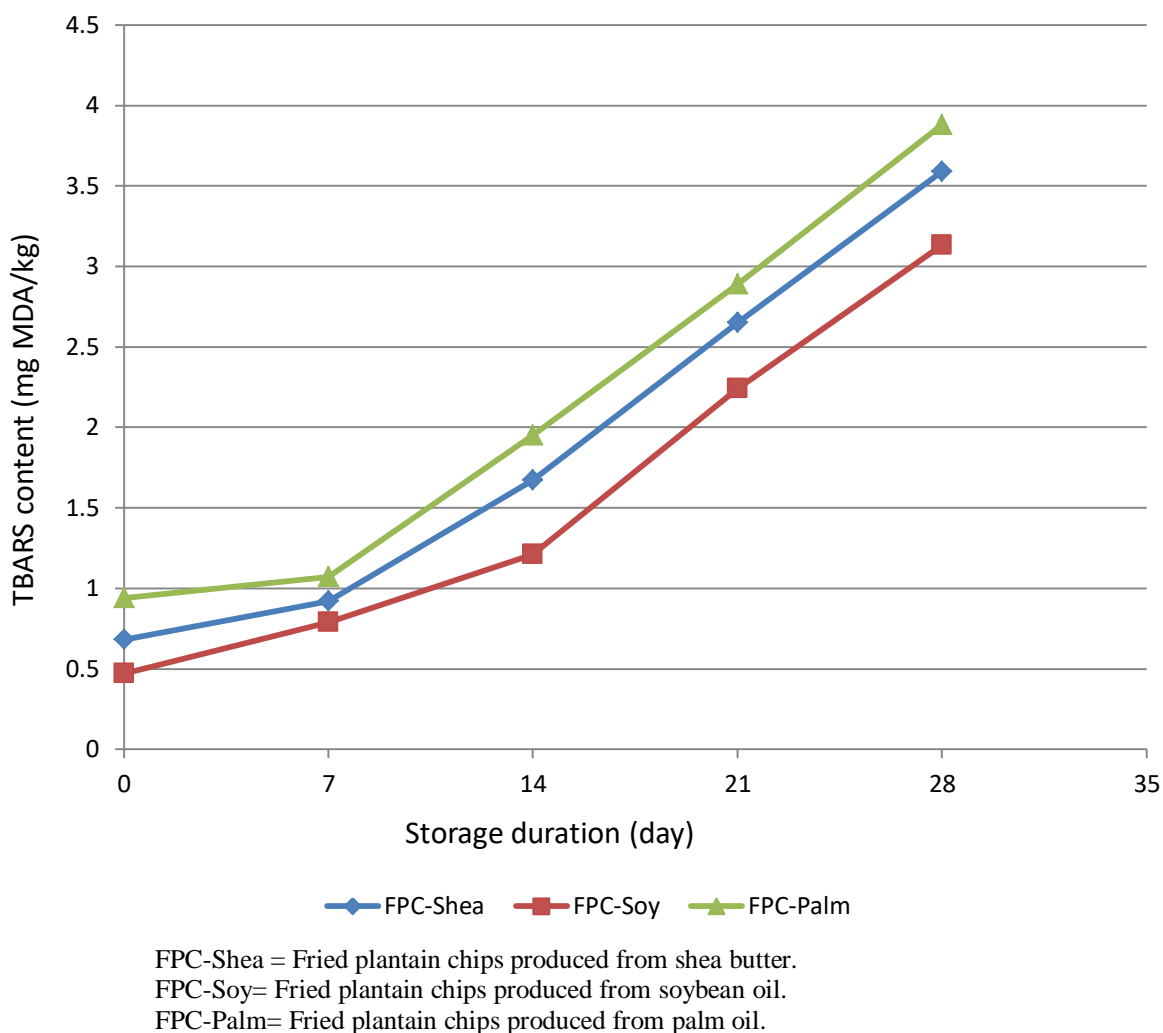
FPC-Shea = Fried plantain chips produced from shea butter.

FPC-Soy= Fried plantain chips produced from soybean oil.

FPC-Palm= Fried plantain chips produced from palm oil.

**Figure 1:** Changes in free fatty acid value of fried plantain chips, under storage, produced from different vegetable oils.





**Figure 2:** Changes in thiobarbituric acid-reactive substance (TBARS) content of fried plantain chips, under storage, produced from different vegetable oils.