Differentials in Chips and Reused Oil Quality of Fried Plantain

Ugwuona Fabian Uchenna[1]*, Ibewuike Nkiruka Precious[1], Ejinkeonye Uju Bridget[2] and Agwo Obinna Eni[1]

[1]*Department of Food Science and Technology, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture, Umudike, Nigeria*

[2]*Department of Home Economics, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture, Umudike, Nigeria*

Corresponding author: ugwuonafu@yahoo.com **Phone no:** +2347039073421

ABSTRACT

Background: *Plantain chips are popular snack enjoyed by all ages in Nigeria; however, repeated use of oil for frying is a common practice among Nigerians.*

Objective: *This study evaluated the oxidative stability of groundnut oil used repeatedly for frying the plantain chips and physicochemical characteristics of the fried chips.*

Methods: *Plantain fingers were peeled, sliced into chips (2 mm thick), soaked (3 min) in 5% salt solution, drained out (5 min) and fried in groundnut oil (2.5 litres) within 12 – 15 minutes on the first day. On the 3rd, 5th, 7th and 9th days of the experiment, fresh plantain chips were similarly prepared and fried with the same groundnut oil. The groundnut oil was analysed for oxidative stability while chips were analysed for physicochemical characteristics.*

Results: *Repeated use of the same oil in subsequent frying significantly ($p < 0.05$) decreased quality of both the oil and chips. The chips appearance darkened; and its protein and ash contents decreased from 3.59% and 9.48% in the 1st day chips; and to 3.11% and 8.84% in the 9th day chips respectively. Calcium (Mg/100g) and β-carotene contents (Mg/100g) respectively decreased from 10.37 and 1077.67 in the 1st day chips to 9.59 and 257.12 in the 9th day chips. Physicochemical parameters of the oil deteriorated. Iodine value decreased while free fatty acid, peroxide value and thiobarbituric acid number increased.*

Conclusion: *The oil darkened in colour with increasing rancid characteristics as it was being used repeatedly for frying fresh plantain chips while this decreased physicochemical characteristic of the fried chips The same oil, particularly groundnut oil, should not be used over time for frying chips in order to protect consumers from health-related issues that might arise from consuming such oil and chips.*

Key wards: Frying, groundnut oil, plantain.
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INTRODUCTION

Fried foods are popular snacks cherished and enjoyed by most Nigerians. Frying oils commonly used in Nigeria include refined vegetable oil, soybean and groundnut oil, and bleached palm oils. Popular fried foods sold in Nigeria include fish, akara, yam, potato and plantain chips [1, 2] (FAO, 2011; FAO, 2013). These foods are cooked by deep-fat frying. Fried foods are valued for their flavour, aroma and crispy texture [3, 4], and characteristics soft, juicy interior and thick, crispy outer crust [5].

Deep-fat frying is a high temperature-short time process at 150 OC to 190 OC [6] within 10 – 15 min. It involves both mass transfer comprising water loss and oil uptake, and heat transfer [7]. The types of food that is being fried, frying oil and frying process are complex parameters involved. It is a value addition process that results in products with unique flavour-texture combinations [8, 9, 10]. Frying time, surface area and initial moisture content of food being fried, types of breading or battering materials and frying oil affect quality characteristics of fried foods [6, 11].

Frying business in Nigeria is practised by numerous street food vendors both early in the morning and late in the evening at busy street corners, junctions,

under shades, in buckers and market places. A common practice is the repeated use of the oil of oil different batches of food on the same day and/ or on later days. These batches of food never had the same shade of colour while the oil continued darkening in colour with repeated frying.

Thus, in Nigeria deep-fat frying is abused; and there is no operating regulatory guideline on fried foods in Nigerian markets for the safety of numerous consumers.

Plantain grows profusely in Nigeria [11], and is rich in carbohydrate, antioxidants and minerals, including iron, calcium, zinc, magnesium, sodium and phosphorus [12, 13]. This study evaluated the effect of repeated use of the same groundnut oil for frying plantain chips, as is practised in most bookers in Nigeria, on quality of both the chips and the oil.

MATERIALS AND METHODS

Materials: Two heads of mature green plantain (identified as Musa paradisaca by the Department of Plant Science and Biotechnology of Michael Okpara University of Agriculture, Umudike) were purchased from Ndioru market, Umuahia, Abia State, Nigeria. First head was purchased on the 1st day while the second head was on 5th day of the experiment. Iodized salt was purchased from Shoprite mall, Umuahia while groundnut oil was purchased from a local producer at Birni Market, Shagari Local Government Area, Sokoto State, Nigeria.

Processing of plantain chips: On each day of frying, plantain fingers were peeled, cut into uniform slices of about 2mm thick, immersed in 2% salt solution (1 g of salt per 50 ml of water) for 5 min and rinsed out with fresh water., removed and drained over basket sieve for 5 min. Groundnut oil (2.5 litres) was heated to 140OC-160OC for 5 min before frying 10 -12 slices of plantain chips within 15 to 18 min until the slices became crispy and golden brown in colour. Two batches were fried on each day and frying was repeated on the 3rd, 5th, 7th and 9th days of the experiment, using the same frying oil for fresh diced mature green plantain. After each day frying, 20 ml of the cooled oil was analysed for physicochemical and rancidity changes while the chips were analysed for nutrient composition.

Analysis of Samples

All laboratory analysis were carried out at the Biochemistry Laboratory Department of the National Root Crops Research Institute, Umudike, Nigeria.

Determination of proximate and mineral compositions and energy value of samples

Proximate composition and energy value were determined using AOAC method [14]. Moisture content was recorded as loss in weight after heating (105OC, 24 h) 2 g of sample in a hot air oven. Total nitrogen was determined by the micro-kjeldahl method, and crude protein calculated by multiplying the total nitrogen (TN) by a conversion factor of 6.25. Crude lipid was determined by ether extraction (40 – 60OC) method using Tecato Soxhlet apparatus. Defatted sample (2 g) was digested with 200 ml of 0.225 N H2SO4, filtered and washed with boiling water through cheese cloth in a fluted funnel. This was mixed and boiled for 30 min with 200 ml of 1.25% NaOH solution, cooled and filtered. The residue was oven-dried (105OC, 4 h), cooled, weighed and incinerated (550OC, 2 h) in a muffle furnace. Loss in weight after incineration was reported as crude fibre content while the remainder was reported as the ash content. The resulting ash was dissolved in 5 ml of 0.1M. HCl solution and then diluted with distilled water to 100 ml in volumetric flask. The extract was used to determine the minerals Ca, Mg, Fe and Zn using atomic absorption spectrophotometer (AAS) model 703, 23. Phosphorus content of the extract was determined spectrophotometrically. Carbohydrate was determined by difference.

Determination of vitamin contents of samples

Determination of β-carotene content: β-carotene content was determined using the method of AOAC [14]. Two millilitres of oil sample was dispersed in 30mls absolute alcohol, and 3 ml of 50% potassium hydroxide solution added. The mixture was boiled under reflux for 30 min, cooled rapidly under running water and transferred to a separating funnel. Distilled water (30 ml) was added, and the mixture washed with 50 ml of ether to extract the β-carotene. The lower aqueous layer was discarded while the upper oil layer containing the β-carotene was further washed four times, each with 50 ml of distilled water. The extract was passed through desiccators and then evaporated to dryness. The extract and standard vitamin A were separately dissolved in 10 ml of isopropyl alcohol; and their absorbance read at 325 nm. β-carotene was calculated as vitamin A equivalent (pro-vitamin A) with

$$\text{Vit. A } (1\mu/100\text{g}) = \frac{\text{Au}}{\text{AS}} \text{ x } \frac{100}{1}, \quad \text{.....i}$$

Where Au - absorbance of sample, AS - absorbance of standard, W - weight of sample, C - concentration of Standard.

Determination of vitamin E: Vitamin E assay was done using the method of Kirk and Sawyer [15]. One gram (1 g) of oil was macerated with 20 ml of ethanol and filtered through what man no 5filter paper. One ml (1 ml) each of ferric chloride (0.02%) solution and 0.5% α-α dipyridine solution were added to 1ml of the filtrate, and diluted to 5 ml with distilled water. Absorbance of the mixture was read at 520 nm using spectrophotometer (Spectronic 21 days, Multon Roy, Rochester Ny, U.S.A). A standard curve of vitamin E was prepared from different absorbance values of vitamin E concentrations, and vitamin E contents of the oils extrapolated from the curve.

Determination of physicochemical properties of oil

Determination of specific gravity: Specific gravity was determined as described by AOAC [14]. A density bottle was washed, oven-dried (105OC, 4h), corked, cooled and weighed (W0). This was filled with cold distilled water, maintained at 25 OC for 30 min in a water bath and then weighed (W1). The bottle was emptied, dried (105OC, 4h) and filled with the frying oil and re-weighed (W2). The specific gravity was calculated thus.

$$\text{Specific gravity} = W_1 - W_0 / W_1 - W_0$$

Where W_0 = Weight of empty bottle (g),
W_1 = weight of water and bottle, (g)
W_2 = weight of oil and bottle (g).

Determination of iodine value: The iodine value was determined using the method of AOAC [14]. Oil sample, 0.4 g was weighed into a 50 ml conical flask and 20 ml of carbon tetrachloride added. Wiji's reagent (25 ml) was pipette into the mixture under fume chamber. This was corked, swirled vigorously and stored in the dark for 2.5 h. Potassium iodide (20 ml) and distilled water (125 ml) were added and the resulting solution titrated with 0.1M sodium thiosulphate solution, using1% starch indicator, until the initial yellow colouration almost disappeared. This was repeated for the blank, and the procedure repeated three times. Iodine value was calculated thus:

$$\text{Iodine Value} = \frac{(S-B)x12.612}{\text{weight of sample}},$$

Where; B = titre value of the blank,
S = titre value of the sample,
12.612 = N which is normality of Na_2SO_3 solution.

Determination of free fatty acids and acid value: The AOAC method [14] was adopted. Free fatty acid (FFA) is usually calculated as oleic acid equivalent (1ml 0.1M sodium hydroxide = 0.0282g oleic acid), with the acid Value gotten by doubling FFA value. Two grams (2.0 g) of oil was mixed with 50 ml n-hexane and 1 ml phenolphthalein indicator in a 250cm Erlenmeyer flask. The mixture was titrated against 0.04 M NaOH until a slight pink colouration persisted for 15s. Free fatty acid (FFA) was calculated as

$$\text{Percentage FFA} = V\ x\ \frac{M}{W}\ x\ 282\ x\ 100$$

Where V = Average volume of NaOH used (ml),
M = Molarity of NaOH,
282g/ mol = molecular weight of oleic acid,
W = weight of oil sample. FFA is calculated as oleic acid (1ml 0.1M sodium hydroxide= 0.0282g oleic acid) with the acid value was gotten by multiplying FFA by 2.

Determination of phytochemical contents of samples

Determination of flavonoid content: Flavonoid content was determined using the AOAC method [14]. Five gram (5 g) of ground potato chips was added to 50 ml of 2M HCl at room temperature, boiled for 30min on a water bath, cool and then filtered through What man No. 40 filter paper. Ethyl acetate (10 ml) was mixed with the filtrate and the mixture filtered through a weighed filter paper (W1). The filter paper was oven dried, cooled and re-weighed (W2). The procedure was repeated thrice and the average value calculated. Flavonoid content was calculated using the formula,

$$\%\ \text{Flavonoid} = \frac{(W2-W1)X100}{W}$$

Where W = weight of sample,
W1 = weight of empty filter paper,
W2 = weight of paper + flavonoids extracts.

Determination of sterols: This was determined as described by Edeoga et al. [16]. Five grams (5g) of oil was homogenised with 100 ml of distilled water in a kitchen warring blender and eluted with normal ammonium hydroxide solution (pH 9). One ml (1 ml) of the eluate was mixed with 2 ml of chloroform, 3 ml of ice-cold acetone anhydride and 3 drops of concentrated H2SO4 in a 25-ml flask.

Standard sterol and blank solutions were prepared similarly. Absorbance of the sample solution and standard sterol were measured at 420 nm using a spectrophotometer, with the blank solution used to calibrate the instrument at zero. The experiment was repeated thrice
and sterol calculated as

$$\% \text{ steroid} = \frac{100}{W} \times \frac{AU}{AS} \times \frac{C}{1000} \times \frac{VF}{VA}$$

Where W = Weight of sample analyze,
AU = Absorbance of test sample,
AS = Absorbance of the standard sterol solution,
C = Concentration of standard solution in mg/ml,
VF = Total volume of extract,
VA = Volume of extract analyzed.

Determination of storage stability of oil during frying

Determination of peroxide value: The method of AOAC [14] was adopted. The oil sample (2 g) was mixed with 12 ml of chlorine, 10 ml of acetic acid and 0.5 ml of potassium iodide in a 50 ml conical flask. This was corked, swirled for 1 minute before adding 30 ml of distilled water, and then titrated with 0.1M sodium thiosulphate (Na2S2O3) solution using 1% starch solution as an indicator. Peroxide value (mgEqH_2O_2/100g) was calculated as

$$\frac{[(S-B)xM\ x\ 100]}{W\ x\ 100}$$

Where, S = sample titre value (cm3),
B = Blank titre value (cm3).
M = Molarity of Na2 S2O3 solution (meq/cm3),
1000 = Conversion unit (g/kg),
W = weight (g) of oil sample.

Determination of thiobarbituric acid number: Thiobarbituric acid number (TBA) was determined using distillation method as outlined by Tarladgis et al., [17]. Ten gram (10 g) of sample was macerated with 50 ml of distilled water, washed into a 250-ml distillation flask and mixed with 47.5ml water, 2.5ml of 4M hydrochloric acid to bring the pH to 1.5, followed by the addition of a few glass beads to act as antifoam. The flask was fitted to a distillation unit and heated by means of an electric mantle so that 50 ml of distillate was collected within 10 min from the time boiling commenced. Five ml (5 ml) of the distillate was pipette into a glass-stoppered text tube, and 5 ml TBA reagent (0.28833g/100ml of 90% glacial acetic acid) added. The tube was Stoppard, shaken and heated in boiling water for 35minutes. A blank was prepared similarly using 5ml water and TBA reagent. The tubes were cooled in water for 10 min, after which the absorbance (D) against the blank read at 538nm using spectrophotometer. TBA no. (Mgmalonaldehyde per kg sample) = 7.8D.

Statistical analysis: Data were subjected to descriptive statistics and analysis of variance (ANOVA) used to compare differences among mean values. Means where significantly different were separated using Fisher's least significant difference (LSD) at $P < 0.05$.

RESULTS

Physical appearance of plantain chips fried with the same oil on five different days

Figure 1 shows samples of plantain chips fried with the same oil on 5 different days. Chips fried the first day had golden yellow colour. Chips fried the second time on the third day had slightly darkened golden yellow colour. Thus, as the oil was repeatedly used for chips each subsequent day, the chips fried become darker in colour than the previous one.

Table 1 shows proximate composition of five batches of plantain chips fried with the same groundnut oil on five different days, namely first, third, fifth, seventh and ninth days of frying regiment. Frying of plantain with fresh frying oil significantly ($p < 0.05$) decreased moisture content to about 20 times but increased most other proximate constituents of the chips. Moisture content (%) decreased from 60.42% in fresh chips to 3.57 in chips fried on the first day; was 3.64% on the 3rd and the 5th day fried chips, and 3.78% on the 9th day chips.

However, protein content (%) decreased on the first day after frying; and ranged from 3.36 in fresh to 3.11 in the ninth day chips. These changes were not significant ($p < 0.05$). The 1.18% ash content in fresh chips increased to 9.48 in the first day fried chips but this decreased continually in the subsequent frying; was 9.01% in the fifth day batch, and 8.46% in the ninth day batch. Crude fat content (%) was 0.17 in fresh chips but increased to 14.39 in first day fried chips and decreased to 13.65 in the fifth day chips, and to 12.51 in the ninth day chips.

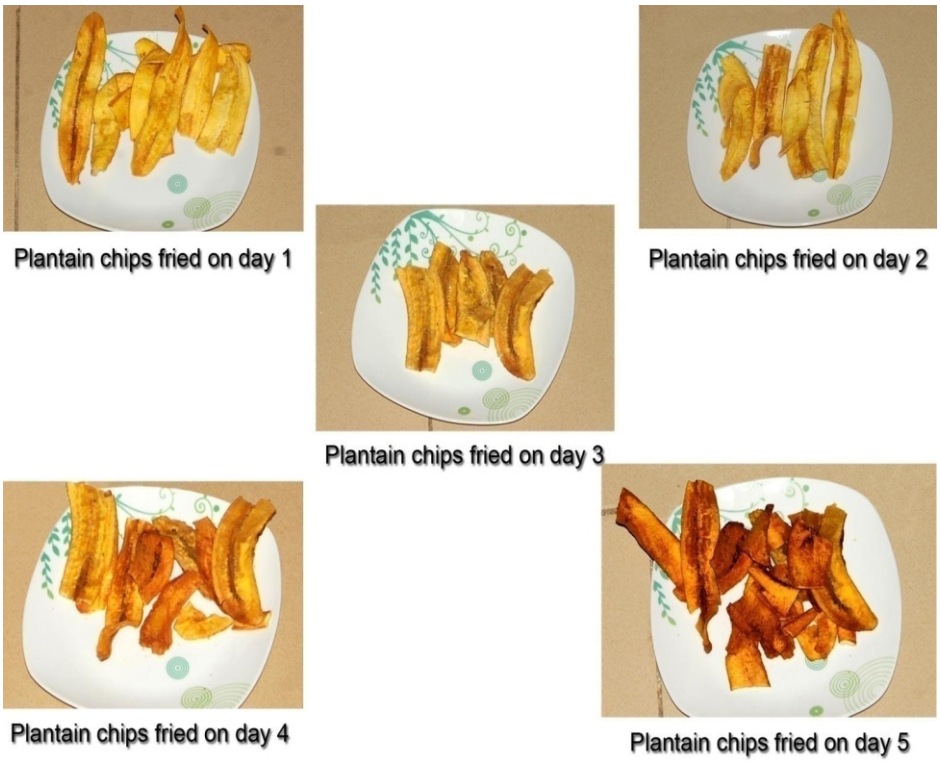

Plate 1. Samples of plantain chips fried with the same oil on five different days

Table 1: Proximate (mg/100g) composition of plantain chips fried in the same groundnut oil on five different

Components analysed (%)	Raw	Day 1	Day 3	Day 5	Day 7	Day 9
Moisture	$60.42^{a} \pm 0.01$	$3.57^{c} \pm 0.01$	$3.64^{c} \pm 0.01$	$3.64^{c} \pm 0.02$	$3.56^{c} \pm 0.02$	$3.78^{b} \pm 0.01$
Protein	$3.66^{a} \pm 0.02$	$3.59^{a} \pm 0.01$	$3.56^{ab} \pm 0.02$	$3.46^{a} \pm 0.01$	$3.32^{a} \pm 0.01$	$3.11^{a} \pm 0.01$
Ash	$1.18^{c} \pm 0.01$	$9.48^{a} \pm 0.01$	$9.31^{a} \pm 0.01$	$9.01^{a} \pm 0.01$	$8.74^{b} \pm 0.01$	$8.46^{b} \pm 0.02$
Crude fat	$0.17^{d} \pm 0.01$	$14.39^{a} \pm 0.01$	$14.33^{a} \pm 0.01$	$13.65^{b} \pm 0.01$	$13.46^{b} \pm 0.01$	$12.51^{c} \pm 0.01$
Crude fibre	$3.56^{f} \pm 0.01$	$8.05^{a} \pm 0.02$	$7.92^{ab} \pm 0.01$	$7.66^{b} \pm 0.01$	$7.32^{c} \pm 0.01$	$7.16^{d} \pm 0.01$
Carbohydrate	$31.01^{f} \pm 0.01$	$60.96^{e} \pm 0.01$	$61.23^{d} \pm 0.02$	$62.54^{c} \pm 0.01$	$63.37^{b} \pm 0.02$	$64.99^{a} \pm 0.02$
Energy (kj)	$140.21^{d} \pm 0.01$	$387.71^{a} \pm 0.01$	$388.17^{a} \pm 0.01$	$386.85^{b} \pm 0.01$	$387.09^{b} \pm 0.01$	$385.01^{c} \pm 0.01$
DM	$39.58^{b} \pm 0.01$	$96.43^{a} \pm 0.01$	$96.36^{a} \pm 0.01$	$96.32^{a} \pm 0.01$	$96.25^{a} \pm 0.01$	$96.22^{a} \pm 0.01$

Table 2 shows that the fried plantain chips had lower mineral contents than the raw one; and that repeatedly using the same oil for frying chips on subsequent days decreased most minerals, except iron, in the fried chips. The fried chips were generally high in calcium (9.59-10.37mg/100g), magnesium (50.15-88.48mg/100g), phosphorus (95.11-95.62mg/100g), potassium (100.02 – 100.82 mg/100g), iron (226.19-227-26mg/100g) and zinc (7.96-9.59 mg/100g) but relatively low in sodium (1.91 – 4.61 mg/100g). As shown in Table 2, these minerals significantly ($P>0.05$) decreased continually in subsequent chips repeatedly fried with the same oil.

Data are mean of triplicate determinations ± standard deviation. Means bearing different superscripts on the same rows are significantly different at $P < 0.05$).

Table 3 shows phytonutrient composition of both the fresh and fried plantain chips. Repeated use of the same oil for frying of plantain chips on different days significantly ($p < 0.05$) reduced phytonutrient

Table 2: Mineral composition (mg/100g) of plantain chips fried with the same groundnut Oil on different days

Minerals	(Raw)	(Day 1)	(Day 3)	(Day 5)	(Day 7)	(Day 9)
Ca	$14.69^{a} \pm 0.01$	$10.37^{b} \pm 0.01$	$10.26^{bc} \pm 0.01$	$10.11^{c} \pm 0.01$	$9.98^{d} \pm 0.01$	$9.59^{e} \pm 0.01$
Mg	$99.17^{a} \pm 0.01$	$86.48^{b} \pm 0.01$	$72.21^{c} \pm 0.01$	$60.76^{d} \pm 0.01$	$50.33^{e} \pm 0.01$	$50.15^{e} \pm 0.01$
Fe	$225.32^{d} \pm 0.01$	$226.19^{c} \pm 0.01$	$226.46^{b} \pm 0.01$	$226.71^{b} \pm 0.01$	$226.92^{ab} \pm 0.01$	$227.26^{a} \pm 0.01$
Zn	$10.97^{a} \pm 0.01$	$9.59^{b} \pm 0.01$	$9.17^{c} \pm 0.01$	$9.01^{d} \pm 0.01$	$8.62^{e} \pm 0.01$	$7.96^{f} \pm 0.01$
Na	$5.76^{a} \pm 0.02$	$4.61^{b} \pm 0.01$	$3.48^{c} \pm 0.01$	$2.77^{d} \pm 0.01$	$2.34^{e} \pm 0.01$	$1.91^{f} \pm 0.01$
K	$102.55^{a} \pm 0.02$	$100.82^{b} \pm 0.01$	$100.79^{b} \pm 0.01$	$100.64^{c} \pm 0.01$	$100.10^{d} \pm 0.02$	$100.02^{d} \pm 0.01$
P	$99.83^{a} \pm 0.01$	$95.62^{b} \pm 0.01$	$95.51^{c} \pm 0.01$	$95.48^{d} \pm 0.01$	$95.37^{e} \pm 0.01$	$95.11^{f} \pm 0.01$

Table 3: Phyto nutrient composition (mg/100g) of plantain chips fried on different days in the same groundnut

Phyto-Nutrients	Raw	Day 1	Day 3	Day 5	Day 7	DAY 9
β-carotene	$1120.81^{a} \pm 0.01$	$1077.67^{b} \pm 0.01$	$1048.53^{c} \pm 0.02$	$1037.01^{d} \pm 0.01$	$617.42^{e} \pm 0.16$	$257.12^{f} \pm 0.01$
Flavonoid	$0.95^{a} \pm 0.01$	$0.86^{b} \pm 0.01$	$0.73^{c} \pm 0.01$	$0.62^{d} \pm 0.02$	$0.55^{e} \pm 0.01$	$0.42^{f} \pm 0.01$
Vitamin C	$9.59^{a} \pm 0.01$	$9.47^{b} \pm 0.01$	$9.23^{c} \pm 0.01$	$9.09^{d} \pm 0.01$	$8.88^{e} \pm 0.02$	$8.76^{f} \pm 0.01$

composition of chips. The plantain chips were relatively high in β-carotene and vitamin C contents but poor in flavonoid contents. β-carotene content ranged from 257.12 mg/100g in the last (5th) batch of chips fried on the 9th day to 1120.81 mg/100g in the raw plantain chips. Vitamin C content ranged from 8.76 mg/100g in the same 5th batch to 9.59 mg/100g in the raw chip. Similarly, flavonoid content ranged from 0.42 mg/100g in the 5th bath fried on 9th day to 0.95 mg/100g in the raw chips.
Data are mean of triplicate determinations ± standard deviation. Means bearing different superscripts on the same rows are significantly different at $P < 0.05$).

Table 4 shows physicochemical parameters of groundnut oil repeatedly used in frying plantain chips on five different days. There were progressive changes in all the physical parameters.
The fresh oil had an acid value of 8.44 mgKOH/g% which increased to 8.51% after frying plantain chips with the oil on the same day. On further frying a second batch of plantain chips with this same oil on the third day, the 8.51% acid value increased to 9.82%. This further increased to 10.83% after frying a third batch of plantain on the fifth day; this was equivalent to 8.5% increase from the previous value. After frying a fifth batch of plantain on the ninth day, the acid value of the oil rose to 12.35%. On the other hand, both iodine and specific gravity of the oil decreased progressively with repeated use for frying plantain chips on subsequent days.
The used groundnut oil was poor in flavonoid and sterol but relatively high in vitamin E and B carotene as shown in Table 5. Both phytohemical and vitamin constituents of the oil decreased with frying on each day. The flavonoid (mg/100g) content of the fresh oil was 0.45 but quickly decreased to 0.42 after frying first batch of plantain chips with it on the same day. The 0.42mg/100g flavonoid decreased to 0.3mg/100g, with 21.43% decrease on the 3rd day after frying a second batch of plantain. On the 7th day after frying forth batch of plantain, it was 0.19mg/100g before it further decreased to 0.09mg/100g on the 9th day after it was used to fry the fifth batch of plantain chip. Sterol content (Mg/100g) was significantly ($p < 0.05$) low and ranged from 0.92 in the fresh oil sample to 0.65 after frying on the 9th day. Thus, sterol content decreased with frying. The vitamin E content (Mg/100g) of the fresh oil was 120.67 but this decreased to 118.33mg/100g, corresponding to 1.94% decrease after frying. This value decreased to 106.67 mg/100g, corresponding to 9.85% on the 3rd day after frying a 2nd batch of plantain chips with it. On the 7th day after 4th frying, vitamin E decreased to 77.67 mg/100g.

Table 4: Physicochemical composition of groundnut oil used in frying of plantain chips on different days

Frying Days	Free fatty acid (%)	% Increase	Acid value (mgKOH/g)s	% Increase	Iodine value (gI_2/100g)	% Decrease	Specific gravity (G)	% Decrease
Fresh oil	$4.22^{f}\pm0.02$	0.00	$8.44^{f}\pm0.04$	0.00	$126.62^{a}\pm0.01$	0.00	$0.99^{a}\pm0.00$	0.00
Day 1	$4.25^{e}\pm0.01$	0.71	$8.51^{e}\pm0.02$	0.82	$104.51^{b}\pm0.01$	17.46	$0.99^{a}\pm0.00$	0.00
Day 3	$4.91^{d}\pm0.01$	13.44	$9.823^{d}\pm0.02$	13.34	$99.74^{c}\pm0.01$	4.56	$0.97^{b}\pm0.00$	2.02
Day 5	$5.37^{c}\pm0.01$	8.57	$10.73^{c}\pm0.02$	8.48	$94.51^{d}\pm0.01$	5.24	$0.95^{c}\pm0.00$	2.06
Day 7	$5.81^{b}\pm0.07$	7.57	$11.63^{b}\pm0.02$	7.73	$86.75^{e}\pm0.02$	8.21	$0.89^{d}\pm0.00$	6.31
Day 9	$6.17^{a}\pm0.01$	5.83	$12.35^{a}\pm0.02$	5.83	$80.11^{f}\pm0.02$	7.65	$0.88^{e}\pm0.00$	1.12

Values are means ± standard deviation of triplicate determinations. Means within the same column bearing different superscripts are significantly different at $P<0.05$.

Table 5: Changes in Phytochemical and vitamin composition of groundnut oil used in frying of plantain chips on different days

Frying days	Flavonoid Mg/100g	% Decrease	Beta carotene mg/100g	% decrease	Vitamin E Mg/100g	% Decrease	Sterol Mg/100g	% Decrease
Fresh oil	$0.45^{a}\pm0.0$	10.00	$1.98^{a}\pm0.02$	0.00	$120.67^{a}\pm1.15$	0.00	$0.92^{a}\pm0.02$	0.00
Day_1	0.42b±0.01	6.67	$1.51^{b}\pm0.01$	43. 94	$118.33^{b}\pm0.56$	1.94	$0.84^{b}\pm0.01$	8.70
Day_3	$0.33^{c}\pm0.01$	21.43	$1.51^{c}\pm0.01$	36.04	$106.67^{c}\pm1.15$	9.85	$0.77^{c}\pm0.01$	8.33
Day_5	$0.26^{d}\pm0.01$	21.21	$1.37^{d}\pm0.01$	9.27	$98.33^{d}\pm0.58$	7.81	$0.65^{d}\pm0.17$	15.58
Day_7	$0.19^{e}\pm0.01$	26.92	$1.21^{e}\pm0.01$	11.68	$77.67^{e}\pm1.15$	21.01	$0.58^{e}\pm0.01$	10.76
Day_9	$0.09^{f}\pm0.015$	2.63	$0.46^{f}\pm0.01$	61.98	$53.67^{f}\pm1.15$	30.89	$0.42^{f}\pm0.01$	27.58

Values are means ± standard deviation of triplicate determinations. Means within the same column bearing different superscripts are significantly different at $P<0.05$.

Repeated frying of plantain chips with the same groundnut oil significantly ($P<0.05$) affected stability of the oil (Table 6). On the 7th day, being the 4th frying, the value rose to 3.08 Meq02/kg after frying. This (3.08Meq02/kg) increased to 3.57 Meq02/kg with a percentage increase of 13.73% on the 9th day after frying with it the fifth time. Also, the thiobarbitric acid value (TBA) (MgMDA/kg) of the fresh oil was 0.17 before and after frying plantain chips with it the same day. However, on the 3rd day on second time of frying the TBA increased significantly ($P<0.05$) mg MDA/kg after frying, and to 0.29 mgMDA, with 3.79% increase on the 7th day after frying. This value (0.29mgMDA/kg) also significantly ($P<0.05$) increased to 0.35 MgMDA/kg on the 9th day after frying the 5th time with the same oil. This caused a percentage increase of 17.14 from the previous value on the 7th day.

DISCUSSION

The fried chips absorbed fat from the frying oil; as indicated with the reducing volume of the frying oil in subsequent use. All the fried chips were good sources of energy which ranged from 387.71 KJ in the 1st day to 385.01 KJ in the 9th. With the drastically reduced water contents in the fried chips, the dry matter (DM) content (%) became very high and ranged from 96.22 to 96.43. These chips were good sources of carbohydrate, crude fibre, minerals and fat; but low in crude protein.

The low moisture content of the fried implies long shelf life and good keeping quality of the fried chips. Repeated frying with the same oil did not significantly ($P > 0.05$) affect protein content of chips which ranged from 3.6% to 3.11%. This range is comparable to 3.48 – 2.99% reported earlier by other researchers [18] in plantain chip fried in palm oil, and in vegetable oil.

The calcium, phosphorus, potassium, iron, zinc, magnesium and sodium contents of the subsequent chips were always lower than those of the previous ones within the 9 days frying regiment of the five

Table 6: Changes in oxidative properties of groundnut oil during frying of plantain chips on different days

Frying days	Peroxide value ($meqO_2/kg$)	% Increase	Thiobarbituric acid(mgMDA/kg)	% Increase
Fresh oil	$1.63^{f}\pm0.01$	0.00	$0.17^{e}\pm0.01$	0.00
Day_1	$1.96^{e}\pm0.01$	16.84	$0.17^{e}\pm0.01$	0.00
Day_3	$2.21^{d}\pm0.01$	11.31	$0.20^{d}\pm0.01$	15.00
Day_5	$2.66^{c}\pm0.0$	16.91	$0.25^{c}\pm0.00$	20.00
Day_7	$3.08^{b}\pm0.02$	13.64	$0.29^{b}\pm0.00$	13.79
Day_9	$3.57^{a}\pm0.01$	13.73	$0.35^{a}\pm0.00$	17.14

Values are means ± standard deviation triplicate determination, means on the same column with different superscript are significantly ($P<0.05$) different.

batches. This suggests that some of the magnesium and sodium salts present in the fresh chips were oil soluble. The mineral content of our fried chips is similar to 50.26% to 99.28% recorded by other researchers [19, 20, 21] (Dobarganes et al., 2000; Bastida and Sanchez-Muniz, 2001; Crosa et al., 2014) in chips fried in canola oil, soya oil and vegetable oil.

Repeated frying with the same oil decreased β-carotene, carotenoid and vitamin C contents of the plantain chips fried on the subsequent days. Both flavonoid and vitamin C contents decreased continually with repeated frying. Similar decreases of these minerals in plantain chips fried with canola and soya oils reported earlier by other researchers [22, 23] (Xu et al.,1999; Miranda et al., 2009).

Significant changes ($p < 0.05$) were also developed in the frying oil during the repeated frying process. Iodine value dictates the degree of unsaturation in fatty acids. The iodine value (GI/100g) of the fresh oil was 126.62, indicating high degree quality and unsaturation of the fresh oil (24) (Thomas, 2002). This value decreased with repeated use of this same oil for frying. The specific gravity also decreased with repeated frying. Decrease in specific gravity implies increasing tri glycerides probably due to high temperature frying (25) (Yoshida et al., 2005), implying high degree of deterioration in the oil. β-carotene content of the oil was at variance during various stages of frying. High temperature treatment decreased β-carotene, vitamins E, steroid and flavonoid contents of the chips. This was in line with the report of Loku et al. (2001) (26).

Both peroxide values (mg 02/kg) and thiobarbituric acid values (TBA) (mg MDA/kg) increased significantly ($P<0.05$) with refrying. Oxidative deterioration was more prone during the last day of frying. Oxidation can cause shift of double-bond position in PUFA (27) (Amit et al., 2013).

CONCLUSION

Repeated use on the same groundnut oil in frying of plantain chips resulted in quality loss in the oil and plantain chips. The β-carotene, vitamin E, specific gravity, and flavonoid contents decreased while the free fatty acid, acid value, peroxide value and iodine value increased respectively. Also, protein, ash and fibre contents of the chips decreased. The chips also darkened in colour from golden yellow to brownish yellow with repeated frying. The study suggests that repeated use of the same frying oil for frying should be avoided completely if it is to be used as cooking oil.

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REFERENCES

1. FAO, (2011). Production, Commodity by Country; FAOSTAT Data. Food and Agriculture Organization of the United Nations, Rome. http://faostat:fao.org/site/339/default.aspx

2. FAO, (2013). Food and Agriculture Organization of the United Nations. Crop yield http://faostat.org/site/567/DesktopDefault.aspx?pageID567#ancor.

3. Boskou, D. (2000). Quality of frying Oils. In: VarelaG, Bender AE, Morton ID, Editors Frying of Food: Principles, Changes, New approaches. New York: VCH Publishers p174-182.

4. Hindra, F. and Baik, O. D. (2006). Kinetics of

Quality Changes during Food Frying. Critical Review on Food Science and Nutrition, 46:239-258.
5 Garcia, M. A., Ferrero, C., Bertola, N., Martino, M. and Zaritzky, N. (2002). Edible Coatings from Cellulose Derivatives to Reduce Oil Uptake in Fried Products. Inn Food ScienceEmerging Technology. 3 391-397.
6. Moreira, R. G., Sun, X. and Chen, Y. (1997). Factors Affecting Oil Uptake In Tortilla Chips In Deep-Fat Frying. Journal on Food Engineering.31:485–98.
7. Vitrac, O., Dufor, D., Trystram, G. and Raoult-Wack, A. (2002). Characterization of heat and mass transfer during deep fat frying and its effect on cassava chips quality. Journal of Food Engineering, 53: 161-176.
8. Mellema, M. (2003). Mechanism and reduction of fat uptake in deep-fat fried foods. Traditional Food Science and Technology, 14:364-373.
9. Pedreschi, F., Moyano, P., Kaack, K. and Granby, K. (2005). Colour Changes and Acrylamide Formation in Fried Potato Slices. Food Research International.38:1–9.
10. Pedreschi, F. (2012). Frying of Potatoes: Physical, Chemical and Microstructural Changes. Dry Technology. 30:707-725.
11. Avallone, S., Rojas-Gonzalez, J.A., Trystram, G. &Bohuon, P. (2009).Thermal Sensitivity of some plantain micronutrients during deep-fat frying.Journal of Food Science, 74 (5): 339-347.
12. Kanazawa, K. and Sakakibara, H. (2000). High Content of Dopamine, a Strong Antioxidant in Cavendish Plantain. Journal of Agriculture and Food Chemistry, 48: 844-848.
13. Mohapatra, D., Sabyasachi, M. and Namraba, S. (2010). Banana and its by product Utilization: An Overview. Journal of Scientific and Industrial Research, 69: 323-329.
14. AOAC. (2010). Official method of Analysis, Washington D .C. Assocition of official Analytical Chemists. Washington D.C, U.S.A. Pp. 12-22.
15. Kirk, R.S and Sawyer, R. (1991). Pearson's Composition and Analysis of Foods. 9th edition (student edition), England, AddisionWealey Longman Ltd. pp.33-36.
16. Edeoga, H.O., Okwu, D.E and Mbaele, B.O (2005). Phytochemical Constituent of Some Nigeria Medical Plant. African Journal of Biotechnology, 4(7):685-688
17. Tarladgis, B.G, Watta, B.M. Younathan, M.T. and Dugan, L.. (1960). A distillation method for the quantitative determination of malonaldehyde in rancid foods. Journal of American Oil Chemical Society, 37: 41 -48.
18. Beldrock, B. and Abengoa, S. G. (2000). Plantain chips production: Frying using palm oil and vegetable oil. P3 ISBN 0-7923, 6883-3.
19. Dobarganes, C. Marquiz-Ruiz, G, and Velasco. (2000). Interactions between fat and food during deep frying. European Journal of Lipid Science and Technology. 102(89):521-528
20. Bastida S., Sanchez-Muniz F. J. (2001): thermal oxidation of olive oil, sunflower oil and a mix of both oils during forty discontinuous domestic frying of different fools. Food Science and Technology, 7 (20): 15-21.
21. Crosa, M. J., Skerl, V. Cadenazzi, M. Olazabal, L, Torres, M. (2014). Changes produced in oils during vacuum and traditional frying of potato chips food chemistry, 146: pg. 603-607
22. Xu, X. Q., Tran, V. H., Palmer, M., White, K. and Salisbury, P. (1999). Chemical and physical Analyses and Sensory Evaluation of Six Deep-Frying Oils. Journal of American Oil Chemists Society, 76:1091–9.
23. Miranda, M., Maureira, H., Rodriguez, K. & Vega-Galvez, A. (2009). Influence of temperature on the drying kinetics, physicochemical properties, and antioxidant capacity of Aloe Vera (Aloe Barbadensis Miller) gel. Journal of Food Engineering, 91: 297–304.
24. Thomas, Alfred. (2002). "Fats and Fatty oils". ULLmann'sEncyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH.
25. Yoshida, H., Tomiyamakita, Y.S and Mizushina, Y. (2005). Roasting Effects on Fatty Acids Distribution of Triacylglycerol and Phospholipids in the Kernels of Pumpkin (Cucurbitta) seeds. Journal of Science and Food Agriculture, 85:2061-2066
26. Loku, K., Aoyama, Y. and Tokuno. (2001). A Various Cooking Methods and Flavonoid Cotent in Onion. Journal of Nutrition Science Vitaminol(Tokyo), 41(7): 78- 83.
27. Amit, k., Das, R., Babylatha, A.S. Pavithra and Sakinakhatoon. (2013). Thermal Degradation of Groundnut oil During Continuous and Intermittent Frying. Journal of food science and technology, 50(6):1186-1192.