Original Research Article

Effect of Re-Use of African Breadfruit *(Treculia Africana)* Seed Oil on the Physicochemical and Fatty Acid Profile of the Oil

ABSTRACT

The effect of re-use of African breadfruit (*Treculia africana*) seed oil on the physicochemical and fatty acid profile of the oil was studied. Oil was extracted from *Treculia Africana* seeds and the oil was repeatedly used in frying sweet potatoes. The physico-chemical properties of the oil in fresh and reused forms and sensory analysis of the fried potato chips were determined. The performance of African breadfruit*(Treculiaafricana)* seed oil and fried product (potato chips) were compared to those of selected vegetable oils (sunflower and groundnut oil). The results showed that the free fatty acid, iodine value, saponification value, moisture content, specific gravity, smoke point, fire point and flash point of breadfruit oil decreased while peroxide value increased. The fatty acid profile compositions of African breadfruit *(Treculia Africana)* seed oil before and after frying varied from 58.51±0.00 - 43.37±0.00 (Oleic acid), 22.56±0.00 - 17.48 ±0.00 (Linoleic acid), 0.26 ±0.00 - 0.18 ±0.00 (Linolenic acid). The physico-chemical properties of African breadfruit seed oil used for frying were observed to depreciate with reuse. This depreciation in pysico-chemical properties was also observed in reused groundnut oil and sunflower oil. Consumer preference test through sensory analysis showed that potato chips fried with fresh frying oils were significantly ($p<0.05$) different from those fried with reused oil.

Keywords: Nutrient quality, African breadfruit oil, Sweet potato, Fatty acid profile, Sunflower oil

1. INTRODUCTION

African breadfruit (Treculia africana) serves as essential food nutrients that are readily available when other sources of these nutrients very scarce [1]. The seeds from the fruit can be used in making different dished such as boiled, fried, pounded, or mashed to make porridge; it can also serve as flour for bread and biscuit making. [2]. Breadfruit seed is a rich source of edible oil which contain oil of about 20.83% when properly extracted [3]. The seed oil contains hydrocarbon mainly monoterpenes, terpenoids, etc; alcohol and ketene which contribute to its unique flavor. African breadfruit (*Treculia africana*) contains a good quantity of fatty acid that increases during processing which is comparable to that of some conventional oils when processed [4].

Frying is one of the ways in which food is prepared and its demand becomes higher when deep fried. Sensory quality of food as appreciated by the consumers is been improved by frying [5]. Oil is normally heated to about 170 °C to 220°C during frying and these temperatures make the oil undergo physical and chemical reactions [6]. These chemical reactions such as oxidation, hydrolysis, and polymerization of unsaturated fatty acid change the composition of the frying medium [7]. The changes in the reactions lead to the formation of degraded products like free fatty acids, hydro-peroxides and polymerized triglycerides [8]. Reuse of oil affect the quality thus, the more degradation takes place as the oil is heated, the more toxic compounds are formed in the oil [9]. The quality of frying oil affects the quality of the fried food as it contributes some unique organoleptic and sensory characteristics [10,11].

Reuse of frying oil before discarding is a widespread practice and this is normally done to reduce cost. Different research works have shown that the quality of repeatedly heated frying oil deteriorates, leading to the formation of undesirable chemical compounds in the oil [12]. There are health hazards associated with the consumption of oxidized products from oils used repeatedly in frying processes [13]. Health hazards like atherosclerosis and cancer have been associated with these undesirable substances formed [14].

This study, therefore, seeks to establish the effect of re-use of African breadfruit (*Treculia africana*) seed oil on the physicochemical and fatty acid profile of the oil.

2. MATERIALS AND METHODS

2.1 Source of raw materials

African breadfruit (*Treculia africana*) seeds were bought from Ekeoha market, Mbaise in Imo State. Groundnut oil and sunflower oil were bought from Hausa Quarter's Market, Eket Street, Umuahia Abia State. Sweet potatoes tubers were bought at Ahia Eke market in Umuahia Abia State, Nigeria.

2.2 Raw materials preparation

African breadfruit seeds were cleaned to remove contaminants before being oven dried at 55℃ for 48 hours and threshed before manually dehulled to recover the kernels. The kernels were then milled to fine flour particle size using a hammer mill. The flour was preserved in an airtight container at room temperature (28℃) until further needed.

2.3 Processing of raw materials

Extraction of oil from African breadfruit seed was carried out according to the method of Onwuka [15].

The sweet potato tubers were carefully selected and washed in potable water before peeling with knife. The peeled potatoes were washed again before slicing.

Frying of the potato chips were carried out as described by Ikanone and Oyekan, [16] with slight modifications.

2.4 Determination of physicochemical properties

Moisture content, specific gravity, iodine value, peroxide value, free fatty acid and saponification value were determined as described by Onwuka [15].

Smoke, Flash and Fire points were determined as described by Pike [17].

2.5 Determination of fatty acid profile

GC-MS was used to determine the fatty acid profile. BF3 methanolic solution was used to prepare the fatty acid methyl esters and extracted using hexane. Two µL volume of each samples were injected in a HP6890 Series Gas Chromatograph coupled with a Hewlett Packard 5973 Mass Selective Detector at a temperature range of 230^{0}C with 6^{0}C/min, and a solvent delay of 7 min. The gas chromatograph was made with a split-splitless injector and a Factor FourTM Capillary Column VF- 35ms fused silica column of 5% phenylmethylpolysiloxane, 30m*0.25 mm, film thickness 0.25µm. Helium at 1.0 mL/min was used as the carrier gas and the sample was injected in the splitless mode. The MS conditions were as follows: ionization energy, 70 eV; electronic impact ion source temperature, 200^{0}C; quadrupole temperature, 100^{0}C; scan rate 1.6 scan/s; mass, 40-500 amu. The mass spectra of the samples were compared with those of the NIST/EPA/NIH Mass Spectral Library 2.0 for the identification of the compounds.

2.6 Sensory evaluation

Method of Iwe [18] was used to determine the sensory evaluation.

2.7 Data analysis

Analysis of variance was carried out using the statistical product of service solution version 22.0 to compare between the mean values, while treatment means were separated using Duncan multiple range test at 95 % confidence level (p<0.05).

3. RESULTS AND DISCUSSIONS

3.1 Physicochemical properties of the oil

From Table 1 the moisture contents of the fresh oil samples ranged from 0.20 - 0.29 %. Fresh groundnut oil had the highest moisture content while fresh African breadfruit seed oil had the least value. Moisture content of the fresh oil fall within the range of 0.17 - 0.35 % reported by Enyi and Ojimelukwe [19] for freshly processed palm oil. The percentage moisture contents decreased to the range of 0.14 – 0.24 % after reused. There were significant (p<0.05) differences between the fresh oil samples and reused oil. The decrease in the moisture content of the frying oil with continuous reuse of the frying oil could be as a result of continuous heat application during frying. SON [20] reported 0.29% as the safe moisture content for fresh oil and all the oil samples were within this safe range. The quality and storage life of oil is being affected by moisture content [21].

Table 1. Changes in the percentage (%) moisture content of frying oil

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	0.20^a±0.00	0.29^a±0.00	0.25^a±0.00

Initial use	$0.14^{b}\pm0.00$	$0.24^{b}\pm0.00$	$0.19^{b}\pm0.01$
Reused ×1	$0.11^{c}\pm0.00$	$0.19^{c}\pm0.00$	$0.16^{c}\pm0.01$
Reused ×2	$0.06^{d}\pm0.01$	$0.10^{d}\pm0.00$	$0.07^{d}\pm0.00$
Reused ×3	$0.01^{e}\pm0.00$	$0.04^{e}\pm0.00$	$0.02^{e}\pm0.00$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

Table 2 shows that the specific gravity of the oils for fresh, used and reused samples. The specific gravity of the fresh and reused African breadfruit and groundnut oils were 0.92 g/cm^{3} while sunflower was 0.93 g/cm^{3}. These range of specific gravity compares with the ranges reported for palm oil (0.91 g/cm^{3}) and ground-nut oil (0.84 g/cm^{3}) by Ebuehi, *et al.* [22]; 0.91 g/cm^{3} for pumpkin (*Cucurbita pepo*) seed oil Ihediohanma *et al.* [23] and 0.89-0.92 g/cm^{3} by Enyi and Ojimelukwe [19] for freshly processed palm oil. There were no significant ($p>0.05$) differences between fresh and the reused oil samples. This shows that reusing of oil did not affect the specific gravity. The specific gravity of the frying oil samples showed that they are less dense than water meaning that they will float. These values obtained were within the standard range of 0.898 – 0.907 g/cm^{3} reported by the Standard Organization of Nigeria [20]. Idun-Acquah *et al.* (2016) reported 0.90 g/cm^{3} for specific gravity of oil before frying and 0.89 g/cm^{3} after frying.

Table 2. Changes in the specific gravity of frying oil

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	$0.92^{a}\pm0.00$	$0.92^{a}\pm0.00$	$0.93^{a}\pm0.00$
Initial use	$0.92^{a}\pm0.00$	$0.92^{a}\pm0.00$	$0.93^{a}\pm0.00$
Reused ×1	$0.92^{a}\pm0.00$	$0.92^{a}\pm0.00$	$0.93^{a}\pm0.00$
Reused ×2	$0.92^{a}\pm0.00$	$0.92^{a}\pm0.00$	$0.93^{a}\pm0.00$
Reused ×3	$0.92^{a}\pm0.00$	$0.92^{a}\pm0.00$	$0.93^{a}\pm0.00$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

Table 3 shows that the smoke points of the oil samples in their fresh state ranged from 180.0 - 324.0^{0}c with African breadfruit seed oil having the least value and sunflower oil the highest value. The value for smoke point vary from the values 231 – 240℃ reported by Enyi and Ojimelukwe [19] for fresh palm oil. After the frying oil samples were used and reused, these values decreased to 130.0^{0}c (African breadfruit seed oil), 167.3^{0}c (groundnut oil) and 226.0^{0}c (sunflower oil). There were significant ($p<0.05$) differences between fresh and reused oil samples. The smoke point of oils is lowered by release of free fatty acid during frying operations. This is as a result of smoke point being directly proportional to the concentration of low-molecular-weight decompositions like free fatty acid and volatile compounds in the oil [24]. This shows the decrease in the smoke points of the oil samples. Lower smoke point of the oil samples as a result of reused will make them smolder and have a burnt-flavor that would affect the quality of the fried food. The temperature at which oil begins to burn and produce smoke is known as the smoke point [25]. At this temperature, the oil will break down to glycerol and free fatty acids while the glycerol is further broken down to acrolein which is a component of the smoke. The presence of acrolein causes the smoke to be very irritating to the eyes and throat. Frying oil should have a smoke point of above 200℃ as reported by Canadian specifications Appelqvist and Ohlson [26].

Table 3. Changes in the smoke point of frying oil (^{O}C)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	180.0^{a}±0.00	225.0^{a}±1.40	324.0^{a}±2.80
Initial use	169.5^{b}±0.70	210.5^{b}±0.00	304.0^{b}±2.20
Reused ×1	157.0^{c}±0.00	190.0^{c}±0.00	277.0^{c}±1.40
Reused ×2	142.0^{d}±0.00	178.0^{d}±0.00	252.0^{d}±2.80
Reused ×3	130.0^{e}±0.00	167.3^{e}±2.80	226.0^{e}±0.00

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

From Table 4 the flash points of fresh African breadfruit seed oil, groundnut, and sunflower oil were 279.0, 320.0 and 408.0^{0}c respectively which varies from the values 294 - 303℃ reported by Enyi and Ojimelukwe [9]. These values, however, decreased to 264.0, 290.0 and 388.0 ^{0}c after first frying to 172.0, 219.0 and 265.0^{0}c when reused for frying. There were significant ($p<0.05$) differences among the flashpoints of reused oil samples and at their fresh state. The temperature at which the decomposition products from frying oils ignite is called flash point and this temperature ranges from 275℃. - 330℃ for different oils and fats as reported by Canadian specifications [26].

Table 4. Changes in the flashpoint of frying oil (^{O}C)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	279.0^{a} ±1.40	320.0^{a} ±0.00	408.0^{a} ±2.80
Initial use	264.0^{b} ±0.00	290.0^{b}±2.80	388.0^{b} ±0.00
Reused ×1	232.0^{c}±2.80	275.0^{c}±0.00	340.0^{c}±2.80

Reused ×2	$216.0^{d}\pm0.00$	$242.0^{d}\pm2.80$	$313.0^{d}\pm1.40$
Reused ×3	$172.0^{e}\pm0.00$	$219.0^{e}\pm0.00$	$265.0^{e}\pm0.00$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

From Table 5 the fire point of the oil samples in their fresh forms ranged from $337.0–470.0^{0}$c with African breadfruit seed oil having the least value and sunflower the highest. These values, however, had a decreasing trend with continuous reuse. There were significant ($p<0.05$) differences between fresh and the reused oils samples. The decreasing trend of fire point with repeated use observed was as a result of activity of active lipase available in the oil which is responsible for the breakdown of triacylglycerols to fatty acid and glycerol resulting in the increase of free fatty acid content which affects the oil quality.

Table 5. Changes in the fire point of frying Oil (^{O}C)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	$337.0^{a}\pm4.20$	$368.0^{a}\pm0.00$	$470.0^{a}\pm0.00$
Initial use	$318.0^{b}\pm0.00$	$336.0^{ab}\pm2.80$	$424.0^{b}\pm2.80$
Reused ×1	$276.0^{c}\pm0.00$	$312.0^{ab}\pm0.00$	$378.0^{lc}\pm2.80$
Reused ×2	$241.0^{d}\pm1.40$	$270.0^{b}\pm0.00$	$334.0^{d}\pm0.00$
Reused ×3	$208.0^{e}\pm0.00$	$236.5^{ab}\pm68.0$	$301.0^{e}\pm0.00$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

From Table 6 the iodine value of fresh African breadfruit seed oil, groundnut oil, and sunflower oil varied from 95.49 to 135.13 g/100 g. After the initial use for frying, iodine values of the oil samples decreased to the range of 86.36 g/100 g to 130.19 g/100 g. This decreasing trend continued with reuse of the oil till the third time of reuse. There were significant ($p<0.05$) differences between fresh and the reused oil samples. Oxidation and hydrolysis during the process of frying causes decrease in the iodine value as reported by Akinhanmi and Akintokun [27]. Iodine value represents the number of double bonds present in oil which shows the likeness of oil to oxidation [28]. From the results, it was observed that reusing of frying oil lowered the level of unsaturation of the oil samples. The decrease in Iodine resulted to increase in the oxidation rate during frying and this is as a result of breakdown of double bonds in fatty acid by oxidation and polymerization leading to decrease in the degree of unsaturation [29]. Few unsaturated bonds is as a result of low iodine and hence an increase in the level of saturation [30]. Consumption of foods that contain saturated fat is considered to be detrimental to health if consumed in large amounts and has been linked to health concerns of obesity, cancer, diabetes, and cardiovascular disease [31].

Table 6. Changes in the iodine value of frying oil (g/100g)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil

Fresh oil	135.13^{a}±0.0	95.49^{a}±0.28	126.3^{a}±0.36
Initial use	130.19^{b}±0.0	86.36^{b}± 0.09	117.40^{b}±0.0
Reused ×1	124.23^{c}±1.3	77.37^{c}±0.09	108.16^{c}±0.4
Reused ×2	109.46^{d}±0.0	68.24^{d}±0.16	95.38^{d}±0.00
Reused ×3	94.37^{e}± 0.0	57.39^{e}± 0.38	81.60^{e} ±0.00

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

Table 7 shows that the peroxide value of the fresh frying oil samples were 3.18, 1.51 and 1.76 meq/kg for African breadfruit seed oil, groundnut oil and sunflower oil respectively. These values vary from the values of Enyi and Ojimelukwe [19] for fresh palm oil. These values increased after the samples were used for frying and maintained an increasing trend with reuse. Significant ($p<0.05$) differences were observed between fresh and reused oils. The peroxide value gives the early evidence of rancidity in oils which are mostly referred to as lipid peroxidation or oxidative degradation. The peroxide value is also used to determine the stability of fats. This is done by measuring the number of lipid peroxides and hydroperoxides formed during the early stages of oxidation and thus determine the level of spoilage of the oil. Peroxide in oil makes it harmful for consumption by both man and animals, as the free radicals formed by this process proves to be carcinogenic [32]. This, therefore, suggests that the oil samples which were observed to increase in their peroxide values with reuse are unfit for consumption or production of food for consumption. The lower peroxide value of the frying oil samples in their fresh form indicates that they will not easily go rancid.

Table 7. Changes in the peroxide value of frying oil (mEq/kg)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	3.18^{a}±0.00	1.51^{a}±0.02	1.76^{a}± 0.00
Initial use	5.12^{b}± 0.00	2.24^{b}± 0.00	2.28^{b}± 0.00
Reused ×1	7.65^{c}± 0.11	4.97^{c}± 0.17	3.59^{c}±0.00
Reused ×2	9.01^{d}± 0.09	7.33^{d}± 0.00	5.68^{d}± 0.00
Reused ×3	11.8^{e}±0.09	9.75^{e} ± 0.00	7.25^{e} ± 0.00

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

Table 8 shows that the free fatty acid of the frying oil samples in their fresh forms ranged from 0.13 - 0.77 (%). These values were observed to increase with reuse which corresponds to the report of Serna-Saldivar [33] that free fatty acid values increase with an increase in the frying oil use. There were significant ($p<0.05$) differences between the fresh and reused African breadfruit seed oils. Although the fatty acid concentrations of groundnut oil and sunflower oil increased slightly, there were no significant ($p>0.05$) differences between their fresh and reused oil samples. Fatty acids are present in oils as part of triacylglycerol molecules. Free fatty acid residues present in oil shows that the quality of the oil is poor [28]. High FFA in oil is as a result of level of exposure to sunlight, degree of ripeness before harvest and period of fermentation according to Enyi and Ojimelukwe [19].

Table 8. Changes in the free fatty acid of the frying oil (%)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	$0.33^{a} \pm 0.01$	$0.77^{a} \pm 0.14$	$0.13^{a} \pm 0.01$
Initial use	$0.67^{b} \pm 0.01$	$1.02^{a} \pm 0.00$	$0.23^{a} \pm 0.00$
Reused ×1	$0.77^{c} \pm 0.01$	$1.47^{a} \pm 31.5$	$0.33^{a} \pm 0.00$
Reused ×2	$1.30^{d} \pm 0.00$	$1.82^{a} \pm 0.02$	$0.68^{a} \pm 0.01$
Reused ×3	$1.60^{e} \pm 0.00$	$2.31^{a} \pm 0.01$	$1.50^{b} \pm 0.49$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

Table 9 shows the saponification values for the fresh frying oil samples were 209.3 mg/KOH/g for African breadfruit seed oil, 194.2 mg/KOH/g for groundnut oil and 199.9 mg/KOH/g for sunflower oil which slightly vary from the values 194.48 -196.82 mg/KOH/g reported by Enyi and Ojimelukwe [19] for fresh palm oil. These values were observed to decrease with increase in reuse. There were significant ($p<0.05$) differences between fresh and the reused oil samples. The saponification values of the fresh oil samples were within the TZS and Codex standard requirements range of 194-202 mg KOH/g oil specified for the saponification value of unblended vegetable oil.

Saponification value shows the mean molecular weight and hence chain length. It is inversely proportional to the molecular weight of the lipid [15]. Saponification and acid values give information on the quantity, type of glycerides and average weights of the acids in a given sample [34]. Saponification value has no nutritional benefit as such it will be useful for industrial purposes [35]. The soap making ability of the oil is better when there is an increase in the saponification number [36].

Table 9. Changes in the saponification value of the frying oil (mgKOH/g)

Frequency of Reuse	Breadfruit Oil	Groundnut Oil	Sunflower Oil
Fresh oil	$209.3^{a} \pm 0.16$	$194.2^{a} \pm 1.3$	$199.9^{a} \pm 0.19$
Initial use	$198.6^{b} \pm 0.00$	$191.4^{b} \pm 0.00$	$189.4^{b} \pm 0.47$

Reused ×1	$192.8^{c}\pm0.00$	$185.3^{c}\pm0.48$	$182.8^{c}\pm 0.36$
Reused ×2	$186.4^{d}\pm0.00$	$180.8^{d}\pm0.28$	$177.7^{d}\pm0.94$
Reused ×3	$179.3^{e}\pm0.00$	$175.3^{e}\pm0.00$	$168.3^{e}\pm0.27$

Values show the means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different.

3.2 Fatty acid profile of the fresh and reused oil

The Changes in Fatty acid composition of African breadfruit seed oil, groundnut oil and Sunflower oil along with the CODEX standards are shown in the Tables 10, 11 and 12. The Linoleic acid value of fresh breadfruit oil was 22.56%. It decreased to 17.98% after being used in the frying process and 17.48% when reused. Groundnut oil had an initial linoleic acid composition of 21.74%. After the frying process, the percentage composition decreased to 18.98% and 16.56% when reused. These values were within the CODEX standard (12.0 - 43.0 %). The linoleic acid value of sunflower oil were 20.37% before the frying process, 18.98% after use and 18.06% when reused. There were significant ($p<0.05$) differences among the linoleic acid composition of the oil samples.

Linoleic acid is an important anti-inflammatory agent which helps in the body defense and improves the immune system and decreases blood cholesterol. Studies have shown that linoleic acids helps human health in the prevention of cardiovascular disease (DVD), inflammatory, thrombotic, coronary heart disease and cancer, hypertension diabetes type two, renal diseases, rheumatoid arthritis, ulcerative colitis and Crohn’s disease [37,38].

The oleic acid value of breadfruit oil samples were 58.51% for fresh, 45.26% for used and 43.37% for reused. Groundnut oil had an initial oleic acid composition of 56.37%. It however, decreased to 45.24% after use and 42.48% when reused. These values were within the CODEX standard (35.0 - 69.0 %).. The initial Oleic acid composition of sunflower oil was 48.59%, 46.15% after use and 43.36% when reused. There were significant ($p<0.05$) differences among the oleic acid contents of the oil samples. A decreasing trend in oleic acid compositions were observed with increase in frying oil use. This reduction in oleic acid values could make these oil samples less desirable in terms of nutrition and high stability [39].

Oleic acid is important in membranes build up, available in the epidermis (outermost skin layer), with the function of protection and barrier from dehydration and also in the formation of hormones. Mono unsaturated fatty acids such as oleic acids lower low density lipoprotein cholesterol, while it might possibly increase high-density lipoprotein cholesterol. It may promote insulin resistance [40]. Oleic acid has also been reported as anti-apoptotic and anti-inflammatory agent [41].

The linolenic acid value of Fresh breadfruit oil samples were 0.26% before the frying process, 0.18% after use and 0.18% for reused. In groundnut oil, percentage values of 0.35%, 0.18% and 0.17% were observed respectively. There were significant ($p<0.05$) differences among the groundnut oil samples. Sunflower oil had an initial linolenic acid composition of 0.34%, 0.22% after use and 0.19% when reused. The initial linolenic acid composition of 0.34% was significantly ($p<0.05$) different from others, while the percentage value after use and when reused for the third time had no significant difference. Linolenic acid being the most vital fatty acid for humans helps in the development of the central nervous and visual systems. It aids in the formation and regeneration of neurons, reduces the risk of cardiovascular diseases, bad cholesterol and blood sugar, being also an anti-inflammatory agent. Alph-linolenic acids are components of the phospholipids of cell membranes and with linoleic acids provide energy for the body and serve as precursors for eicosanoids [39].

The Palmitoleic acid value of breadfruit oil samples were 0.11% for fresh, 0.04% for reuse and 0.04% for reused. In groundnut oil sample the initial palmitoleic acid composition was 10.0%, 0.04% after use and 0.03% when reused. Palmitoleic acid value of sunflower oil was 10.0% before being used for frying. It however decreased to 0.07% after use and 0.05% when reused. There were significant ($p<0.05$) differences among the palmitoleic acid values of the oil samples. According to Hirayama *et al.* [42] unsaturated fatty acids are chemically more reactive than saturated fatty acids because of the presence of double bond and their reaction increases as the number of double bonds increases. This could have resulted to the variations in the percentage values of unsaturated fatty aicd values of these oil samples with reuse.

The Linoleic acid compositions of sunflower oil and groundnut oil samples ranged from 20.37% – 21.39%. This is in agreement with El-adawy and Taha, [43] that Linoleic acid is present mostly in sunflower oil, soybean oil, safflower, corn oil, sesame oil, peanut oil, grape seed oil and wheat sprout oil.

The Palmitic acid value of fresh breadfruit oil was 7.49%. However, 5.46% was recorded after use and 4.46% when reused. In groundnut oil samples, an initial palmitic acid value of 8.36% which was gotten prior to frying corresponded to (8.39%) reported by Misuna *et al.* [44]. After use, 6.45% was gotten and 5.74% when reused. Sunflower oil had initial Palmitic acid composition of 7.86%, 6.46% after use and 5.96% when. These values were comparable to the CODEX [45] standard of (8.0 - 14.1 %) for groundnut oil and (2.6 - 5.0 %) for sunflower oil. There were significant ($p<0.05$) differences among the palmitic acid values. According to Sano *et al*. [46], Palmitic acid is the main fatty acid responsible for the high caloric power. Thus, consuming products with high content of this acid provides a feeling of satisfaction due to its high satiety capacity.

The Arachidic acid value of fresh breadfruit oil 1.68% was higher than 1.55% after it was used for frying and 1.43% when reused. Significant ($p<0.05$) differences were observed among them. A decreasing trend was observed in the Arachidic acid values of groundnut oil (1.75%, 1.45% and 1.28%). These ranges were similar to 1.44–2.36 % reported for arachidic acid by Ozcan [47] and 0.15–1.67 % reported by Ozcan and Steven, [48] for arachidic acids in groundnut oil recovered by different techniques. Sunflower oil, had initial value of 1.85%, 1.40% after use and 1.38% when reused. The arachidic values were slightly high compared to the CODEX [45] standard of (0.2 – 0.5%) for sunflower oil.

The Lauric acid composition of breadfruit oil ranged from 0.28% to 0.17% after reused for the frying process. In groundnut oil, Lauric acid composition was 0.28% before use, 0.19% after use and 0.16% when reused. Initial lauric acid composition of sunflower oil was 0.27%. It decreased to 0.26% after use and 0.26% when reused. There were significant ($p<0.05$) differences among them. Lauric acid is present in human at 5.8% as a medium-chain fatty acid. This fatty acid is known for its antiviral [49] and antibacterial [50] functions. Medium-chain saturated fatty acids and their monoacylglycerol derivatives can affects on microorganisms such as bacteria, yeast, fungi, and enveloped viruses, by altering the lipid membranes of the organisms and thus making them inert. In addition to disrupting membranes to inert the viruses, lauric acid has an effect on virus reproduction by interfering with assembly and maturation. [49].

The Caprylic acid value of fresh breadfruit oil was 0.01%. The percentage value remained the same throughout the frying stages. Caprylic acid value of groundnut oil (0.15%) decreased to 0.14% after use and 0.13% when reused. There were significant ($p<0.05$) differences among them. The Caprylic acid of sunflower oil ranges were (0.01% - 0.00%) and concurred with the stated standard. Studies by Bruce and Cora [51] has it that the negative effects of these caprylic acids on coronary artery disease and cholesterol have not been a dietary issue. Caprylic acid was also reported to have antitumor activity in mice. [52].

The behenic acid value of oil extracted from breadfruit seed was 3.65%. This value changed to 1.59% after use and 1.38% when reused. In the groundnut oil samples, behenic acid values ranged from (3.64% - 1.28%) with significant ($p<0.05$) differences observed among them.

Sunflower oil had initial behenic acid value 3.46% prior to frying. It decreased to 1.33% after use and 1.19% when reused. The Myristic acid composition of fresh breadfruit oil was 0.11%. It decreased to 0.06% after use and 0.04% when reused. Myristic acid composition of fresh groundnut oil was 0.11%. After being used for frying, 0.08% was gotten and 0.06% when reused. The initial myristic acid content of sunflower oil was 0.10%. It decreased to 0.05% after second use and 0.04% when reused.

Myristic acid is one of the main saturated fatty acids that have been linked with an increased risk of coronary artery disease, and human epidemiologic studies have shown that myristic acid and lauric acid are the saturated fatty acids mostly related to average serum cholesterol concentrations. However, it increases both low density lipoprotein and high density lipoprotein cholesterol concentrations compared with oleic acid in health subjects [53].

The Stearic acid value of fresh breadfruit oil 2.37% was higher than the value (1.56%) after use and (1.48%) when reused for frying. Groundnut oil had initial stearic acid value of 2.36%, 1.88% after use and 1.63% when reused. Misuna *et al*. [44], reported the stearic acid value of groundnut oil to be 3.56%. Stearic acid composition of fresh sunflower oil was 2.43%. It decreased to 1.58% after use and 1.35% when reused for frying for the third time. There were significant (p<0.05) differences among the sample.

Table 10. Fatty Acid Composition of fresh and reused African breadfruit seed oil

Fatty Acids	Breadfruit Oil	Used Breadfruit Oil	Reused Breadfruit Oil
Caprylic (C_8)	$0.01^a \pm 0.00$	$0.01^b \pm 0.00$	$0.01^c \pm 0.00$
Stearic (C_{18})	$2.37^a \pm 0.00$	$1.56^b \pm 0.00$	$1.48^c \pm 0.00$
Capric (C_{10})	$0.01^a \pm 0.00$	$0.01^b \pm 0.00$	$0.000^c \pm 0.00$
Lauric (C_{12})	$0.28^a \pm 0.00$	$0.19^b \pm 0.00$	$0.17^c \pm 0.00$
Myristic (C_{14})	$0.11^a \pm 0.00$	$0.06^b \pm 0.00$	$0.04^c \pm 0.00$
Palmitic (C_{16})	$7.49^a \pm 0.00$	$5.46^b \pm 0.00$	$4.46^c \pm 0.00$
Arachidic(C_{20})	$1.68^a \pm 0.00$	$1.55^b \pm 0.00$	$1.43^c \pm 0.00$
Linoleic ($C_{18:2}$)	$22.56^a \pm 0.00$	$17.98^b \pm 0.00$	$17.48^c \pm 0.00$
Linolenic($C_{18:3}$)	$0.26^a \pm 0.00$	$0.18^b \pm 0.00$	$0.18^c \pm 0.00$
Oleic ($C_{18:1}$)	$58.51^a \pm 0.00$	$45.26^b \pm 0.00$	$43.37^c \pm 0.00$
Palmitoleic(C_{12})	$0.11^a \pm 0.00$	$0.04^b \pm 0.00$	$0.04^c \pm 0.00$
Behenic(C_{22})	$3.65^a \pm 0.00$	$1.59^b \pm 0.00$	$1.38^c \pm 0.00$

Values are means $\pm$ standard deviation; Column with different superscript are significantly (p<0.05) different.

Fatty Acids	Groundnut Oil	Used Groundnut Oil	Reused Groundnut Oil	CODEX
Caprylic (C_8)	$0.15^a \pm 0.00$	$0.14^b \pm 0.00$	$0.13^c \pm 0.00$	ND

Stearic (C_{18})	2.36 ^{a}±0.00	1.88 ^{b}±0.00	1.63 ^{c}±0.00	1.0-4.5
Capric (C_{10})	0.01 ^{a}±0.00	0.01 ^{b}±0.00	0.01 ^{c}±0.00	ND
Lauric (C_{12})	0.28 ^{a}±0.00	0.19 ^{b}±0.00	0.16 ^{c}±0.00	ND-0.1
Myristic (C_{14})	0.11 ^{a}±0.00	0.08 ^{b}±0.00	0.06 ^{c}±0.00	ND-0.1
Palmitic (C_{16})	8.36 ^{a}±0.00	6.45 ^{b}±0.00	5.74 ^{c}±0.00	8.0-14.1
Arachidic(C_{20})	1.75 ^{a}±0.00	1.45 ^{b}±0.00	1.28 ^{c}±0.00	1.0-2.0
Linoleic ($C_{18:2}$)	21.74 ^{a}±0.00	18.98 ^{b}±0.00	16.59 ^{c}±0.00	12.0-43.0
Linolenic($C_{18:3}$)	0.35 ^{a}±0.00	0.18 ^{b}±0.00	0.17 ^{c}±0.00	ND-0.3
Oleic ($C_{18:1}$)	56.37 ^{a}±0.00	45.24 ^{b}±0.00	42.48 ^{c}±0.00	35.0-69
Palmitoleic(C_{12})	0.10 ^{a}±0.00	0.04 ^{b}±0.00	0.03 ^{c}±0.00	ND-0.1
Behenic(C_{22})	**3.64 ^{a}±0.00**	**1.39 ^{b}±0.00**	**1.28 ^{c}±0.00**	**1.5-1.4**

Table 11. Fatty Acid Composition of fresh and reused groundnut oil
Values are means ± standard deviation; Column with different superscript are significantly ($p<0.05$) different.

Fatty Acids	Sunflower Oil	Used Sunflower Oil	Reused Sunflower Oil	CODEX

Caprylic (C_8)	0.01^{a}±0.00	0.00^{b}±0.00	0.0^{c}±0.00	ND
Stearic (C_{18})	2.43^{a}±0.00	1.58^{b}±0.00	1.35^{c}±0.00	2.9-6.2
Capric (C_{10})	0.01^{a}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	ND
Lauric (C_{12})	0.27^{a}±0.00	0.26^{b}±0.00	0.26^{c}±0.00	ND
Myristic (C_{14})	0.10^{a}±0.00	0.05^{b}±0.00	0.04^{c}±0.00	ND-0.1
Palmitic (C_{16})	7.86^{a}±0.00	6.46^{b}±0.00	5.96^{c}±0.00	2.6-5.0
Arachidic(C_{20})	1.85^{a}±0.00	1.40^{b}±0.00	1.38^{c}±0.00	0.2-0.5
Linoleic ($C_{18:2}$)	20.37^{a}±0.00	18.98^{b}±0.00	18.06^{c}±0.00	2.1-17
Linolenic($C_{18:3}$)	0.34^{a}±0.00	0.22^{b}±0.00	0.19^{b}±0.00	ND-0.3
Oleic ($C_{18:1}$)	48.59^{a}±0.00	46.15^{b}±0.00	43.36^{c}±0.00	75-90.7
Palmitoleic(C_{12})	0.10^{a}±0.00	0.07^{b}±0.00	0.05^{c}±0.00	ND
Behenic(C_{22})	3.46^{a}±0.00	1.33^{b}±0.00	1.19 ^{c}±0.00	ND-0.5

Table 12. Fatty Acid Composition of fresh and reused Sunflower oil
Values are means ± standard deviation; Column with different superscript are significantly ($p<0.05$) different.

3.2 Sensory Evaluation of Potato Chips Fried with African Breadfruit Seed Oil, Groundnut, and Sunflower Oil

Table 13 shows the mean sensory scores of the potato chips fried with African breadfruit seed oil, groundnut, and sunflower oil. The appearance scores of potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil, ranged from 7.00 - 7.70. Although there were no significant ($p>0.05$) differences in the appearance among fresh oil potato chips, those produced with groundnut oil emerged the most preferred. Potato chips produced with sunflower oil used once did not differ significantly ($p>0.05$) from those of groundnut oil used once. The appearance scores of potato chips produced with African breadfruit seed oil, groundnut oil, and sunflower oil used once decreased compared to those of the fresh oil. The decreasing trend continued with an increase in the reuse of these frying oils. There were significant ($p<0.05$) differences in the appearance scores of potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil and those from the reused oil.

From the scores, potato chips produced with these frying oils in their fresh forms were preferred most than those from the reused oil. The appearance of the potato chips depreciated with continuous reuse of the same. Preference to potato chips fried on the first day with lighter colour agrees with Tfouni *et al.* [54] report that consumers prefer potato chips with a light golden colour, with no dark spots or traces. Potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil appeared bright but it was found to be darker with reuse. Abdulkarim *et al*. [55] reported that intake of non-volatile decomposition products like oxidized triacylglycerols and FFA during oxidation can lead to colour changes which shows the level of oil deterioration. Also, Miranda and Aguilera [56] reported that the colour of food product is formed as a result of Maillard during frying operations and is affected by factors like reducing sugar and amino acid content.

The taste scores of the potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil ranged from 7.56 – 8.60. The taste of potato chips produced with groundnut oil were the most preferred. There were no significant ($p>0.05$) differences in the taste scores between potato chips produced with fresh African breadfruit seed oil, and fresh sunflower oil. Potato chips produced with sunflower oil used once did not differ significantly ($p>0.05$) from that of groundnut oil used once. There were no significant ($p>0.05$) differences among the taste scores of the potato chips produced with African breadfruit seed oil, groundnut oil, and sunflower oil used two times. Potato chips fried with African breadfruit oil, had the least scores in all stages of the process. This is because the unique taste of breadfruit, interfered with the taste of the product, giving it Potato chips with these frying oils for three times had the least score rating. Unlike many other frying oil, groundnut oil does not absorb any flavor from foods fried in it, making it possible to save and reuse without tainting the flavor of food fried later with the same oil. This could have influenced the high taste scores of potato chips produced with groundnut oil in this study.

The scores for aroma of the potato chips ranged from 4.85 - 7.25. There were no significant ($p>0.05$) differences in the aroma scores among potato chips produced with fresh African breadfruit seed oil and fresh sunflower oil but those produced with fresh groundnut oil differed significantly. After using the different frying oil three times, the aroma score values at this stage did not vary significantly ($p<0.05$) among them. Potato chips produced with groundnut oil were the most preferred while that of African breadfruit seed breadfruit oil were least preferred. The least preference to chips produced with African breadfruit oil could be as a result of the impact of breadfruit aroma on the product. The obviousness of African bread fruit aroma on the processed product (potato chips) was in agreement with the reports of Nwabueze and Emenonye, 2016, that African breadfruit contains appreciable volatile compounds which improve during processing.

The mouthfeel scores of the potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil ranged from 4.50 – 6.00. The highest scores for mouthfeel were chips produce with groundnut oil and sunflower oil used twice having the same scores of 6.00. There was no significant ($p>0.05$) difference among them. These were much closer to the mouthfeel scores of the chips produced with frying oil used once. From the mouthfeel scores of the potato chips produced with African breadfruit seed oil, groundnut oil, and sunflower oil used three times, it was observed that reuse of these frying oil did not significantly affect the mouthfeel attribute of the fried potatoes chips.

The crispness scores of the potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil were 5.00 and did not differ significantly (p>0.05). Those produced with African breadfruit oil used once were more crisp compared to those of sunflower and groundnut oil. Slight differences were observed in the crispiness scores of fried potatoes subsequently when reused with these frying oil twice. There were significantly (p<0.05) different in the crispiness scores of the potato chips produced with fresh oil and potato chips from reused oil. Crispness in potato chips shows the quality indicators in the final product, together with colour, aroma, and flavour [57]. Variation in crispness could come from air spaces that may form within the crisp structure [58], sogginess, and moisture uptake after frying [56] as well as variation in starch and other chemical components of the food product [59].

The acceptability scores of potato chips produced with the frying oils in its fresh form ranged from 6.59 - 8.20. Potato chips produced with fresh African breadfruit seed oil, groundnut oil, and sunflower oil were significantly (p<0.05) different from those produced with reused oil in their acceptability scores. Potato chips produced with frying oil used three times received the lowest acceptability score rating. The general acceptability of the potato chips depreciated with continuous reuse of the same.

Table 13. Sensory evaluation of potato chips fried with African breadfruit seed oil, groundnut and Sunflower oil

Sample	Appearance	Taste	Aroma	Mouth feel	Crispiness	Acceptability

BO1	$7.50^{e}\pm0.11$	$7.56^{ef}\pm0.28$	$6.50^{ab}\pm0.71$	$4.50^{ab}\pm0.71$	$5.00^{ab}\pm0.00$	$6.59^{bc}\pm0.69$
GO1	$7.70^{e}\pm0.42$	$8.60^{f}\pm0.17$	$7.25^{b}\pm0.35$	$6.00^{b}\pm1.41$	$5.00^{ab}\pm0.00$	$8.05^{d}\pm0.07$
SO1	$7.00^{de}\pm0.00$	$7.60^{ef}\pm0.07$	$5.54^{ab}\pm0.65$	$5.50^{ab}\pm0.01$	$5.00^{ab}\pm0.00$	$8.20^{d}\pm0.28$
BO2	$7.27^{e}\pm0.33$	$7.20^{de}\pm0.28$	$5.50^{ab}\pm0.71$	$5.50^{ab}\pm0.71$	$6.00^{bc}\pm1.41$	$7.00^{c}\pm0.00$
GO2	$6.27^{bc}\pm0.33$	$5.65^{ab}\pm0.49$	$6.04^{ab}\pm0.06$	$5.00^{ab}\pm0.00$	$5.00^{ab}\pm0.00$	$6.00^{abc}\pm0.00$
SO2	$6.10^{cd}\pm0.00$	$5.90^{bc}\pm0.14$	$5.28^{a}\pm0.39$	$4.00^{a}\pm0.00$	$5.00^{ab}\pm0.00$	$6.00^{abc}\pm0.00$
BO3	$5.20^{ab}\pm0.70$	$6.05^{cd}\pm0.21$	$4.85^{a}\pm1.20$	$5.00^{ab}\pm1.41$	$4.26^{a}\pm0.34$	$5.00^{a}\pm0.00$
GO3	$6.00^{cd}\pm0.01$	$6.30^{bcd}\pm0.00$	$6.25^{ab}\pm0.35$	$6.00^{b}\pm0.00$	$7.00^{c}\pm0.00$	$6.00^{abc}\pm0.00$
SO3	$6.25^{bcd}\pm0.35$	$6.10^{bc}\pm0.42$	$5.61^{ab}\pm0.55$	$6.00^{b}\pm0.00$	$5.55^{b}\pm0.64$	$6.00^{bc}\pm0.00$
BO4	$4.23^{a}\pm0.32$	$4.60^{a}\pm0.57$	$5.77^{ab}\pm1.08$	$5.00^{ab}\pm0.00$	$4.26^{a}\pm0.37$	$5.50^{ab}\pm0.70$
GO4	$5.10^{ab}\pm0.02$	$5.75^{bc}\pm0.35$	$6.55^{ab}\pm0.78$	$6.00^{b}\pm0.00$	$6.09^{bc}\pm0.13$	$6.00^{bc}\pm0.00$
SO4	$4.70^{ab}\pm0.42$	$6.15^{bc}\pm0.21$	$6.60^{ab}\pm0.85$	$5.00^{ab}\pm0.00$	$5.08^{ab}\pm0.04$	$5.60^{ab}\pm0.57$

Values show means of triplicate analysis ± standard deviation. Values with different superscripts in the column are significantly ($p<0.05$) different. BO1 = Potato chips produced with fresh breadfruit oil; GO1 = Potato chips produced with fresh groundnut oil; SO1 = Potato chips produced with fresh sunflower oil; BO2 = Potato chips produced with breadfruit oil used once; GO2= Potato chips produced with groundnut oil used once; SO2= Potato chips produced with sunflower oil used once;BO3= Potato chips produced with breadfruit oil used two times; GO3= Potato chips produced with groundnut oil used two times; SO3= Potato chips produced with sunflower oil used two times; BO4 = Potato chips produced with breadfruit oil used three times; GO4= Potato chips produced with groundnut oil used for three times; SO4 = Potato chips produced with sunflower oil used three times.

4. CONCLUSIONS

The results of this research showed that Breadfruit oil can be produced from African breadfruit (*Trecalia africana*) seed and successfully used in frying just like other conventional oil. Its physicochemical properties are also comparable to those of groundnut and sunflower oil. The physicochemical properties of breadfruit, groundnut and sunflower oil used in frying potato chips were revealed to deteriorate with reuse. The study further revealed that potato chips fried initially with fresh African breadfruit seed oil, groundnut, and sunflower oil had better organoleptic quality and were preferred by consumers to those produced with reused oil. African breadfruit oil, impacts its unique taste and aroma on products (potato chips) fried with it, even when reused. The Fatty acid profile compositions of frying oil especially the unsaturated and essential fatty acids are affected negatively when the same oil is repeatedly used during frying operations.

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