ADAN J. Agric. 2025, 6 (2): 178-191
© *Association of Deans of Agriculture in Nigerian Universities (ADAN)*
ISSN 2736-0385
DOI: 10.36108/adanja/5202.60.0291

Investigating the frying stability of African oil bean seed (*Pentaclethra macrophylla*) and refined palm olein oil blends

Onwuzuruike, U. A.[1], Uluocha, M. D.[3], Agwo, O. E.[1*], Edima-Nyah, A. P.[2] and Iroegbu, F. E.[1]
[1]*Department of Food Science and Technology, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.*
[2]*Department of Food Science and Technology, Faculty of Agriculture, University of Uyo, Uyo, Akwa Ibom, Nigeria.*
[3]*Independent Researcher, Alumnus of Sheffield Hallam University, United Kingdom.*

**** Corresponding Author:*** *agwo.obinna@mouau.edu.ng, agwoobinnaeni@gmail.com,*
Phone Number: *080135268144*

Abstract

The present study evaluated the frying stability of African oil bean seed oil (AB) and refined palm olein (RPO) and their blends. African oil bean seed oil was extracted via the Soxhlet method, yielding a high oil content of 47.95%. AB was then blended with RPO in seven proportions: 100: 0 (AB100), 0: 100 (RPO100), 90:10 (AB90:RPO10), 80:20 (AB80:RPO20), 70:30 (AB70:RPO30), 60:40 (AB60:RPO40) and 50:50 (AB50: RPO50). Unmixed and blended oils were used to fry potato strips (175 $\pm$ 5^{o}C) over four consecutive days without oil replenishment. After each daily cycle, oil samples were analyzed for smoke point, iodine value, moisture content, peroxide value (PV), free fatty acid (FFA) value, and thiobarbituric acid (TBA) value. Frying stability studies showed that smoke points and iodine values significantly decreased ($p < 0.05$) as frying cycles increased, while moisture content, PV, FFA, and TBA values increased. The 100% African oil bean seed oil (AB100) showed the highest degradation, with moisture content increasing from 1.90% to 3.24% and the highest final PV, FFA, and TBA values across all cycles. Conversely, blending AB with RPO steadily reduced the increases in these degradation products, with reductions observed from the 10% RPO blend up to the 50% RPO blend. Oil blends containing up to 50% refined palm olein (AB50:RPO50) demonstrated the highest overall frying stability. Conclusively, oil blends containing up to 50% refined palm olein had the highest frying stability, hence, blending African oil bean seed oil and refined palm olein reduced the incidence of hydroperoxide formation, FFA and secondary oxidation products during frying.

Keywords*: Frying stability, African oil bean seed, Palm Olein, Oil yield, Blending.*

Introduction

One of the oldest and most widely used methods of food preparation is frying which takes place between 150°C and 190°C (Dobargenes and Marquez-Ruiz, 2015). Compared to baking, frying offers faster cooking times due to more efficient heat transfer (Oke *et al.*, 2017). The frequent practice of repeatedly using frying oils causes a variety of unfavourable reactions in used oils when exposed to ambient oxygen, which has negative effects on the oil's physical and chemical qualities (Emelike *et al.*, 2020). The most common method of stabilizing frying oils is modifying the fatty acid composition of the oil. This can be done by several methods; physically by fractionation or blending, chemically by hydrogenation or interesterification, an genetically by plant breeding (Akusu *et al.*, 2020). Blending the polyunsaturated oils with more saturated or monounsaturated oils is a potential solution to improve oil stability (Alzaa *et al.,* 2018).

The African oil bean seeds (*Pentaclethra macrophylla* Benth) is a tropical tree crop that belongs to the family of *Leguminosae* (*Mimosoideae*). The seeds are flat in shape, hard, but smooth in texture and have an average length of 56.18 mm and width of 37.89 mm. It is commonly referred to as "ugba" or "ukpaka", "apara" and "ukana" among the Igbo, Yoruba and Efik tribes, respectively (Igbozulike *et al.,* 2021), and has been reported to be a good source of edible oil. The oil has a pleasant aroma and bunt taste possibly due to the presence of alkaloid (Akinlabu *et al.,* 2019). African oil bean is excellent source of essential mineral elements such as phosphorus and calcium and contains vitamins such as thiamin, riboflavin and niacin (Akinlabu *et al.,* 2019). It also contains protein, carbohydrate, crude fibre, oil, and contain many phytochemicals such as alkaloids, flavonoids, oxalate, phenol, phytate, saponin and tannin (Aladekoyi *et al.,* 2017; Igbozulike *et al.,* 2021).

Palm oil, the second most abundantly produced oil in the world, is not favoured in many countries due to consumer concern about saturated fatty acids (SFA). Palm oil contains approximately 50% SFA with 46.80% palmitic acid (C16:0) (Ahmad and Ismail, 2014). The second most abundant fatty acid in palm oil is oleic acid at 37.60%. Refined palm olein oil (RPO), a fraction obtained from palm oil during the production of stearin, is less saturated than palm oil and contains 38.30% palmitic acid, 42.10% oleic acid, and 10.60% linoleic acid (Dodoo *et al.,* 2022). RPO is being used increasingly in frying operations, and because of its inherent excellent frying properties, improves the frying quality of other vegetable oils when it is blended with them (Ambindei *et al.,* 2020). Unsaturated and saturated fatty acid content of RPO was found contributing to good flavour stability. Emelike *et al.* (2020) reported that RPO performed satisfactorily and produced fried foods with acceptable cooking qualities compared to other major commercial vegetable oils as frying media.

Blending edible oils has been developed as a cost-effective method of enhancing the organoleptic and physicochemical properties of vegetable oils, as well as their oxidative stability (Kiralan *et al.,* 2017). The blended oil exhibits a wide range of applications due to their high Ω-9 contents as compared to single oils. African oil bean seed has been reported to contain highly unsaturated fatty acid (Onwuzuruike *et al.,* 2024) which may affect their frying stability. In an attempt to improve its usability and processing stability for food processing operations, this study blended African oil bean seed oil with refined palm olein, a more stable oil in order to reduce the over-dependence on oils from soybean, peanut, canola, maize etc. and add value to African oil bean seed crop. This study assessed the changes in oil quality that occur during repeated frying in order to preserve the quality of the fried product, thereby, revealing the frying frequency of African oil bean seed oil; unmixed and blended.

Materials and Methods

Materials

Fresh raw seeds of African oil bean seeds and sweet potatoes (white variety) were procured from Garki market in Enugu North Local Government Area, Enugu. Refined palm olein was purchased from edible oils segment of shoprite stores, Umuahia Abia State. Processing of African oil bean seed was done at Food Science and Technology Laboratory, Michael Okpara University of Agriculture, Umudike (MOUAU). Extraction of African oil bean seed oil was done using soxhlet apparatus at the National Root Crop Research Institute. All reagents were of analytical grade.

Chemicals

N-hexane, acetic acid-dichloromethane in the ratio of 3:2, potassium iodide solution, diluted starch solution, 0.01 N $Na_2S_2O_3$ solution, solvent mixture of diethyl ether/ethanol in the ratio of 1:1, phenolphthalein indicator, 0.1 N potassium hydroxide solution (KOH), 3.86 % perchloric acid, 20 mM TBA, Wij's solution, potassium iodide, 0.1 N sodium thiosulphate solution, 1% starch solution.

Processing of African oil bean seed into flour

The method described by Oyinloye and Enujiugha (2019) was used in processing African oil bean seeds into flour for Soxhlet extraction with slight modification relative to the drying time. One kilogram of African oil bean seeds was sorted, manually cracked, and dehulled using a stainless-steel knife. The seeds were rinsed with tap water, and the cotyledons were cut into pieces of roughly 1.5 cm. These were then dried in an electronic hot-air oven (Model SX3-4.5-15, China) at 60°C for 24 hours. After drying, the seeds were milled into flour using an electric blender (Model 2268-94A, Binatone, China). The resulting flour was stored in an airtight plastic container for subsequent use.

Extraction of African oil bean seed oil

Oil from African oil bean seed flours was extracted using Soxhlet extraction method described by Onwuzuruike *et al.* (2022) with slight modification in quantity of African oil bean seed flours used. Three hundred and fifty milliliters (350 ml) of n-hexane was first introduced into 500 ml round bottom flask. African oil bean seeds flour (100 g) was measured into thimbles and inserted at the centre of the Soxhlet extractor. The extractor was heated to 69°C for 7 h and was held at that temperature during the extraction process. At the end of the extraction process, the extract was removed from the set-up, and connected to the rotary evaporator to recover the solvent and leaving the extract (oil) behind. The quantity of extract was quantified to determine the yield. The oil sample was packaged in a coloured airtight plastic container for further use. This process was repeated to obtain the needed quantity.

Oil yield determination

The percentage yield of African oil bean seed oil was calculated using the equation described by Adepoju *et al.* (2019):

$$Oil\ yield\ (\%) = \frac{W_o}{W_s} \times 100$$

Where; Wo = mass of oil extracted (g), Ws = mass of the seed (g).

Formulation of oil blends

The extracted African oil bean seed oil (AB) was blended with refined palm olein (RPO) in the following ratios of; 100: 0 (AB100), 0: 100 (RPO100), 90:10 (AB90:RPO10), 80:20 (AB80:RPO20), 70:30 (AB70:RPO30), 60:40 (AB60:RPO40) and 50:50 (AB50: RPO50) respectively.

Frying operation

Preparation of potato slices

Sweet potatoes (white variety) were sorted to remove unwholesome ones, cleaned of adhesive sands, washed using portable tap water to reduce dirt, peeled using a clean stainless steel kitchen knife, washed again and sliced to about 4 cm. Thereafter, the sliced potatoes were steam blanched at 100°C for 3.5 min to prevent enzymatic browning. They were then allowed to cool-dry at room temperature and under normal air flow. Dried potato slices were packed in a clean air-tight plastic container prior to frying operation. The potato slices were packed in two batches of 30 g per each oil blend.

Frying process

Each oil blend of exactly 350 mls, was used to fry two batches of potato slices (30 g). Consequently, the frying oil was used to fry two times per day. Each oil blend was placed in a deep frying pan of 1 L capacity. Batches of potato slices (30 g) was introduced into the hot oil (175±5°C) and fried for 2 minutes. After each batch and a 30 min interval, the frying operation was carried out with new potato batches until all potato batches were fried for the first day. The same procedures were carried out for the four days of frying. The same quality and variety of potatoes was used in all four days of experiment. At the end of each daily frying experiment, the oil was allowed to cool, transferred to an airtight plastic container and stored in a dark and cool place. Tweny grams oils were sampled into a clean glass dark container and stored in the refrigeration condition (0 to 4°C) until assessment to prevent changes in its chemical composition. The refrigerated oil samples were prepared for analysis by allowing it to thaw at room temperature. The oil was not replenished during the frying process (Topkafa, 2020).

Physicochemical analysis of frying oils

Triplicate determination of physicochemical analysis of frying oils were carried out. The smoke points of the oil blend samples were carried out according to AOCS (1998) method. The moisture content was determined as described by AOAC (2012). Peroxide value was determined according to the AOCS (1993c) method. Free fatty acid was determined according to AOCS (1993d) method. The thiobarbituric acid number was determined as described by AOAC (1999) while iodine value was determined according to the AOCS (1993b) method.

Colour analysis

Colour of oils was read as L*, a* and b* using Hunter Lab Colorimeter (D-25, Hunter Associated Laboratory, USA) as described by Devi and Haripriya (2014). Colour attributes of each oil blends were carried out using the CIELAB (L*, a*, b*) colour scale with a Minolta portable spectrophotometer CM-2300d (Konica Minolta Sensing, Inc. Osaka, Japan). The colour was expressed by CIE L*a*b*, where L* is the whiteness or brightness component ranging from 0 to 100, a* is the redness/greenness and b* is the yellowness/blueness. The a* and b* are two chromatic components ranging from -120 to +120. The instrument was calibrated with the zero-calibration box and the white calibration plate respectively. The oil samples were filled into 13 ml solvent-resistant petri-plates. The final colour score of each oil sample was obtained by averaging the scores of the duplicate measurements of the L*, a*, b* from the SCE (Specular Component Excluded) mode.

Statistical analysis

The experimental data were expressed as mean ± SD (standard deviation). The data were subjected to one-way analysis of variance (ANOVA) while the Duncan Multiple Range Test (DMRT) method was used to compare the means of experimental data at 95% confidence interval. All statistical analysis was done using the Statistical Product of Service Solution version 20.0 software.

Results and Discussion

Oil yield of African oil bean seed oil

The percentage oil yield of African oil bean seeds was 47.95% which was appreciably high, classifying the oil seed as a viable source of vegetable oil. The oil content obtained from this study was in agreement with the oil content reported by Esther *et al.* (2008) (47.90%), while Ordu and Yingobo (2021) and Osabor *et al.* (2017) reported lower oil yield of 38.09% and 25.54%, respectively. Oil seeds with oil content above 25% are considered to be good sources of edible oils (Akindele and Nsuhoridem (2018). The oil yields of the present study exceeded 25% and may therefore be classified as good sources of edible oils for possible commercial exploitation.

Changes in the Smoke Point of oil samples During Repeated Frying Cycles

The changes in the smoke point of African oil bean seed oil, refined palm olein and blends of African oil bean seed oil and refined palm olein during repeated frying are shown in Table 1. Smoke points of the oils exhibited a significant ($p < 0.05$) decrease as the frying cycles increased. This could be attributed to water abstracted from the potato during, hence, the lipolysis process speeds up and more free fatty acids are produced. This matched the findings of Choudhary and Grover (2013), who reported that repeated frying using rice bran oil blends reduced the smoke point of the oil samples. The 100% refined palm olein oil had a relatively smaller decrease in smoke point compared to the other oils, while the 100% African oil bean seed oil had relatively higher decrease of smoke point. The smoke point is the temperature at which oil will begin to burn, losing its sheen and producing a bluish haze (Emelike *et al.*, 2020). At this point, the fat begins to break down into glycerol and fatty acids, and the glycerol that forms is broken down further creating acrolein, one of the primary constituents of bluish smokes (Wang, 2002). In addition, these molecules are altering the smell and flavour of fried foods in an undesirable way. There is a correlation between the chain length of the fatty acids present in an oil and its smoke point. Oils high in short-chain fatty acids have a lower smoke point than oils with longer chain fatty acids. More so, minor components, level of impurities, moisture content affects oils smoke point. The higher the impurities/moisture, the lower the smoke point and vice versa (Hashem *et al.,* 2017). Free fatty acid level and partial glyceride concentration also play roles in determining smoke point (Alzaa *et al.,* 2018). The greater the concentration of free fatty acids, the lower the oil's smoke point because of the greater propensity of fatty acids to be broken down into smoke-emitting compounds. African oil bean seed oil is an unrefined oil with higher FFA (Table 5) and possible high concentration of impurities, minor components, moisture contents etc which may explain its lower smoke point than refined palm olein. Akusu *et al.* (2020) reported that the initial smoke point of avocado oil is 171°C and recycled avocado oil had between 171.50-156.00°C which was lower than the values of this study. A greater smoke point is desirable in frying oils, since it indicates a longer shelf life. Refined palm olein had higher smoke point than African oil bean seed oil which may be due to removal of impurities, moisture content and minor components during the refining process. Consequently, Blending African oil bean seed oil with refined palm olein improved the smoke point of the oil samples. Increasing the proportion of refined palm olein in the oil blends increased the smoke points.

Table 1: Changes in the smoke point (^{0}C) of oil samples during repeated frying cycles

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	1.90^{a,E}±0.01	2.17^{a,D}±0.02	2.66^{a,C}±0.04	3.02^{a,B}±0.01	3.24^{a,A}±0.15
RPO100	0.10^{g,E}±0.01	0.19^{g,D}±0.01	0.28^{g,C}±0.02	0.42^{g,B}±0.01	0.52^{g,A}±0.01
AB90:RPO10	1.72^{b,E}±0.01	1.98^{b,D}±0.01	2.14^{b,C}±0.01	2.89^{b,B}±0.01	3.04^{b,A}±0.03
AB80:RPO20	1.55^{c,E}±0.02	1.62^{c,D}±0.01	1.96^{c,C}±0.04	2.38^{c,B}±0.02	2.97^{c,A}±0.02
AB70:RPO30	1.37^{d,E}±0.03	1.52^{d,D}±0.01	1.85^{d,C}±0.03	2.02^{d,B}±0.01	2.45^{d,A}±0.05
AB60:RPO40	1.15^{e,E}±0.04	1.38^{e,D}±0.01	1.42^{e,C}±0.01	1.58^{f,B}±0.01	2.14^{e,A}±0.01
AB50:RPO50	0.92^{f,E}±0.01	1.02^{f,D}±0.01	1.25^{f,C}±0.05	1.97^{e,B}±0.05	2.06^{f,A}±0.03
Oil samples	Initial	1st day	2nd day	3rd day	4th day

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different (p<0.05). Mean values in the same row with different superscript (A-E) are significantly different (p<0.05). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50% African oil bean seed oil: 50% refined palm olein.

Changes in the Moisture Content of oil samples During Repeated Frying Cycles

The moisture content of African oil bean seed oil, refined palm olein and blends of African oil bean seed oil and refined palm olein are presented in Table 2. The results showed that 100% African oil bean seed oil (AB100), being a crude oil had more moisture than refined palm olein, a commercial oil sample. Prior to frying, the moisture content decreased steadily from 1.90% to 0.92% as with increase substitution of refined palm olein from 10 to 50%. The moisture content of the oil samples differs significantly (p<0.05) from each other throughout the frying process. The moisture content of the oils increased significantly (p < 0.05) with each subsequent frying cycle which may be coming from the abstraction of moisture from the potato strips into the frying medium. AB100 increased from 1.90% to 3.24% and had the higher moisture increase amongst the oil samples as a result of its initial moisture content. RPO100 increased the least, from 0.10% to 0.52%, AB90:RPO10 increased from 1.72 to3.04%, AB80:RPO20 increased from 1.55 to 2.97%, AB70:RPO30 increased from 1.37 to 2.45%, AB60:RPO40 increased from 1.15 to 2.14% while AB50:RPO50 increased from 0.92 to 2.06% respectively. At the end of the frying cycles, 100% African oil bean seed oil had a significantly higher moisture content (3.24%). At the initial stage prior to frying, all oil samples except 100% refined palm olein (RPO100) had a moisture content above the Codex specification criterion of 0.2% (w/w) (Codex Alimentarius Commission/FAO/WHO, 2011). However, after the second frying cycle, the moisture content of RPO100 exceeded the specification limit. Monitoring the moisture content of oils is crucial in assessing their storage stability. Excessive water in the oil leads to hydrolysis and quality deterioration. The rate of oil degradation increases with higher moisture levels (Otunola *et al.*, 2009). During frying, significant mass transfer occurs, primarily involving water but also oil and heat. The presence of water in the food and oil accelerates the hydrolysis of the oil.

Table 2: Changes in the moisture content (%) value of the oil samples during repeated frying cycles.

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	191.85^{f,A}±2.13	188.13^{g,B}±0.14	186.36^{g,C}±0.04	183.14^{g,D}±0.01	179.24^{g,E}±0.02
RPO100	221.14^{a,A}±1.42	217.15^{a,B}±0.01	213.95^{a,C}±0.02	211.35^{a,D}±0.02	204.76^{b,E}±0.04
AB90:RPO10	203.44^{e,A}±0.64	199.85^{f,B}±0.01	195.89^{f,C}±0.01	191.66^{f,D}±0.01	188.58^{f,E}±0.01
AB80:RPO20	207.90^{d,A}±0.01	203.60^{e,B}±0.01	202.45^{e,C}±0.01	196.17^{e,D}±0.02	192.91^{e,E}±0.01
AB70:RPO30	211.82^{c,A}±0.01	208.22^{d,B}±0.03	205.05^{d,C}±0.05	201.76^{d,D}±0.04	197.24^{d,E}±0.01
AB60:RPO40	215.77^{b,A}±0.01	211.05^{c,B}±0.04	209.62^{c,C}±0.01	205.24^{c,D}±0.04	202.58^{c,E}±0.01
AB50:RPO50	217.68^{b,A}±0.01	214.92^{b,B}±0.05	211.65^{b,C}±0.03	207.04^{b,D}±0.01	204.86^{a,E}±0.04

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different (p<0.05). Mean values in the same row with different superscript (A-E) are significantly different (p<0.05). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50% African oil bean seed oil: 50% refined palm olein.

Changes in the Peroxide Value of oil samples During Repeated Frying Cycles

The result of the changes in the Peroxide Value (PV) of the samples in this study is shown in Table 3. Peroxides are major initial reaction products of lipid oxidation that major for primary oxidation. There was significant (p<0.05) difference in the values obtained for each day. Peroxide value ranged from 2.48 to 3.35 meq O_2 /kg for the initial quality, 2.93 to 8.60 meq O_2 /kg for the first day, 3.76 to 9,12 meq O_2 /kg for the second day, 4.37 to 14.49 meq O_2 /kg for third day and 5.68 to 17.87 meq O_2 /kg for the fourth day of frying. The 100% African oil bean seed oil (AB100) had the highest peroxide value throughout the frying cycle, however, the peroxide value decreased from 3.24 meq O_2 /kg to 2.06 meq O_2 /kg with increasing substitution of African oil bean seed oil with refined palm olein. This showed that blending African oil bean seed oil and refined palm olein reduced the incidence of hydroperoxide formation as indicated by the peroxide value. The initial PV for all oils was lower than 5 meq O_2/kg which suggest good quality. Che Man and Wan Hussin (1998) mentioned that a good-quality vegetable oils should have a PV of lower than 5 meq O_2/kg. During frying AB100 increased from 3.35 to 17.87 meq O_2/kg, RPO100 increased from 2.48 to 7.20 meq O_2/kg, AB90:RPO10 increased from 3.23 to 11.30 meq O_2/kg, AB80:RPO20 increased from 3.16 to 10.95 meq O_2/kg, AB70:RPO30 increased from 3.08 to 8.70 meq O_2/kg, AB60:RPO40 increased from 2.95 to 7.34 meq O_2/kg and AB50:RPO50 increased from 2.86 to 5.68 meq O_2/kg respectively. It is evident from Table 3 that frying at 180°C for four days increased the PV of African oil bean seed oil more than refined palm olein and the oil blends respectively, which is an indication of a greater extent of oxidation in African oil bean seed oil. Notably, PV is useful as an indicator of oxidation at the initial stages. However, during frying, the changes in PV were not related to duration of frying, but were dependent on rate of formation and breakdown of oxidation procedure. Increase in peroxides is facilitated by the presence of free fatty acids, pro-oxidants micro-nutrients, and lipases, amongst others.

Table 3: Changes in the peroxide content (meq O_2 /kg) of the oil samples during repeated frying cycles.

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	$3.35^{a,E}\pm0.04$	$8.60^{a,D}\pm0.05$	$9.12^{a,C}\pm0.01$	$14.49^{a,B}\pm0.02$	$17.87^{a,A}\pm0.08$
RPO100	$2.48^{g,E}\pm0.05$	$3.17^{f,D}\pm0.22$	$5.53^{c,C}\pm0.08$	$6.53^{e,B}\pm0.01$	$7.20^{e,A}\pm0.01$
AB90:RPO10	$3.23^{b,E}\pm0.01$	$5.42^{b,D}\pm0.01$	$7.99^{b,C}\pm0.01$	$9.89^{b,B}\pm0.02$	$11.30^{b,A}\pm0.09$
AB80:RPO20	$3.16^{c,E}\pm0.01$	$4.26^{c,D}\pm0.06$	$5.46^{c,C}\pm0.01$	$8.18^{c,B}\pm0.08$	$10.95^{c,A}\pm0.04$
AB70:RPO30	$3.08^{d,E}\pm0.02$	$3.87^{d,D}\pm0.01$	$4.77^{d,C}\pm0.01$	$6.90^{d,B}\pm0.01$	$8.70^{d,A}\pm0.03$
AB60:RPO40	$2.95^{e,E}\pm0.04$	$3.46^{e,D}\pm0.01$	$4.15^{e,C}\pm0.03$	$5.74^{f,B}\pm0.01$	$7.34^{e,A}\pm0.14$
AB50:RPO50	$2.86^{f,E}\pm0.01$	$2.93^{g,D}\pm0.03$	$3.76^{f,C}\pm0.01$	$4.37^{g,B}\pm0.05$	$5.68^{f,A}\pm0.04$

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different (p<0.05). Mean values in the same row with different superscript (A-E) are significantly different (p<0.05). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50 %African oil bean seed oil: 50% refined palm olein.

Changes in the Free Fatty Acid content of oil samples During Repeated Frying Cycles

Table 4 presents the result of the changes in free fatty acid of African oil bean seed oil, refined palm olein and blends of African oil bean seed oil and refined palm olein oils during repeated frying. The free fatty acid (FFA) content of the oils during frying cycles ranged from 0.07 to 3.54% at the initial stage, 0.12 to 4.17% on the 1st day of frying, 0.45 to 6.68% on the 2nd day, 0.96 to 8.41% on the 3rd day and 1.19 to 9.63% on the 4th day of frying. The free fatty acids of the oil samples increased significantly (p<0.05) during the frying cycle. The 100% African oil bean seed oil (AB100) had higher FFA while 100% refined palm olein (RPO100) had the lowest FFA. Blending reduced the rate of FFA formation in the oil samples during frying such that, the rate of FFA formation decreased with an increase in the amount of refined palm olein in the oil blends. The FFA content of the oils increased significantly ($p < 0.05$) with each subsequent frying cycle. This is because frying abstracts water from the food into the hot oil which rapidly hydrolyzes triglycerides into free fatty acids (FFA) as well as other components like monoacylglycerols, diacylglycerols and glycerols. Idun-Acquah *et al.* (2016) conducted a study that also showed similar results, with FFA ranging from 0.62% to 2.41% after 5 days of frying. The degradation of natural fatty acids in the oil due to high temperatures and water from the fresh food product may explain the variation in FFA readings (Emelike *et al.*, 2020). Emelike *et al*. (2020) suggested that oil with low moisture content has lower free fatty acid content, while oil with high moisture content has increased free fatty acid content. This report corresponds with the findings of this study such that 100% African oil bean seed oil (AB100) with the highest moisture (Table 3) had higher FFA while 100% refined palm olein (RPO100) with the lowest moisture content (Table 3) had the lowest FFA. The increase in FFA observed in this study can also be attributed to heat and oxidative decomposition, which breaks down large carbon chains into shorter ones. At very high temperatures, double bonds are cleaved and oxidized, leading to the formation of free fatty acids (Lalas, 2009). More so, higher value in AB100 could be due to the fact that the initial FFA was higher than that of RPO100. Generally, the increase in FFA levels were due to the cleavage and oxidation of double bonds to form carbonyl compounds which oxidized to low molecular fatty acids during frying treatments (Che Man and Irwandi, 2000). Furthermore, the water coming from fried potato accelerated the hydrolysis cleavage of the oil. The determination of FFA by titration does not differentiate between acids formed by oxidation and those formed by hydrolysis. For these reasons, the increase in FFA level is a poor measure of frying oils deterioration. Although FFA measurement is not a perfect indicator of frying-oil deterioration, it is still widely used because it provides specific, practical, and regulatory-relevant information that other tests do not. In formal terms, the method remains valuable because free fatty acids originate primarily from hydrolysis of triglycerides, especially when food contains moisture. Even though FFA does not distinguish oxidation-induced acids from hydrolytic ones, it still reflects the extent of hydrolytic degradation, which is an important mechanism of quality loss in frying systems. Among all oils, RPO100 was the only oil below 0.5% which is the value normally used by snack food producers to discard the oil, which could be due to its refined nature.

Table 4: Changes in the free fatty acid content of the oil samples during repeated frying cycles

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	$3.54^{a,E}\pm0.02$	$4.17^{a,D}\pm0.01$	$6.68^{a,C}\pm0.06$	$8.41^{a,B}\pm0.03$	$9.63^{a,A}\pm0.01$
RPO100	$0.07^{g,D}\pm0.01$	$0.12^{g,D}\pm0.01$	$0.45^{g,C}\pm0.01$	$0.96^{g,B}\pm0.01$	$1.19^{g,A}\pm0.12$
AB90:RPO10	$3.21^{b,E}\pm0.01$	$3.42^{b,D}\pm0.01$	$5.83^{b,C}\pm0.03$	$7.34^{b,B}\pm0.21$	$8.25^{b,A}\pm0.01$
AB80:RPO20	$2.87^{c,E}\pm0.02$	$3.10^{c,D}\pm0.01$	$4.47^{c,C}\pm0.03$	$5.16^{c,B}\pm0.04$	$7.91^{c,A}\pm0.04$
AB70:RPO30	$2.74^{d,E}\pm0.04$	$2.98^{d,D}\pm0.01$	$3.78^{d,C}\pm0.02$	$4.72^{d,B}\pm0.04$	$5.79^{d,A}\pm0.01$
AB60:RPO40	$2.18^{e,E}\pm0.02$	$2.76^{e,D}\pm0.01$	$3.19^{e,C}\pm0.02$	$4.17^{e,B}\pm0.01$	$5.54^{e,A}\pm0.01$
AB50:RPO50	$1.82^{f,E}\pm0.01$	$2.24^{f,D}\pm0.04$	$2.77^{f,C}\pm0.03$	$3.32^{f,B}\pm0.01$	$3.69^{f,A}\pm0.05$

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different ($p<0.05$). Mean values in the same row with different superscript (A-E) are significantly different ($p<0.05$). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50 %African oil bean seed oil: 50% refined palm olein.

Changes in the Thiobarbituric Acid Content of the oil samples During Repeated Frying Cycles

The thiobarbituric acid value of the oil samples are presented in Table 5. There was significant ($p<0.05$) difference in the values obtained. The 100% African oil bean seed oil (AB100) had the highest TBA throughout the frying period while 100% refined palm olein (RPO100) had the lowest TBA values. Consequently, blending both oils resulted to lower TBA values in the blended oils throughout the frying cycles. Decreasing TBA values could be linked to the reduction in the amount of oxidation-enhancing micro component and impurities capable of sporulating the oxidation process. Furthermore, high TBA in blends containing high proportion of African oil bean seed oil suggests a more pronounced and possible occurrence of secondary oxidation and the presence of its subsequent products such as aldehydes and ketones compared to other oil samples. However, the TBA values increased steadily after each frying cycle up until the 4th day of frying. AB100, RPO100, AB90:RPO10 AB80:RPO20, AB70:RPO30, AB60:RPO40 and AB50:RPO50 increased from 1.15 to 11.85 mg/g, 0.02 to 1.05 mg/g, 1.05 to 10.28 mg/g, 0.92 to 10.01 mg/g, 0.80 to 8.34 mg/g, 0.68 to 6.96 mg/g and 0.58 to 3.71 mg/g respectively. The secondary stage of oxidation occurs when the hydroperoxides decompose to form carbonyls and other compounds, particularly aldehydes. This gives the oil a rancid smell and they are measured by thiobarbituric acid (TBA), being a quality marker for evaluating the quality of oils and fats. Thiobarbituric acid assay is the most widely used method for the measurement of secondary oxidation products, which may contribute to off-flavour of oxidized oils (Iqbal and Bhanger, 2007).

Table 5: Changes in the thiobarbituric acid content of the oil samples during repeated frying cycles.

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	$1.15^{a,E}\pm0.02$	$3.37^{a,D}\pm0.01$	$5.37^{a,C}\pm0.06$	$8.64^{a,B}\pm0.01$	$11.85^{a,A}\pm0.04$
RPO100	$0.02^{g,E}\pm0.01$	$0.05^{g,D}\pm0.01$	$0.34^{g,C}\pm0.04$	$0.66^{g,B}\pm0.01$	$1.05^{g,A}\pm0.05$
AB90:RPO10	$1.05^{b,E}\pm0.04$	$3.15^{b,D}\pm0.02$	$4.53^{b,C}\pm0.06$	$7.97^{b,B}\pm0.01$	$10.28^{b,A}\pm0.01$
AB80:RPO20	$0.92^{c,E}\pm0.01$	$3.10^{c,D}\pm0.01$	$4.06^{c,C}\pm0.01$	$6.21^{c,B}\pm0.03$	$10.01^{c,A}\pm0.01$
AB70:RPO30	$0.80^{d,E}\pm0.01$	$2.90^{d,D}\pm0.01$	$3.78^{d,C}\pm0.02$	$4.69^{d,B}\pm0.01$	$8.34^{d,A}\pm0.03$
AB60:RPO40	$0.68^{e,E}\pm0.01$	$2.76^{e,D}\pm0.01$	$3.23^{e,C}\pm0.05$	$4.48^{e,B}\pm0.01$	$6.96^{e,A}\pm0.04$
AB50:RPO50	$0.58^{f,E}\pm0.01$	$1.24^{f,D}\pm0.02$	$1.87^{f,C}\pm0.02$	$2.35^{f,B}\pm0.01$	$3.71^{f,A}\pm0.02$

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different ($p<0.05$). Mean values in the same row with different superscript (A-E) are significantly different ($p<0.05$). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50 %African oil bean seed oil: 50% refined palm olein.

Changes in the Iodine Value (IV) of the Oil Samples during Repeated Frying Cycles

The results of the iodine value of African oil bean seed oil, refined palm olein and blends of African oil bean seed oil and refined palm olein are presented in Table 6. The iodine value (IV) of an oil is an index used to assess its level of unsaturation and susceptibility to rancidity (Amoo *et al.*, 2004). AB100 had the highest value until after the first day of frying but had the lowest value at the end of the frying period which indicates faster deterioration due to its high unsaturation level while RPO100 had the lowest level of deterioration throughout the frying period. The IVs of the oils decreased as the frying cycles increased and the values differed significantly ($p < 0.05$) from each other. Heating oil to high temperatures, as in deep frying, accelerates its oxidation process, as indicated by the iodine index (Otunola *et al.*, 2009). Omara and Kigenyi (2019) noted that as the number of frying cycles increased, the iodine content decreased, which is due to decrease in double bonds arising from oxidation and heat-induced breakdown. According to Chebet *et al.* (2016), a decline in the iodine value is indicative of degradation in vegetable oils. The oxidative stability of oils after frying is of great interest, and the iodine value plays a crucial role in assessing it. The iodine value of the oils decreased with frying time due to consumption of double bonds by oxidation and polymerisation, which could be considered as indication to the extent of thermal and oxidative degradation for the frying oils. The lower the IV, the lower the unsaturation of a specific oil or fat. The present study showed that the stability of palm olein was higher than African oil bean seed oils during frying of potato strips. This discrepancy in stability of palm olein compared to African oil bean seed oil can be attributed to the high oleic acid and low linoleic content of refined palm olein. Consequently, the stability of the oil blends increased with increase in refined palm olein substitution from 10 to 50% such that, the level of iodine value reduction during frying was lower in the oil samples containing higher proportion of refined palm olein. For instance, the IV of 100% African oil bean seed oil (AB100) reduced from 118.48 g I_2/100 g to 72.31 g I_2/100 g at the end of the frying period while 50 %African oil bean seed oil and 50% refined palm olein (AB50:RPO50) reduced from 104.96 g I_2/100 g to 96.94 g I_2/100 g, indicating higher stability.

Table 6: Changes in the Iodine value (g I_2 /100 g) of the oil samples during repeated frying cycles.

Oil samples	Initial	1st day	2nd day	3rd day	4th day
AB100	118.48 ^{a,A}±0.01	107.41 ^{a,B}±0.06	101.29 ^{a,C}±0.03	89.40 ^{e,D}±0.01	72.31 ^{g,E}±0.01
RPO100	85.04 ^{g,A}±0.04	83.86 ^{d,B}±0.04	81.16 ^{f,C}±0.01	80.97 ^{f,D}±0.03	80.06 ^{f,E}±0.04
AB90:RPO10	114.22 ^{b,A}±001	103.22 ^{c,B}±0.01	98.86 ^{e,C}±0.01	91.98 ^{d,D}±0.01	84.25 ^{e,E}±0.01
AB80:RPO20	111.44 ^{c,A}±0.01	104.20 ^{b,B}±0.01	100.42 ^{c,C}±0.04	96.28 ^{c,D}±0.08	87.95 ^{d,E}±0.04
AB70:RPO30	108.15 ^{d,A}±0.01	103.90 ^{c,B}±0.01	99.30 ^{d,C}±0.05	96.71 ^{c,D}±0.03	92.73 ^{c,E}±0.01
AB60:RPO40	105.15 ^{e,A}±0.16	103.06 ^{c,B}±0.01	100.15 ^{c,C}±0.04	97.97 ^{b,D}±0.01	93.16 ^{b,E}±0.02
AB50:RPO50	104.96 ^{f,A}±0.77	103.93 ^{c,B}±0.03	101.78 ^{b,B}±0.01	99.02 ^{a,C}±0.01	96.94 ^{a,BC}±0.02

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different ($p<0.05$). Mean values in the same row with different superscript (A-E) are significantly different ($p<0.05$). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50 %African oil bean seed oil: 50% refined palm olein.

Changes in the colour properties of the Oil Samples during Repeated Frying Cycles

The result of the colour properties of the oil samples are shown in Table 7. Colour of edible oil influences consumer's choices to a great extent because it is an indicator to determine the quality of frying oil. As shown in Table 7, L*-values (which denotes brightness) of all oil samples decreased during the frying cycles, however, the rate of decreased was lower for RPO100 (100% refined palm oil) and oil samples containing higher percentage of RPO. Colour changes in oil samples is a reflection of oil deterioration. Lower reduction of L*-value of RPO100 and oil blends with higher percentage of RPO may be due to lower deterioration rate relative to the higher saturation level of RPO. More so, diminishing lightness of the oil samples as frying continues may be due to accumulation of degradation products in the frying oil (Dodoo *et al.,* 2022). Ujong *et al.* (2023) also reported that L*-value for soybean oil decreased significantly ($p<0.05$) as the frying cycles increased, which was in-line with the findings of this study.

a*-values which denotes redness increased significantly ($p<0.05$) in all oil samples as shown in Table 8. This may also be due to accumulation of degradation products in the frying oil (Dodoo *et al.*, 2022), indicating a shift towards redness. Furthermore, frying food at elevated temperatures can cause the migration of many constituents which include but not limited to sulphur compounds, phosphates, carbohydrate, transition metals, trace metals into the oil, thereby raising the colour value of the oil. Ujong *et al.* (2023) reported that a ∗ values of the oils were observed to decrease for avocado and almond oils as the frying cycles increased whereas that of soybean oil and sesame seed oil increased. Increasing a*-values of soybean oil and sesame seed oil reported by Ujong *et al.* (2023) corresponds with the findings of this study.

Table 7: Colour changes of the oil samples during repeated frying cycles.

Colour parameters	Oil samples	Initial	1st day	2nd day	3rd day	4th day
	AB100	$62.75^{g,A}\pm0.07$	$62.13^{g,B}\pm0.01$	$62.04^{g,B}\pm0.01$	$59.65^{e,C}\pm0.01$	$56.44^{b,D}\pm0.01$
	RPO100	$69.55^{a,A}\pm0.07$	$68.92^{a,A}\pm0.07$	$67.07^{a,A}\pm0.02$	$64.24^{b,B}\pm0.01$	$60.21^{c,C}\pm0.01$
L*	AB90:RPO10	$64.55^{f,A}\pm0.64$	$63.55^{f,B}\pm0.21$	$63.31^{f,C}\pm0.01$	$62.40^{d,D}\pm0.14$	$61.85^{f,E}\pm0.07$
	AB80:RPO20	$65.80^{e,A}\pm0.14$	$64.45^{e,B}\pm0.07$	$63.92^{e,C}\pm0.01$	$63.12^{c,D}\pm0.01$	$62.23^{g,E}\pm0.01$
	AB70:RPO30	$66.38^{d,A}\pm0.03$	$65.32^{d,B}\pm0.01$	$64.98^{d,B}\pm0.01$	$62.45^{e,C}\pm0.01$	$62.32^{e,D}\pm0.01$
	AB60:RPO40	$67.05^{c,A}\pm0.07$	$66.90^{c,A}\pm0.04$	$66.86^{b,A}\pm0.02$	$64.15^{d,B}\pm0.04$	$63.22^{d,C}\pm0.03$
	AB50:RPO50	$67.95^{b,A}\pm0.05$	$66.96^{b,A}\pm0.07$	$66.78^{c,B}\pm0.01$	$65.27^{a,C}\pm0.08$	$64.01^{h,D}\pm0.01$
	AB100	$6.60^{a,D}\pm0.42$	$6.80^{a,D}\pm0.14$	$7.40^{a,C}\pm0.14$	$8.02^{a,B}\pm0.01$	$9.73^{a,A}\pm0.11$
	RPO100	$-0.30^{f,E}\pm0.01$	$-0.14^{g,D}\pm0.01$	$0.08^{g,C}\pm0.01$	$0.18^{g,B}\pm0.02$	$0.48^{g,A}\pm0.01$
a*	AB90:RPO10	$4.50^{b,D}\pm0.14$	$4.80^{b,D}\pm0.14$	$6.15^{b,C}\pm0.07$	$7.72^{b,B}\pm0.09$	$8.27^{b,A}\pm0.08$
	AB80:RPO20	$3.91^{c,E}\pm0.01$	$4.45^{c,D}\pm0.07$	$5.85^{c,C}\pm0.07$	$6.25^{d,B}\pm0.07$	$7.45^{c,A}\pm0.07$
	AB70:RPO30	$3.16^{d,E}\pm0.05$	$3.85^{d,D}\pm0.08$	$4.09^{d,C}\pm0.14$	$6.60^{c,A}\pm0.14$	$6.40^{d,B}\pm0.14$
	AB60:RPO40	$2.85^{d,E}\pm0.03$	$3.10^{e,D}\pm0.07$	$3.85^{e,C}\pm0.07$	$4.45^{e,B}\pm0.07$	$5.93^{e,A}\pm0.04$
	AB50:RPO50	$1.92^{e,E}\pm0.03$	$2.50^{f,D}\pm0.14$	$2.92^{f,C}\pm0.01$	$3.30^{f,B}\pm0.14$	$4.90^{f,A}\pm0.01$
	AB100	$25.80^{a,A}\pm0.00$	$21.05^{c,B}\pm0.01$	$17.27^{f,C}\pm0.07$	$15.33^{e,D}\pm0.02$	$12.40^{f,E}\pm0.14$
	RPO100	$16.35^{g,A}\pm0.21$	$15.93^{f,B}\pm0.01$	$14.45^{g,C}\pm0.06$	$14.15^{f,D}\pm0.05$	$13.28^{c,E}\pm0.08$
b*	AB90:RPO10	$24.87^{c,A}\pm0.04$	$21.73^{a,B}\pm0.21$	$20.16^{a,C}\pm0.07$	$18.30^{b,D}\pm0.05$	$17.20^{b,E}\pm0.14$
	AB80:RPO20	$24.12^{b,A}\pm0.01$	$21.37^{b,B}\pm0.21$	$18.33^{c,C}\pm0.01$	$17.02^{c,D}\pm0.01$	$16.44^{c,E}\pm0.07$
	AB70:RPO30	$23.65^{d,A}\pm0.21$	$20.41^{d,B}\pm0.10$	$17.81^{d,C}\pm0.01$	$15.35^{de,D}\pm0.07$	$14.34^{d,E}\pm0.15$
	AB60:RPO40	$22.85^{e,A}\pm0.07$	$20.15^{d,B}\pm0.07$	$17.41^{e,C}\pm0.01$	$15.45^{d,D}\pm0.07$	$13.64^{a,E}\pm0.04$
	AB50:RPO50	$20.15^{f,A}\pm0.07$	$19.35^{e,B}\pm0.07$	$19.01^{b,C}\pm0.01$	$18.77^{a,D}\pm0.01$	$18.59^{a,E}\pm0.03$

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscript (a-g) are significantly different ($p<0.05$). Mean values in the same row with different superscript (A-E) are significantly different ($p<0.05$). AB100= 100% African oil bean seed oil. RPO100= 100% refined palm olein. AB90:RPO10= 90% African oil bean seed oil: 10% refined palm olein. AB80:RPO20= 80% African oil bean seed oil: 20% refined palm olein. AB70:RPO30= 70% African oil bean seed oil: 30% refined palm olein. AB60:RPO40= 60% African oil bean seed oil: 40% refined palm olein. AB50:RPO50= 50% African oil bean seed oil: 50% refined palm olein.

Conclusion and Recommendation

This study was able to establish the frying stability of African oil bean seed oil and its blends with refined palm olein. Extraction results showed that African oil bean seed is a rich source of edible oils but it easily undergoes oxidation which will affects its suitability in food applications. Blending African oil bean seed oil and refined palm olein improved the frying (thermal) stability of African oil bean seed oil. Repeated frying, had deleterious effect on all oil samples but was more pronounced in African oil bean seed oil as a single oil than on the oil blends. From the findings of this study, 100% African oil bean seed oils, although highly unsaturated, lacked superior hot food applicative properties compared to refined palm olein, a commercial oil sample but showed prospect as a food ingredient when blended with other seed oil with high thermal stability like refined palm olein. Optimising the formulations of African oil bean seed oils in food systems could improve the prospects of utilizing African oil seed oils in food applications with better nutritional and health benefits.

References

Adepoju, T. F., Esu1, I. O., Olu-Arotiowa, O. A., & Blessed, E. (2019). Oil extraction from butter fruit (*Dacryodes edulis*) seeds and its optimization via response surface and artificial neural network. *Nigerian Journal of Technological Development,* 16(2), 56-62.

Akindele, F. A., & Nsuhoridem, I. J. (2018). *Extraction of vegetable oils from agricultural materials:* A Review. Proceedings of the 12th CIGR Section VI International Symposium, held at the International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria, 22–25 October, 2018.Pp. 1185-1206.

Akinlabu, D. K., Owoeye, T. F., Owolabi, F. E., Audu, O. Y., Ajanaku, C. O., Falope, F., & Ajani, O. O. (2019). Phytochemical and proximate analysis of African oil bean (*Pentaclethra macrophylla* Benth) seed. *Journal of Physics: Conference Series,* 378, 032057

Akusu, M. O., Obinna-Echem, P. C., & Chibor, B. S. (2020). Comparative analysis of the physicochemical characteristics, phytochemical components and fatty acid profile of avocado pear (*Persia Americana* L.) pulp and seed oil. *European Journal of Agriculture and Food Sciences, 3* (1), 11–16.

Aladekoyi, G., Orungbemi, O.O., Karimu, O.A., & Aladejimokun, A.O. (2017). Comparative studies of the nutritional and phytochemical constituents of African oil bean (*Pentaclethra macrophylla* Benth) and African bean (*Anthonotha macrophylla*) for human consumption. *Chemistry Research Journal*, 2(3), 16-21.1

Alzaa, D. F., Guillaume, C., & Ravetti, L. (2018). Evaluation of chemical and physical changes in different commercial oils during heating. *Acta Scientific Nutritional Health, 2* (6), 2–11.

Ambindei, W. A., Jazet, P. M. D., Tatsadjieu, L. N., Priya, P. & Nisha, P. (2020). Stabilization potentials of the essential oils of *Thymus vulgaris* L.., *Ciinnamomum zeylanicum* B. and *Mentha piperita* L. on palm olein at accelerated storage. *African Journal of Biotechnology,* 19 (7): 464–477.

Amoo, I. A., Eleyinmi, A. F., Illelaboye, N. A. O. & Akoja, S. S. (2004). Characteristics of oil extract from gourd (*Cucurbita maxima*) seed. *Food Agriculture and Environment, 2:* 38–39.

AOAC (1999*). Residue (unsaponifiable) of oils and fat.* Official Methods of Analysis of AOAC International 16th ed.; Cunniff, P., editor: AOAC International: Gaithersburgh, Maryland, USA. Method 933.08.

AOAC. (2012). *Association of Official Analytical Chemists and Association of Official Agricultural Chemists (US) Official methods of analysis*. Association of Official Analytical Chemists,

AOCS (1993b). Official Methods and Recommended Practices of the American Oil Chemists' Society Champaign. Method Ca 5a-40.

AOCS (1993c). Official Methods and Recommended Practices of the American Oil Chemists' Society Champaign. Method Cd 1d-92.

AOCS (1993d). Official Methods and Recommended Practices of the American Oil Chemists' Society Champaign. Method Cd 8-53.

AOCS (1998). Official methods and recommended practices of the American oil chemists' society.

AOCS, 5*:* 2–93.
Chebet, J., Kinyanjui, T., & Cheplogoi, P. K. (2016). Impact of frying on iodine value of vegetable oils before and after deep frying in different types of food in Kenya. *Journal of Science and Innovative Research*, *5,* 193–196.
Che Man, Y. B., & Irwandi, J. (2000). Effect of rosemary and sage extract on frying performance of refined, bleached and deodorzed (RBD) palm olein during deep fat frying. *Food Chemistry,* 69, 301-307
Che Man, Y. B., & Wan Hussin, W. R. (1998). Comparison of the frying performance of refined, bleached and deodorized palm oleic and coconut oil. *Journal of Food Lipids*, 5, 197-210.
Choudhary, M., & Grover, K. (2013). Effect of deep-fat frying on physicochemical properties of rice bran oil blends. *Journal of Nursing and Health Science, ,:*1–10.
Codex Alimentarius Commission/FAO/WHO. (2011). *Food standards. Standard for named vegetable oils*. FAO/WHO CODEX-STAN 210, Ed2011
Devi, K., & Haripriya, S. (2014). Pasting behaviours of starch and protein in soy flour enriched composite flours on quality of biscuits. *Journal of Food Processing and Preservation*, *38*(1), 116– 124
Dobarganes, C., & Marquez-Ruiz, G. (2015). Possible adverse effects of frying with vegetable oils. *British Journal of Nutrition, 113*(2), 49–57. 10.1017/S0007114514002347
Dodoo, D., Adjei, F., Tulashie, S. K., Adukpoh, K. E., Agbolegbe, K., Gawou, K., & Manu, G. P. (2022). Quality evaluation of different repeatedly heated veg-etable oils for deep-frying of yam fries. *Food: Measurement, 7,* Article 100035. 10.1016/j.meafoo.2022.100035.
Emelike, N. J. T., Ujong, A. E., & Achinewhu, S. C. (2020). Physicochemical and antioxidant properties of oils used by local fried food vendors in d/line-port harcourt, rivers state. *Agriculture and Food Sciences Research,* 7(1), 89–96. 10.20448/jour-nal.512.2020.71.89.96.
Esther, U. I., Anthony, E. A., Peace, O., & Macdonald, I. (2008). Characteristics and Composition of African Oil Bean Seed (*Pentaclethra macrophylla Benth*). *Journal of Applied Sciences*, 8(7), 1337-1339. DOI:10.3923/jas.2008.1337.1339
Hashem, H. A., Shahat, M., El-Behairy, S. A., & Sabry, A. (2017). Use of Palm Olein for Improving the Quality Properties and Oxidative Stability of Some Vegetable Oils during Frying Process. *Middle East Journal of Applied Science and Technology*, 7 (1), 68–79.
Idun-Acquah, N., George, Y. O., & Ebenezer, M. (2016). Repetitive use of vegetable cooking oil and effects on physico-chemical properties–Case of frying with redfish (*Lutjanus fulgens*). *Science and Technology*, 6, 8–14.
Igbozulike, A. O., Ndirika, V. I. O., & Simonyan, K. J. (2021). Postharvest processing, packaging and storage of African oil bean seed. *Scientific Journal Agricultural Engineering*, 1, 31-46.
Kiralan, M., Ula¸ S. M., Özaydin, A., Özdemır, N., Özkan, G., Bayrak, A., & Ramadan, M. F. (2017). Blends of Cold Pressed Black Cumin Oil and Sunflower Oil with Improved Stability: A Study Based on Changes in the Levels of Volatiles, Tocopherols and Thymoquinone during Accelerated Oxidation Conditions. *Journal of Food Biochemistry*, 41, e12272.
Lalas, S., Sahin, S., & Sumnu, S. G. (2009). Quality of frying oil. editors. *Advances in deep-fat frying of foods*. Boca Raton: CRC Press
Oke, K. E., Idowu, M. A., Philip, S. O., Adeyeye, S. O., & Akinsola, A. O. (2017). Frying of food: a critical review. *Journal of Culinary Science and Technology*, 10.1080/15428052.2017.1333936
Omara, T., & Kigenyi, E. (2019). Effects of continuous deep fat frying on the physical and chemical properties of assorted brands of cooking oils sold in Metropolitan Kampala. *Asian Journal of Applied Chemistry Research*, 3, 1–13.

Onwuzuruike, U. A., Okakpu, C. J., Ndife, J., & Eke, C. I. (2022). Production and quality assessment of mayonnaise from blends of soybean oil and African pear(*Dacryodes edulis*) pulp oil. *Agro-Science*, 21(1), 88-97.

Onwuzuruike, U.A., Inyang, U.E. Edima-Nyah, A.P., Okwunodulu, I.N., & Anyanwu, CU. (2024).

Chemical Composition, Quality Indices and Viscosity of Edible Oils from Blends of African Oil Bean Seed Oil and Sesame Seed Oil. *Journal of Bio & Geo Material and Energy* (BiGME) 4(1), 33-47.

Ordu, J. I., & Yingobo, F. E. (2021). Preliminary investigation of oil from *Pentachlethra microphylla* seeds as new excipient in cosmetic/pharmaceutical cream formulation. *Asian Journal of Science and Technology*, 12(3), 11575-11580.

Osabor, V. N., Okonkwo, P. C., & Ikeuba, A. I. (2017). Chemical profile of leaves and seeds of *Pentaclethra macrophylla* Benth. *Journal of Medicinal Plant and Herbal Therapy Research,* 5(1), 11-17.

Otunola, G., Adebayo, G., & Olufemi, O. (2009). Evaluation of some physicochemical parameters of selected brands of vegetable oils sold in llorin metropolis. *International Journal of Physical Sciences*, 4, 327–329

Oyinloye, A. M., & Enujiugha, V. N. (2019). Antioxidant properties of African oil bean seed phenolics as influenced by extraction solvents and heat treatments. *Applied Tropical Agriculture*, 24(1), 42-48.

Topkafa, M. (2020). Application of the central composite design and response surface methodology for investigation of induction time, conjugated diene, conjugated triene and trans fatty acid content of corn oil enriched with carotenoids. *Journal of the Iranian Chemical Society*, 17(12), 3383–3392.

Wang, T., & Gunstone, F. (2002). Soybean oil. In *Vegetable Oils in Food Technology: Com-position, Properties and Uses* (pp. 18–58). UK: Blackwell Publishing Ltd.