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Antioxidant and Physicochemical Properties of African Oil Bean (*Pentaclethra macrophylla*) Seed Oil Blended with Roasted Sesame (*Sesamum indicum* L.) Seed Oil

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Abstract

This study evaluated the antioxidant and physicochemical properties of African oil bean seed oil (AOBO) blended with roasted sesame seed oil (RSO). Oils were extracted from African oil bean seeds, unroasted sesame seeds, and roasted sesame seeds. AOBO was blended with unroasted and roasted sesame seed oil at two ratios: 90:10 and 85:15, respectively, using soybean oil as the reference. Following extraction, oil yields were calculated (AOBO: 47.95%; Unroasted Sesame: 46.88%; RSO: 53.70%). The unmixed and blended oils were assessed for their physicochemical properties (viscosity, refractive index, specific gravity, melting point, cloud, smoke, flash, and fire points) and antioxidant activity (DPPH, ABTS, and FRAP assays). Physicochemical properties varied, ranging from 36.66–42.06 cP for viscosity, 29.80–31.09°C melting point, 185.49–191.85°C smoke point and 319.05–337.94°C (flash point). Antioxidant activity assays showed values of 3.51–11.03% (FRAP), 54.74–96.28% (DPPH), and 46.27–91.47% (ABTS). The results indicate that blending African oil bean and roasted sesame oils achieved a product with better complementary benefits: enhanced thermal stability from higher smoke (185.49 – 191.85) and flash points (319.05 - 337.94), improved fluidity due to improved viscosity and melting point, and robust antioxidant activity than African oil bean seed oil blended with unroasted sesame seed oil. These findings suggest the potential of the blended oil as a versatile ingredient in culinary and nutraceutical applications. This study contributes to understanding how oil blending can optimize both the functional and health-promoting qualities of vegetable oils, particularly those derived from underutilized food material.

Keywords: *African oil bean seed, Roated Sesame, Oil extraction, Oil quality, Blending*

Introduction

The African oil bean (*Pentaclethra macrophylla* Benth) is a crop found mostly in the Southern and Middle Belt Regions of Nigeria and in other coastal parts of West and Central Africa. It belongs to the *Leguminosae* family and the sub-family of *Mimosoideae* (Akinlabu *et al.,* 2019). To be eaten as food supplement, their edible seeds require careful but tedious processing and fermentation before it is considered ready for consumption. Some parts of the plant like pods, roots and bark have medicinal values. It was investigated and discovered by Aremu and Ogunlade (2017) that this oil seed contains 23 – 28% protein and twenty (20) essential amino acids and essential fatty acids that make up over 10% of the fatty acids in the oil according to (Nwanagba *et al.*, 2020). The oil content and carbohydrate contained in raw African oil bean seeds are

53.98% and 19.16% dry wt, respectively (Ordu and Yingobo, 2021). The seed when cooked, processed and fermented is called “ugba” (in Igbo language of Nigeria) and used for the preparation of many delicious African delicacies including African salad, soups and sausages for eating with different staples (Oyedeji *et al.*, 2019). It is rich in vitamins and minerals and in high demand for both local consumption and for export. It is a low-acid food which could be prepared into flour and explored in food fortification and confectionaries (Kar and Okechukwu, 2018).

Sesame (*Sesamum indicum* L.) plays a very important role in human nutrition. The diminutive sesame seed is used wholly in cooking because of its rich nutty flavour and oil (Mehmood *et al.*, 2018). Sesame is grown primarily for its oil rich seed, which come in a variety of colours from cream-white to charcoal black but the most common varieties are white and black. Other colours of sesame seed varieties include, yellow, black, red or brown (Agidew *et al*., 2021). The seeds of sesame are usually used for oil extraction and the rest are fit for human consumption (Ji *et al.,* 2019). The oil derived from sesame seeds oil has a mild odour and pleasing taste and, as such, is a natural salad oil. It can be used as a cooking oil, in shortening and margarine, as a soap fat, in pharmaceuticals and as a synergist for insecticides. Sesame oil according to Aly *et al.* (2021) is very popular as cooking oil in many countries. It has a pleasant flavour, more expensive and superior than other vegetable oils. It ranks second after olive oil with regard to nutritional value. Berk *et al.* (2019), reported that sesame seeds contain significant amount of protein (18-25%), carbohydrate (13.5%) and ash (5%). It was also reported by Aly *et al.* (2021) that around 35% of oil presents in sesame consists of monounsaturated fatty acids and 44% polyunsaturated fatty acids, whereas 20% of the meal consists of proteins.

Nigeria has numerous oilseeds ready for exploitation to meet the growing demand for edible oils. With daily increase in human population, cost of these conventional vegetable oils has increased which necessitate the need to pay close attention to local oil seeds for possible use. African oil bean seed oil is one of such local oil seed than can be exploited for oil production. However, due to its high unsaturation, its stability is readily affected by various factors like moisture, heat, light and oxygen. These lead to deteriorative changes in their physical, chemical, sensory and nutritional properties during storage and results in reduced quality, increased economic loss, reduced shelf life and processing stability. More so, commercial utilization of its seed oil and even that of sesame seed as a viable ingredient for industrial purposes has not been adequately harnessed in the edible oil industry. Consequently, the present study was designed to develop an oil blend from African oil bean seed oil and sesame seed oil with improve processing and storage stability while creating an additional segment and varieties of available oils in the market. The comparative changes taking place in the physicochemical and antioxidant properties of blends of African oil bean seed oil with either roasted sesame or unroasted sesame seed oil would be uncovered. Such information will be beneficial to vegetable oils processing industries and prospective researchers.

Materials and Methods

Materials

African oil bean seeds and sesame seeds were purchased from Garki market in Enugu North Local Government Area, Enugu. African oil bean seed and sesame seeds were processed into flour at the Food Science and Technology Laboratory, Michael Okpara University of Agriculture, Umudike (MOUAU). Extraction of oil samples was done using Soxhlet apparatus and was carried out at the National Root Crop Research Institute Umudike, Abia State Nigeria. All reagent that used for this study is of analytical grade.

Chemicals

A 0.2 M sodium phosphate buffer, a 1% (w/v) potassium ferricyanide solution, a 10% (w/v) trichloroacetic acid (TCA) solution, a 0.1% (w/v) ferric chloride solution, a 100 µM DPPH solution, a 7 mM or (mmol/l) aqueous solution of ABTS with 2.45 mM potassium persulfate ($K_2S_2O_8$), ethanol

Material Preparation

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 with the aid of stainless steel knife, washed with tap water and the cotyledon cut into small pieces of approximately 1.5 cm before drying in an electronic hot air oven (Model no.SX3-4.5-15: China) at 60°C for 24 h. Thereafter, the dried African oil bean seeds were ground with an electric blender (Model no.2268-94A; Binatone: China) to obtain African oil bean seed flour. The flour was packaged in an airtight plastic container for further use.

Processing of roasted/unroasted sesame seed into flour

Two kilograms (2 kg) of sesame seed was divided into two parts of 1 kg each for processing into unroasted and roasted sesame seed flour. For unroasted sesame seed flour production, sesame seeds were processed into flour using the method described by Ugwuona and Obeta (2016). The seeds were cleaned and sorted, washed (in tap water) and dried (at a temperature of 55˚C) in a Gallenkamp hot air oven (Model OV 160, England) for 24 hours. Afterwards, the dried sesame seeds were milled with attrition mill (Model 178F Chomgqing GECO, China) to obtain sesame seed flour and was packaged in an airtight polyethylene bag prior to Soxhlet extraction.

For roasted sesame seed flour production, sesame seeds were roasted and processed into flour using the method described by Udomkun *et al.* (2019). One (1) kg of sesame seeds was cleaned and sorted, roasted in a ceramic pan in a conventional hot-air oven (Techno-gas, M-GC Mystro cooker with fan and 5 burners, silver, Egypt) at 180°C for 20 min and cooled to room temperature. Afterwards, the cooled sesame seeds were milled with attrition mill to obtained roasted sesame seed flour and packaged in an airtight polyethylene bag prior to Soxhlet extraction.

Extraction of African oil bean and sesame seeds 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 and sesame 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 from the oil seeds 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

Sesame seed oils and oil from African oil bean seeds was blended in different proportions as shown in Table 1. The sample codes are also presented in Table 1. Commercial oil sample (soybean oil) was used as the control.

Table 1: Formulation of oil blends (%).

Sample codes	African oil bean seed oil	Unroasted sesame seed oil	Roasted sesame seed oil
AO100	100	0	0
URSO100	0	100	0
RSO100	0	0	100
AO90:RSO10	90	0	10
AO85:RSO15	85	0	15
AO90:URSO10	90	10	0
AO85:URSO15	85	15	0

Keys: RSO – Roasted sesame seed oil, AO - African oil bean seed oil, URSO- Unroasted sesame seed oil

Determination of antioxidant activities of oil blends

The antioxidant activity by Ferric Reducing Antioxidant Power (FRAP) assay was determined using the method of Ojah *et al.* (2020). The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay follows a well-established procedure described by Famurewa (2023). The method described by Ehiobu *et al.* (2021) as used to perform the ABTS assay.

Determination of Physicochemical proper-ties

Specific gravity was determined by the method described by Sankar *et al*. (2019). Specific gravity of the oil samples was determined as the ratio of the density of oil in to the density of water. Specific gravity was calculated using the equation; Specific gravity = (Density of oil)/(Density of water).

The method described by Ajai *et al*. (2016) was used to determine the refractive index of the oil samples. The Abbes' refractometer was reset with a light compensator (water at 20°C), then (10 ml) of the oil samples was smear on the lower prism of the instrument and closed. A light was passed by means of the angled mirror (the reflected light appears in form of a dark background). After which, the telescope tubes were moved using the fine adjustment until the black shadow appeared central in the cross-wire indicator and then the refractive index was read.

Viscosity was determined by using the method described by Egbe *et al.* (2023). Five milliliters of the oil sample was placed into a glass U-tube. The oil sample was drawn through the tube using suction until it reached the starting position indicated on the tube side. Viscosity was calculated in duplicate as the time it takes the oil to flow from the starting point to the stopping point using a calibration constant supplied for each tube. The smoke and flash points of the oil samples were carried out according to AOCS (2012) method. A test portion of each oil was filled into a cup, and heated until a continuous bluish smoke appeared. The temperature at which the smoke begins to appear is the smoke point. Each measurement was made by duplicate. The oil sample is filled up to the mark in the cup. It is heated with constant stirring at the rate of about 50ºC per min. At every 10ºC rise in temp, test flame is introduced for a moment with the help of a shutter door. When test flame produces a distance flash in the oil cup, the temperature noted and recorded as flash point.

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

Estimated oil yield from African oil bean seeds and sesame seeds

The result of the oil yield of the different samples is presented in Table 2. Oil yield refers to the quantity of oil that can be extracted from seeds, a parameter critical in assessing the economic viability of oil-producing crops. The result showed variation among the oil seeds. Roasted sesame seeds exhibited the highest oil yield (53.70%), followed by African oil bean seeds (47.95 %) while raw sesame seeds had the lowest yield (46.88%). The results showed that roasted sesame seed gave the highest oil yield than raw sesame seed oil. This result was in line with that of Ankapong (2010) who stated that sesame seeds often produce more oil following light roasting due to enhanced cell wall disruption, facilitating oil release. Roasting is a heat treatment process that can lead to structural changes in the oil-bearing matrix. This might result in increased oil accessibility and extraction efficiency. Additionally, roasting can potentially reduce moisture content, concentrating the oil content. The roasted sesame seed oil content (53.70%) of the present study exceeded 50.66% reported by Onwuzuruike *et al.* (2024) and the 36.00% reported by Ogbonna and Ukaan (2013) but lower than the 54.30% and 56.00% reported by Unal and Yalcin (2008) and Hassan (2012) respectively. More so, the oil content from this study for African oil bean seed oil (47.95%) was in agreement with 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. Factors influencing oil yield include the type of oil source, extraction method, and processing conditions (Onwuka, 2018). Oil yield can be influenced by pre-treatment processes like roasting, fermentation, steaming etc, which can increase yield by breaking down oil-bearing cell structures. The oil yield of all the samples exceeded 25% and may therefore be a source of edible oils for commercial exploitation (Ziyadi, 2025).

Table 2: Oil yield of African oil bean seeds, roasted and unroasted sesame seeds

Sample	Oil yield (%)
Unroasted sesame seed	$46.88^{b} \pm 0.64$
Roasted sesame	$53.70^{a} \pm 0.70$
African oil bean	$47.95^{c} \pm 0.07$
p-value	0.002

a-b values are the means ± standard deviation of two replicate determinations. a-b means having different superscripts within the same column are significantly different ($p<0.05$).

Antioxidant activities of African oil bean seed and sesame seed oils

The results for antioxidant activities of the oil samples are presented in Table 3.

Ferric reducing antioxidant power (FRAP)

The ferric reducing antioxidant power measures the reducing power of antioxidants in the samples. This method specifically measures the reducing capacity rather than the radical scavenging capacity, as it does not involve free radicals directly but evaluates the ability of antioxidants to donate electrons. By assessing the ability of antioxidants to reduce ferric ions, FRAP provides insight into the sample's capability to counter oxidative stress (Igwe *et al.*, 2018). Table 3 shows the FRAP values of the different oil blends. The value ranges from 3.51 mg/ml to 11.05 mg/ml. The control sample had a FRAP value of 5.21 mg/ml. All the samples recorded a FRAP value lower than the control except for URSO100 (100% unroasted sesame seed oil) and RSO100 (100% roasted sesame seed oil) whose values were 8.23 mg/ml and 11.03 mg/ml, respectively, and significant ($p<0.05$). The RS0100 (100% roasted sesame seed oil) sample had highest FRAP value of 11.03 mg/ml, indicating strong antioxidant activity. This result was higher than Kim *et al.* (2013), who reported a higher FRAP value of 9.50 mg/ml for roasted sesame seeds than other samples on her research on antioxidant activities of sesame (*Sesamum indicum* L.) seed and industrial sesame meal extract thereby highlighting the enhancement of antioxidant properties through roasting. The AO100 (100% African oil bean seed oil) sample, had the lowest FRAP value of 3.51 mg/ml, and lower than the value (5.80 mg/ml) reported by Visavadiya and Narasimhacharya (2018) on comparative analysis of phytochemical and proximate composition of seeds and leaves of African oil bean (*Pentaclethra macrophylla* Benth). This suggests that AO100 (100% African oil bean seed oil) may have a lower concentration of phenolic compounds, which is an indication of a lower antioxidant capacity, making the oil more susceptible to oxidation, off-flavours, and spoilage, especially when exposed to air, heat, and light (Frankel, 1996). Notably, FRAP value of roasted sesame seed oil was higher than the value of unroasted sesame seed oil. The higher FRAP values of the roasted sesame seed oil is due to the chemical transformations induced by heat. Consequently, blending of African oil bean seed oil with roasted sesame seed oil had higher FRAP value than when blended with oil from unroasted sesame seeds. The significant ($p<0.05$) differences in FRAP values among the samples reflect the influence of the composition and processing, particularly roasting, on the antioxidant potential of the oil. More so, it was observed that the FRAP values increased from 3.93 to 4.48 mg/ml and 3.63 to 4.02 mg/ml as the proportion of roasted sesame seed oil and unroasted sesame seed oil increased from 10 to 15%, respectively in the oil blends. This suggests positive effect of sesame seed oil on the antioxidant activity of African oil bean seed oil.

Table 3: Antioxidant properties of oil blends of African oil bean seeds and sesame seed oil blends

Sample	FRAP (mg/mL)	DPPH (%)	ABTS (%)
Control	$5.21^{c} \pm 0.03$	$77.38^{c} \pm 0.06$	$51.32^{e} \pm 0.06$
AO100	$3.51^{f} \pm 0.16$	$54.74^{h} \pm 0.32$	$46.27^{h} \pm 0.06$
URSO100	$8.23^{b} \pm 0.28$	$82.19^{b} \pm 0.06$	$88.32^{b} \pm 0.16$
RSO100	$11.03^{a} \pm 0.01$	$96.28^{a} \pm 0.39$	$91.47^{a} \pm 0.04$
AO90:RSO10	$3.93^{e} \pm 0.01$	$58.88^{f} \pm 0.09$	$50.75^{f} \pm 0.01$
AO85:RSO15	$4.48^{d} \pm 0.01$	$63.60^{d} \pm 0.02$	$55.36^{c} \pm 0.04$
AO90:URSO10	$3.63^{f} \pm 0.00$	$57.23^{g} \pm 0.01$	$50.43^{g} \pm 0.02$
AO85:URSO15	$4.02^{e} \pm 0.01$	$61.38^{e} \pm 0.08$	$54.85^{d} \pm 0.01$

a-h: Values are means ± standard deviation of two replicate determinations. $^{a-h}$ means having different superscripts within the same column are significantly different ($p<0.05$). AO100=100% African Oil bean oil, URSO100=100% Unroasted sesame seed oil, RSO100=100% roasted sesame seed oil, AO90:RSO10=90% African Oil bean oil and 10% roasted sesame seed oil, AO85:RSO15=85% African Oil bean oil and 15% roasted sesame seed oil, AO90:URSO10=90% African Oil bean oil and 10% unroasted sesame seed oil, AO85:URSO15=85% African Oil bean oil and 15% unroasted sesame seed oil. Control: commercial soybean oil.

2,2-Diphenyl-1-picrylhydrazyl (DPPH)

DPPH radical scavenging activity assesses the capability of antioxidants to neutralize free radicals. The DPPH assay measures the ability of antioxidants in a sample to reduce DPPH, resulting in a change in colour that can be quantified spectrophotometrically (Wang *et al.*, 2021). High DPPH scavenging activity indicates that the oil contains significant amounts of antioxidant properties, which can protect it from oxidative stress and prolong its shelf life. This is crucial for maintaining the flavour, nutritional quality, and safety of the oil for consumption (Huang *et al.*, 2020). The DPPH values ranges from 54.74% to 96.28%, with sample AO100 (100% African oil bean seed oil) recording the lowest value and sample RSO100 (100% roasted sesame seed oil) recording the highest value. The RS0100 sample exhibited the highest activity at 96.28%, which is higher than the 85.2%

reported by Nakai *et al*. (2003) for roasted sesame seeds on their research titled novel antioxidative metabolites in the reaction of sesamol with peroxyl radicals. This higher activity could be due to differences in roasting conditions or sesame seed varieties. The AO100 (100% African oil bean seed oil) sample recorded a significantly lower DPPH activity of 54.74%, compared to 60.50% reported by Visavadiya and Narasimhacharya (2018) for African oil bean seeds. Roasting improves the antioxidant properties of the oil through the chemical mechanism of the heat-induced transformations which dramatically enhances the potency of the compounds responsible for antioxidant activity (Jannat *et al.,* 2010). The lower DPPH value in AO100 (100% African oil bean seed oil) compared to sesame seed oils suggests a weaker free radical scavenging capacity, potentially due to lower antioxidant properties or different environmental factors affecting the seeds' phenolic profiles. Conversely, low DPPH readings suggest that the oil has a lower antioxidant capacity, making it more susceptible to oxidation and resulting in a shorter shelf life and potential deterioration of quality. Oils with low antioxidant activity may develop off-flavors, rancidity, and reduced nutritional benefits over time (Cai *et al*., 2018). Thus, the DPPH assay serves as a valuable tool in determining the antioxidant potential of oils, impacting both their commercial value and health benefits. Blending African oil bean seed oil with either roasted or unroasted sesame seed oil at increased proportion of 10 to 15% improved the DPPH value from 58.88 to 63.60% for roasted sesame seed oil and 57.23 to 61.38% for unroasted sesame seed oil, suggesting improved antioxidant activities. However, blends of roasted sesame seed oil with African oil bean seed oil had higher activity.

ABTS (2,2'azino-bis (3-ethylbenzothiazoline-6-sulfonic acid))

ABTS radical cation scavenging activity measures the ability of antioxidants to quench ABTS radicals. ABTS stands for 2,2' azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) a compound commonly used in antioxidant assays to evaluate the free radical scavenging activity of various substances, including oils. The ABTS assay measures the ability of antioxidants to quench the ABTS radical cation, which results in a colour change detectable through spectrophotometry (Wu *et al.*, 2019). The ABTS values ranges from 46.27% AO100 (100% African oil bean seed oil) to 91.47% RSO100 (100% roasted sesame seed oil) with significant ($p>0.05$) difference among the samples. The control sample had an ABTS activity of 51.32% which is higher than the values obtained for AO100 (100% African oil bean seed oil) (46.27%), AO90:URSO10 (90% African oil bean seed oil blended with 10% unroasted sesame seed oil) (50.43%) and AO90:RSO10 (90% African oil bean seed oil blended with 10% roasted sesame seed oil) (50.75%). The RS0100 (100% roasted sesame seed oil) sample showed the highest ABTS activity at 91.47%, which is higher than the 83.1% reported by Kim *et al*. (2021) for roasted sesame seeds, this could be due to the variety of seeds used, roasting conditions, etc. The enhanced ABTS activity in RS0100 (100% roasted sesame seed oil) indicates a high concentration of antioxidant compounds, possibly influenced by roasting. Roasting in sesame improves the development of lignans, specifically, when sesame seeds are roasted at high temperature, the lignin sesamolin breaks down and produces the lignan sesamol, a stronger antioxidant (Onwuzuruike *et al.*, 2024). Previous studies have shown that microwave and conventional oven roasting treatments increased the levels of bioactive compounds such as tocopherols, phytosterols, resveratrol, flavonoids, and lignans in sesame oil (Mohamed *et al*., 2020). The AO100 sample exhibited the lowest ABTS activity at 46.27%, compared to the 52.30% reported by Visavadiya and Narasimhacharya (2018) for African oil bean seeds. The variations in ABTS values among the samples suggest differences in the antioxidant composition and efficacy, with the blends containing sesame seeds generally showing higher activities.

The significance of ABTS in oils lies in its ability to assess oxidative stability, which is crucial for shelf life and quality preservation. High ABTS scavenging activity in a sample translates to it containing strong antioxidant compounds, which can effectively slow down the oxidative processes that lead to rancidity, off-flavours, and nutritional degradation. Consequently, such oils are considered higher in quality and are more desirable for both consumption and culinary applications (Sakakibara *et al*., 2023). In contrast, oils with low ABTS values have a lower antioxidant capacity, making them more susceptible to oxidation and faster degradation. This reduces their shelf life, flavour stability, and overall quality, especially under conditions that promote oxidative stress, such as high temperatures or prolonged storage (Kanner and Lapidot, 2021).

Physicochemical properties of African oil bean seed oil blended with sesame seed oils

The results for physicochemical properties of the oil samples are presented in Table 4.

Table 4: Physicochemical properties of African oil bean and sesame seed oil blends

Sample	Viscosity (cP)	Refractive index @ 27°C	Specific gravity @ 27°C	Fire point	Melting point	Smoke point	Flash point
Control	17.93^{e} ±0.09	1.47^{a}±0.00	0.90^{a}±0.00	311.26^{e}±0.4	3.34^{e}±0.01	232.50^{a}±0.71	309.08^{h} ±0.05
AO100	39.37^{c} ±0.71	1.47^{a}±0.00	0.92^{a}±0.00	376.10^{a}±0.14	29.80^{d}±0.01	191.85^{b}±0.14	337.94^{a} ±0.10
URSO100	38.66^{d} ±0.01	1.48^{a}±0.00	0.92^{a}±0.00	363.21^{c}±0.28	30.14^{cd}±0.49	186.65^{de}±0.57	324.26^{f} ±0.05
RSO100	40.88^{b} ±0.00	1.48^{a}±0.00	0.92^{a}±0.00	355.40^{d}±0.14	30.88^{ab}±0.18	185.49^{e}±0.63	319.05^{g} ±0.07
AO90:RSO10	39.96^{c} ±0.02	1.48^{a}±0.00	0.92^{a}±0.00	375.92^{a}±0.01	30.94^{ab}±0.02	188.28^{cd}±0.35	336.30^{c} ±0.14
AO85:RSO15	42.03^{a} ±0.03	1.48^{a}±0.00	0.92^{a}±0.00	374.30^{b}±0.85	31.09^{a}±0.06	187.15^{de}±0.05	335.40^{e} ±0.14
AO90:URSO10	39.75^{c} ±0.01	1.47^{a}±0.00	0.48^{a}±0.63	374.60^{b}±0.00	30.01^{d}±0.02	189.71^{c}±0.00	336.61^{b} ±0.01
AO85:URSO15	41.70^{a} ±0.04	1.48^{a}±0.00	0.48^{a}± 0.64	373.96^{b}±0.00	30.55^{bc}±0.27	188.22^{cd}±0.11	335.92^{d} ±0.01

a-g: Values are means± standard deviation of two replicate determinations. a-h means having different superscripts within the same column are significantly different (p<0.05). AO100=100% African Oil bean oil, URSO100=100% Unroasted sesame seed oil, RSO100=100% roasted sesame seed oil, AO90:RSO10=90% African Oil bean oil and 10% roasted sesame seed oil, AO85:RSO15=85% African Oil bean oil and 15% roasted sesame seed oil, AO90:URSO10=90% African Oil bean oil and 10% unroasted sesame seed oil, AO85:URSO15=85% African Oil bean oil and 15% unroasted sesame seed oil. Control: commercial soybean oil.

Viscosity

Viscosity is defined as the measure of a fluid's resistance to flow. For oils, it refers to the internal friction that occurs when the oil molecules move against each other, which affects the ease with which the oil flows. The viscosity of oil is determined by various factors, including temperature, chemical composition, and molecular structure. Generally, viscosity decreases as temperature increases and increases as temperature decreases (Lachman *et al.,* 2019). From Table 4, the viscosity ranges from 17.93 cP centipoise (control) to 42.03 cP (AO85:RSO15). The viscosity of the control sample was the lowest which might be due to the elimination of micro component, impurities and pigments through refining, while experimental samples had higher viscosity, with AO90:RSO15 (90% African Oil bean oil and 10% roasted sesame seed oil) had the highest viscosity which may be due to the crude and unrefined nature of the experimental oils. The value obtained in this study for AO100 sample (100% African oil bean seed oil) (39.37 cP), was higher than the findings of Visavadiya and Narasimhacharya (2018) who reported a viscosity of 38.50 cP for African oil bean seed oil. This variation may be due to differences in cultivar, processing conditions etc. notably, roasted sesame seed oil had higher viscosity of 40.88 cP than the viscosity of unroasted sesame seed oil which is 38.66 cP. The higher viscosity of roasted sesame seed oil could be attributed to the development of Maillard reaction products, evaporation of moisture and increased concentration of impurities and micro components arising from roasting at high temperature (Onwuzuruike *et al.,* 2024). Consequently, roasting negatively influence the viscosity of the oil blends by increasing the viscosity of the blended oils. More so, blended oils had higher viscosity than unmixed oils.

Refractive index

Refractive Index at 27°C measures the degree to which light is bent when it passes through the oil. The refractive index of oils typically falls within a specific range, depending on their chemical composition, purity, and degree of unsaturation. For edible oils, the refractive index typically falls between 1.45 and 1.48 (Xu *et al.,* 2019). There was no significant ($p<0.05$) difference in the refractive index of the oil samples. All samples had a refractive index of around 1.47 to 1.48, similar to the control (1.47). This is consistent with the refractive indices reported by Xu *et al.* (2019) and Nakai *et al*. (2003) for sesame oil, which ranged from 1.47 to 1.48. The refractive index is significant for assessing the quality, authenticity, and composition of oils. It is commonly used as a quick method to confirm the purity of edible oils and detect adulteration, as each oil type has a characteristic RI value. Deviations from standard RI values can indicate the presence of impurities, blending with cheaper oils, or degradation due to oxidation (Younis *et al.,* 2014).

Specific gravity

Specific gravity at 27°C measures the density of the oil relative to water. Specific gravity is important for quality control, purity testing, and identification of oils. It serves as a quick reference for comparing different oils and for detecting adulteration, as each oil type has a characteristic specific gravity range. Variations from expected specific gravity values can indicate contamination, blending with other oils, or degradation (Ravindran *et al,* 2019). High specific gravity may mean they contain a greater proportion of unsaturated fatty acids or certain impurities. This can impact the nutritional properties and stability of the oil. Low specific gravity translates to the oil containing a lesser proportion of unsaturated fatty acids. The specific gravity of the present study ranged from 0.90 to 0.98. The commercial oil sample had the lowest value while AO90:URSO10 (90% African Oil bean oil and 10% unroasted sesame seed oil) and AO85:URSO15 (85% African Oil bean oil and 15% unroasted sesame seed oil) had the highest value. Indicating a denser oil composition with no significant difference ($p>0.05$) among the samples. The value of 100% African oil bean seed oil of the present study was higher than the specific gravity of 0.91 reported by Visavadiya and Narasimhacharya (2018) for African oil bean seed oil.

Fire point

Fire Point is the temperature at which oil vapors ignite and continue to burn for at least five seconds when exposed to a flame. The fire point indicates the thermal stability of the oil and its resistance to ignition at elevated temperatures (Pike, 2023). There was significant ($p<0.05$) difference in the fire point of the oil samples. The fire point ranged from 311.26 ^{o}C to 376.10^{o}C. The commercial oil sample had the lowest value while 100% African oil bean seed oil (AO100) had the highest value which could be attributed to their level of unsaturation. More so, among the blends, the AO100 (African oil bean seed oil) had the highest fire point of 376.10°C while RS0100 (100% roasted sesame seed oil) sample had the lowest fire point (355.40°C). Roasting significantly ($p<0.05$) decreased the fire point of sesame seed oils, such that, unroasted sesame seed oil had a fire point of 363.21^{o}C, which decreased to 355.40^{o}C after roasting. The decrease fire point in roasted sesame seed oil might be due to lower unsaturation level in oils obtained from roasted sesame seed (Berk *et al.,* 2019). High temperature have been reported to deplete the double bonds in edible oils, thereby increasing the level of unsaturation. Oils with lower unsaturation level ignites faster. The higher the unsaturation level, the higher the temperature of ignition and vice versa (Sruthi *et al.,* 2021). Consequently, unroasted sesame seed oil (URSO100) had a higher fire point of 363.21

^{o}C than roasted sesame seed oil (RSO100) with a fire point of 355.40^{o}C. While blending African oil bean seed oil with sesame seed oils decreased the fire point of the oil blends, blends containing roasted sesame seed oil had lower fire points. The fire point is critical for safety in both food and industrial applications. Oils with high fire points like 100% African oil bean seed oil, are preferred for high-temperature cooking, such as frying, as they are less likely to ignite or degrade at elevated temperatures. In industrial settings, oils with low fire points are safer for use in machinery that operates at high temperatures, as they reduce the risk of fires (Singh *et al.,* 2020).

Melting point

The melting point of oil is the temperature at which it transitions from a solid or semi-solid state to a liquid state. Unlike pure substances, edible oils are complex mixtures of various fatty acids, so they do not have a single, sharp melting point but rather a melting range. This range is determined by the fatty acid composition of the oil: oils rich in saturated fats generally have higher melting points, while those rich in unsaturated fats have lower melting points (Gunstone, 2011). The melting point of the oil samples ranged from 3.34 to 31.09 ^{o}C and the melting point of the oil samples differ from each other significantly (p<0.05). Commercial oil sample had the lowest melting point which may be due to the refined nature of the oil, and absence of impurities and minimal minor components, while AO85:RSO15 (85% African Oil bean oil and 15% roasted sesame seed oil) had the highest melting point. African oil bean seed oil had lower melting point (29.80 ^{o}C) than sesame seed oils, both roasted (30.88 ^{o}C) and unroasted (30.14 ^{o}C). This is due to the higher unsaturation nature of African oil bean seed oil than sesame seed oil (Onwuzuruike *et al.,* 2024). Consequently, blending African oil bean seed oil with sesame seed oils increased the melting points of the oil blends. More so, roasting increased the melting point of oil obtained from roasted sesame seeds compare to the melting point of oil from unroasted sesame seed. This may be due to the depletion of unsaturation and increase in saturation caused by heat treatment from roasting. The values of this study for African oil bean seed oil was higher than the value of 22 ^{o}C reported by (Ahmed *et al*., 2020) for African oil bean seed oil. Melting point is important in the food industry, as it affects the consistency, texture, and usability of products at different temperatures. For instance, oils with lower melting points are preferred for dressings or spreads that need to remain liquid or semi-liquid at room temperature, while oils with higher melting points are used in applications where a more solid or stable fat structure is desired, such as in baking or confectionery (Park *et al.,* 2020). The experimental oil samples of this study are in crude and unrefined form which contributed to their higher melting point making them suitable for the development of baking fat.

Smoke point

Smoke point is the temperature at which an oil begins to produce visible smoke when heated. This indicates the temperature at which the oil's triglycerides start breaking down and releasing free fatty acids, which then begin to smoke and emit an acrid odor. The smoke point varies widely among different oils and depends on the oil’s degree of refinement and composition (Choe and Min, 2007). The smoke point also marks the beginning of both flavour and nutritional degradation (Pathak *et al.*, 2018). There was significant (p<0.05) difference in the smoke point of the oil samples. RSO100 (roasted sesame seed oil) had the lowest smoke point of 185.49°C, whereas the commercial oil sample had the highest smoke point of 232.50°C. The higher smoke point of the commercial oil over the experimental oil samples could be attributed to refining and absence of impurities and micro components. This means that, the commercial oil will smoke at a higher temperature that the experimental oil samples, a reflection of thermal stability and better quality. More so, African oil bean seed oil (AO100) had higher smoke point than sesame seed oils which may be due to the higher unsaturation of African oil bean seed oil than sesame seed oils (Onwuzuruike *et al.,* 2024). Roasting further decreased the smoke point of oil samples due to increase saturation and depletion of unsaturated double bonds, hence, oils from roasted sesame seeds had lower smoke point than oils from unroasted sesame seeds. Blending decreased the smoke point of the oil blends and oil blends containing roasted sesame seed oils had higher smoke points. This values of the oil blends in the present study are lower than the smoke point of 227°C reported by Gbadamosi *et al*., 2017). When oils reach their smoke point, they not only produce smoke but can also generate harmful compounds and degrade the flavor of food. Oils with high smoke points are more thermally stable, making them ideal for frying, roasting, and other high-temperature applications. Oils with lower smoke points are more likely to oxidize or break down under high heat, releasing potentially harmful compounds and affecting food quality.

Flash point

The Flash Point is the temperature at which oil vapors can ignite momentarily (flash) in the presence of a flame but without sustaining combustion. The flash point is usually higher than the smoke point and indicates the oil's flammability under heat. The flash point is particularly relevant for handling oils in industrial settings, as it marks the temperature at which oil vapors become combustible, posing a fire hazard (Pike, 2023). The flash point of the present study ranged from 309.08 to 337.94°C. There was significant ($p<0.05$) difference among the values obtained in this study. The flash points of the studied oil samples showed that RSO100 (100% roasted sesame seed oil) had the lowest flash point of 319.05°C while the AO100 (100% African oil bean seed oil) had the highest flash point of 337.94°C. This could be attributed to the heat treatment during roasting. Heat influences the fatty acid profile of oils by increasing the concentration of saturation. Oils with higher unsaturation level results to higher flash point. Consequently, African oil bean seed oil (AB100) with a reported higher level of unsaturation than sesame seed oil (Onwuzuruike *et al.,* 2024) can be observed to have higher flash point than sesame seed oils. More so, oil from roasted sesame seed had lower flash point than oil from unroasted sesame seed oil, which is also due to the roasting effect. The values of this study were higher than 248°C reported by Gbadamosi *et al*. (2017). The flash point is an indicator of the oil's resistance to ignition, so oils with higher flash points are generally safer in high-temperature applications. Therefore, oils with high flash points like African oil bean oil and the blended oils are safer at elevated temperatures and less likely to ignite than 100% sesame seed oils, making them suitable for high temperature food processing like frying.

Conclusion and Recommendation

In conclusion, roasted sesame seeds exhibited the highest oil yield (53.70%) and superior antioxidant activities (FRAP: 11.03 mg/mL, DPPH: 96.28%, ABTS: 91.47%) when compared to raw sesame seeds and African oil bean seeds. Blending African oil bean seed oils with oils from roasted sesame seed oil improves significantly the antioxidant potentials and processing stability of African oil bean seed oil. Therefore, oil blends of 85% African oil bean seed oil and 15% roasted sesame seed oil (AO85:RSO15) have the best antioxidant potential and processing qualities. To further advance the findings of this study, further research should be conducted to explore the impact of various roasting temperatures and durations on the oil yield and antioxidant properties of sesame seeds. Such studies will help to optimize the roasting process for maximum yield and quality.

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