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Chemical Composition, Quality Indices and Viscosity of Edible Oils from Blends of African Oil Bean Seed Oil and Sesame Seed Oil

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Abstract

This study adopted the concept of blending in developing and evaluating the properties of binary oil blends from African oil bean seed oil and sesame seed oil. Vegetal oils were extracted from African oil bean seeds (AB) and sesame seeds (SS) through Soxhlet extraction and blended in the following proportions: AB100:SS0, AB0:SS100, AB90:SS10, AB80:SS20, AB70:SS30, AB60:SS40 and AB50:SS50 respectively. The chemical, quality and viscosity properties was investigated. Findings from this study showed that the chemical composition decreased from 124.55 to 101.28 g of I_2/100 g, 208.67 to 191.29 mg KOH/g, 1.94 to 1.62% for iodine, saponification and unsaponifiable matter values while quality properties improved with reduction in PV, FFA, pAV, AV and totox value from 3.12 to 2.79 meq O_2/kg, 4.04 to 2.99%, 0.57 to 0.31, 8.08 to 5.99 mg KOH/g and 6.81 to 5.88 respectively as the proportion of sesame seed oil increased in the blended oils from 10 to 50%. Viscosity results at 5^0C and 37^0C increased in the studied samples from 560.00 mPa.s in AB100:SS0 to 635.00 mPa.s in AB50:SS50 and from 91.00 mPa.s in AB100:SS0 to 103.00 mPa.s in AB50:SS50 respectively. Conclusively, binary oil blends had better oil properties and could be optimized for food applications.

Keywords: *African oil bean, Sesame, Edible oils, Chemical Properties*

1. Introduction

Vegetable oils are one of the major constituent of our daily diet, responsible for nourishing our body and providing several physiological functions (Shahid et al., 2024). Popular oil seeds from which edible oil has been obtained from over the years include but not limited to soybean, sunflower, rapeseed, cottonseed, sesame and peanut (Jing et al., 2024). Nigeria as a tropical country is blessed with a wide variety of both wild and domesticated plants that produce oil bearing seeds. These seeds could be useful in producing edible oils to augment the conventional oils but have largely remained either underexploited or unexploited. Considering the fact that the conventional sources of vegetable oils can no longer meet the demands for domestic and industrial applications, there is increasing need to search for oils from non-conventional sources to meet consumption and specific applications. Consequently, research activities have focused on examining and characterizing new sources of edible oils (Romanić et al., 2021). African oil bean seed and sesame seed are among the unpopular oil seeds that are available in Nigeria and underutilized for oil production.

African oil bean (*Pentaclethra macrophylla* Benth) belongs to the *Leguminosae* family and the sub-family of Mimosoideae, found mostly in the Southern and middle belt regions of Nigeria. It bears several local names such as ‘Ugba/Ukpaka’ by the Igbos, ‘Ebaye’, by the Cameroonians, ‘apara’ by the Yorubas and ‘ukana’ by the Efik (Obi, 2021). The seeds are edible when appropriately processed and contain some reasonable amount of oil, hence its inclusion as “oil bean” (Ifeoluwa et al., 2014).). Esther et al. (2008) reported an oil content of 47.90% while Ordu & Yingobo (2021) reported an oil yield of 38.09%. According to Osabor et al. (2017), African oil bean seeds contain 25.54% crude fat, 34.42% carbohydrate, 24.04% crude protein, 314.12 mg/100 g calcium, 104.33 mg/100 g magnesium, 156.40 mg/100 g sodium, 127.19

mg/100 g potassium, 172.00 mg/100 g phosphorus, and micro-minerals like zinc (10.00 mg/100 g), manganese (27.40 mg/100 g) and iron (52.55 mg/100 g). The seed can be eaten boiled or roasted. They are also fermented to yield snack or condiment with a meaty taste which is very popular in South-Western and South-Eastern Nigeria or used as a condiment in soup, porridge and salad (Duru et al., 2019).

Sesame (*Sesame indicum*, L.) is one of the oldest oilseeds in the world. It is one of the first crops processed for oil production (Amandeep & Vinod, 2019). The oil has high amount of polyunsaturated fatty acids particularly linoleic and oleic acid, with significant amounts of the lignans; sesamin and sesamolin (Idowu et al., 2021). These compounds have beneficial effects on serum lipid levels and liver function and give sesame seed oil a marked antioxidant activity. The lignans are also responsible for the great stability of sesame seed oil to oxidation (Hussain et al., 2018). All these substances have been shown to possess cholesterol-lowering effect in humans and to prevent high blood pressure, increase vitamin E supplies in animals, reduces blood cholesterol, and plays a significant role in preventing atherosclerosis, heart diseases and cancers (Adeniyi et al., 2020). The chemical composition of sesame shows that the seed is an important source of oil (50–60%), protein (18–25%), carbohydrates and ash (Bansal & Kawatra, 2020). The quality of the oil contained in the seed have been shown to depend on ecological, genetics and physiological factors such as soil type, cultivars and maturity of plant respectively (Imran et al., 2020).

Vegetable oils are required for different purposes and no single oil has the chemical makeup required to fulfill all purposes. In order to enhance their utilization, the concept of blending is one of the methods through which the properties of edible oils are enhanced for industrial application, aside hydrogenation, interesterification and fractionation (Pattnaik & Mishra, 2022). Blending is a popular and cheap technique for manipulating oil properties through altering their fatty acid profile, natural antioxidants such as tocopherols, sterols as well as phytochemicals like flavonoids and phenolic contents, resulting in oil blends with superior properties (Sharma et al., 2023). Previous reports are available on blends of different seed oils (Sharma et al., 2023; Pattnaik and Mishra, 2022; Hashempour-Baltork et al., 2016) and those of sesame seed oil with other vegetable oils like soybean, canola, rice bran oil. No study has been conducted on the influence of blending on the oil properties of African oil bean seed oil and sesame seed oil blends. This study therefore aimed at assessing the effect of blending oils extracted from African oil bean seed with sesame seed oil on the chemical composition, quality indices and physicochemical properties.

2. Materials and Methods

Procurement of oil seeds

Ghana variety of African oil bean seed were purchased from Ndoro market in Ikwuano Local Government Area, Abia state. White sesame seeds variety were purchased from Gariki market in Enugu North Local Government Area, Enugu. The varieties of African oil bean seed and sesame seeds were identified at Agronomy Department of Michael Okpara University of Agriculture, Umudike.

Processing of African oil bean seed into flour

The method described by Oyinloye and Enujiugha (2019) was used in processing of African oil bean seeds into flour with slight modification relative to the drying time. One (1) kilograms of African oil bean seeds were sorted, and washed using tap water. The surface moisture was allowed to dry under air movement at ambient temperature. This was followed by manual dehulling by cracking in a mortar and separating the cotyledons from the hulls using a kitchen knife. Afterwards, the dehulled African oil bean seeds were cut into small pieces of approximately 1.5 cm and dried in the oven (Gallenkamp, Model OV 160, England) at 55˚C for 48 h prior to milling into flour with the aid of attrition mill (Model 178F GECO, China). The obtained African oil bean seed flour was stored in an air tight coloured plastic container at room temperature away from sunlight for extraction of vegetable oil.

Processing of sesame seed into flour

Dehulling process

The method described by Moharram et al. (1990) was used for this process. One (1) kg of white variety of sesame seeds were cleaned and sorted to remove undesirable seeds and contaminant. Cleaned sesame seeds were decorticated by soaking the seeds in a mixed solution of 0.04% NaOH and 3% NaCO3 for 40 min with a seed to lye ratio of 1:3 (w/v), then rubbed manually in between palm to loosened and remove the hulls.

Processing of dehulled seeds into flour

White variety of dehulled sesame seeds were processed into flour using the method described by Ugwuona and Obeta (2016). Dehulled sesame seeds were washed (using tap water) to remove the lye solution and dried (at a temperature of 55˚C) in a Gallenkamp hot air oven (Model OV 160, England) for 36 h. Afterwards, the dried sesame seeds were milled with attrition mill (Model 178F Chomgqing GECO, China) to obtained sesame seed flour, packaged in an airtight plastic container and stored at room temperature away from sunlight prior to Soxhlet extraction.

Extraction of oils from oil seeds

The method described by Musa et al. (2015) was adopted and used for extraction of African oil bean seed and sesame seed oils using Soxhlet extraction method. Three hundred and fifty milliliters (350 ml) of n-hexane was first introduced into a 500 ml round bottom flask. African oil bean seeds flour (100 g) and sesame seed flour (100 g) were separately measured into thimbles and inserted at the center of the Soxhlet extractor respectively. The set-up was heated to 69°C, the boiling temperature for n-hexane, for 5 h and was held at that temperature during the extraction process. At the end of 5 h, the extract was removed from the set-up, dried in the oven at 80°C for 10 min to allow any residual n-hexane in the mix to evaporate, cooled in desiccators and weighed to determine the amount of oil extracted. The obtained oil samples were packaged in an airtight plastic container and stored in a refrigerator at 4°C for further use. The same process was repeated until the required oil quantity was obtained.

Oil yield estimation

Oil yield was calculated by dividing the weight of the extracted oil sample by the weight of the powder used for oil extraction as shown below (Adepoju et al., 2019):
Oil yield (%)=(Weight of oil)/(Weight of powder used) x 100

Oil blend preparation

Binary oil blends were prepared by mixing African oil bean seed oil (AB) and sesame seed oil (SS) designated as AB:SS in the following proportions respectively: 100:0, 0:100, 90:10, 80:20, 70:30, 60:40 and 50:50 (v/v). As described by Pan et al. (2020), the binary blends were thoroughly mixed for 5 min using a magnetic stirrer (VELP AREX CerAlTop™, Usmate Velate, MB, Italy) to achieve uniformity. Commercial soybean oil served as the reference sample.

Determination of chemical properties

Standard methods of AOAC (2012), AOCS (1993a) and AOAC (1999) were used to determine the saponification value, Iodine value and unsaponifiable matter of oil samples. Ester value (EV) was evaluated as saponification value–acid value. All analysis were carried out in duplicate measurements.

Quality parameter determination

Peroxide value was determined according to the method described by AOCS (1993b). Free fatty acid was determined by AOCS (1993c) method. Para-anisidine value was determined according to the method described by AOCS (1996). Acid value was determined as described by Ankapong (2010). The total oxidation or TOTOX value was calculated as described by Ali et al. (2013).

Determination of viscosity properties

The viscosity measurement of each oil sample was determined using the rheometer AR2000 (TA Instruments, New Castle, USA). Standard-size-DIN or conical concentric cylinders geometry was used. About 20 ml of each liquid oil sample was introduced into the measuring cup. The viscosity of each oil sample was determined at 5°C and 37°C in duplicates. The flow procedure comprised a conditioning step of the desired temperature and a peak hold step of 5 min at a shear rate of 10 1/s. The viscosity data was automatically generated by the rheology advantage software at the desired temperature in duplicates, after which the data were analysed statistically to obtain the mean viscosity value and standard deviation (AOCS, 1995).

Experimental design

Completely randomnized design (CRD) was used for this study.

Statistical analysis

All experimental data were expressed as mean ± SD (standard deviation). The data were subjected to a one-way analysis of variance (ANOVA) using the SPSS software (version 21, IBM, USA) to determine the significant difference among the experimental data, while Duncan Multiple Range Test (DMRT) method was used to compare the means of experimental data at 95% confidence interval when a significant difference was observed.

3. Results and Discussion

Oil yield of oils extracted from African oil bean seeds and sesame seeds

The oil yield of sesame seed and African oil bean seed was presented in Table 1. The percentage oil from sesame and African oil bean seeds are 50.66% and 47.95% respectively. Sesame seed had higher oil content than African oil bean seed oil. However, the oil yield of African oil bean seed oil was appreciably high and may be a good source of edible oil. Sesame seed oil content exceeded 36.00% reported by Ogbonna & Ukaan (2013) but lower than 52.00%, 47.40%, 54.00%, 54.30% and 56.00% reported by Gharby et al. (2017), El Khier et al. (2008), Nzikou et al. (2009), Unal &Yalcin (2008) and Hassan (2012). Also, oil content obtained from this study for African oil bean seed oil was in agreement with the content reported by Esther et al. (2008) (47.90%), while Ordu & Yingobo (2021) and Osabor et al. (2017) reported lower oil yield of 38.09% and 25.54% respectively. The variation in the oil yields may be attributed to the processing method prior to extraction as well as the method of extraction. Akindele & Nsuhoridem (2018) and Onwuzuruike et al. (2020) stated that solvent extraction is considered the most effective means of oil extraction in terms of oil yield and oil extraction efficiency because milling process prior to extraction increased the surface area for solvent penetration to bring out the oil by leaching. Oil seeds with oil content above 25% are considered to be good sources of edible oils (Akindele & Nsuhoridem, 2018). The oil yields of the African oil bean seed oil and sesame seed oil exceeded 25% and may therefore be classified as good sources of edible oils for commercial exploitation.

Table 1. Percentage oil yield of sesame seed and African oil bean seed oils.

Sample	Percentage oil yield (%)
African oil bean seed oil	47.95±0.07
Sesame seed oil	50.66±0.08

Values are means ± standard deviation of duplicate determination.

Chemical composition of pure oils and binary blends

Results of chemical composition of pure oils and binary oil blends are presented in Table 2. Iodine value, saponification value, unsaponifiable matter and ester values differ significantly ($p<0.05$) from each other and ranged from 101.28-124.55 g of I_2/100 g, 176.45-208.67 mg KOH/g, 0.84-1.94% and 175.50-200.59 mg/g respectively. African oil bean seed oil (AB100) had higher iodine value, saponification value, unsaponifiable matter and ester value than sesame seed oil (SS100). AB50:SS50 had the lowest iodine value, while the control had the lowest saponification, unsaponiiable and ester values. Oil blends containing sesame seed oil had lower iodine value. As the proportion of sesame seed oils increased in the oil blends, the chemical composition (iodine, saponification, unsaponifiable and ester values) decreased concurrently.

Table 2. Chemical composition of pure oils and binary blends

Oil samples	IV (g of I_2/100 g)	SV (mg KOH/g)	USM (%)	EV (mg/g)
Control	111.95±0.07^{a}	176.45±0.78^{g}	0.84±0.01^{g}	175.50±0.81^{f}
AB100	124.55±0.04^{b}	208.67±0.20^{a}	1.94±0.02^{a}	200.59±0.25^{a}
SS100	105.09±0.04^{c}	192.22±1.11^{f}	1.47±0.06^{f}	186.47±0.95^{de}
AB90:SS10	122.60±0.04^{d}	201.64±0.29^{b}	1.87±0.01^{b}	193.86±0.05^{b}
AB80:SS20	120.70±0.16^{e}	198.48±0.64^{c}	1.80±0.01^{c}	190.84 ±0.65^{g}
AB70:SS30	116.46±0.04^{f}	196.92±0.16^{d}	1.72±0.01^{d}	189.62±0.21^{c}
AB60:SS40	108.75±0.24^{g}	194.25±0.49^{e}	1.67±0.01^{de}	187.52±0.49^{d}
AB50:SS50	101.28±0.52^{h}	191.29±0.01^{f}	1.62±0.01^{e}	185.30±0.01^{e}

Means of duplicate samples ± standard deviation. Means with different superscripts (a-h) within each column are significantly different ($p<0.05$). IV=Iodine value. SV= Saponification value. EV= Ester value. USM=Unsaponifiable matter. AB100= 100% African oil bean seed oil. SS100= 100% sesame seed oil. AB90:SS10= 90% African oil bean seed oil: 10% sesame seed oil. AB80:SS20= 80% African oil bean seed oil: 20% sesame seed oil. AB70:SS30= 70% African oil bean seed oil: 30% sesame seed oil. AB60:SS40= 60% African oil bean seed oil: 40% sesame seed oil. AB50:SS50= 50% African oil bean seed oil: 50% sesame seed oil.

Iodine Value (IV)

Iodine value IV is an indicator of the degree of unsaturation in a fat or vegetable oil (. Iodine value test measures the amount of iodine consumed by the acids (Gharby et al., 2015). Singh (2013) stated that low IV implies low saturation level, but high oxidative stability. The iodine value as presented in Table 2 showed significant differences ($p <0.05$) among the oil samples. AB100 had higher iodine value of 124.55 g I^2/100 g than sesame seed oil (105.09 g I_2/100 g). Oils with high iodine value contain more double bonds than oils with lower iodine value, indicating less oxidative stability (Zine et al. 2013). Iodine value of the oil blends decreased from 124.55 g I_2/100 g in AB100 to 101.28 g I_2/100 g in AB50:SS50 as the proportion of sesame seed oil increases. This could be attributed to lower unsaturation level of sesame seed oil (Sunmonu et al., 2017). More so, the lower iodine value recorded as the sesame seed oil increased in the blends implies the presence of higher concentration of saturated fatty acids in the seed oil, as such, the amount of iodine that will be quantitatively added to the double bonds would be lower (Eze, 2012). Results of sesame seed oil (105.09 g I_2/100 g) in the present study corresponds with El-Beltagi et al. (2022) who reported an IV of 102.30 g I_2/100 g to 105.10 g I_2/100 g, Makinde et al. (2016) who reported 104.21 g I_2/100 g to 107.33 g I_2/100 g but lower than Benítez-Benítez et al. (2016) who reported 109.71 g I_2/100 g and Chakraborty et al. (2017) who reported 112.00 g I_2/100 g. More so, iodine value of African oil been seed oil (AB100) (124.55 g I_2/100 g) in the present study was higher than 84.84 g I_2/100 g reported by Ordu & Yingobo (2021), 101.24 g I_2/100 g reported by Akinlabu et al. (2019), 53.19 g I_2/100 g reported by Okpo & Evbuomwan (2014) and 116.00 g I_2/100 g reported by Okoye (2016). In comparison to other vegetable oils, the iodine value recorded in this study was higher than 98.20 g I_2/100 g reported for groundnut oil reported by Katlade et al. (2018), lower than 142.30 g I_2/100 g reported for safflower oil (Katkade et al., 2018), and corresponds with 122.20 g I_2/100 g reported for edible oil extracted from soybean (Katkade et al., 2018). These variations may be due to changes in the raw material uses relative to maturation level, variety, handling, preprocessing, growing condition, soil differences based on geographical location. FAO/WHO (2009) specified that the minimum iodine value for edible oils should be within the range of 80.0 to 106.0 g I_2/100 g to confer nutritional value. The findings of this study fulfilled the minimum requirement for iodine value, hence, satisfies the unsaturation level for edible oil. Also, oils with iodine value less than 100 g I_2/100g are non-drying oils, hence, the studied oil samples can be classified as drying oils and may serve as a useful raw materials in the manufacture of vegetable oil-based ice cream (Oderinde et al., 2009).

Saponification Value (SV)

Saponification reveals the average molecular weight of fatty acid in the oil samples thereby giving an indication of the chain length. Low saponification values suggest the presence of high concentration of long chain fatty acids while high saponification suggest the presence of high amount of short chain fatty acids (Akintayo & Bayer, 2002). Saponification value, SV is also used in checking adulteration and the presence of impurities (Sabinus, 2012). High saponification values suggest a low level of impurities and could, therefore, be useful industrially for soap, shampoo, and paints making (Sabinus, 2012). Control sample had lower SV (176.45 mg KOH/g) compared to the experimental oil samples (191.29 to 208.67 mg KOH/g) which suggested the presence of more long chain fatty acids in the control sample. Higher saponification value of oil blends is an indication that the oil blends may contain higher concentration of short chain fatty acids that favours stability as well as low level of impurities and adulteration and could be useful for industrial applications such as soap making. Findings from this study for sesame seed oil (SS100) corresponds with 189.80 mg/100 g – 195.3 mg/100 g reported by El-Beltagi et al. (2022), 193.01 mg KOH/g reported by Benítez-Benítez et al. (2016), 190.00 mg KOH/g reported by Chakraborty et al. (2017), 190.74 mg KOH/g reported by Dim et al. (2012) and 190.80 mg/100 g – 201.3 mg/100 g reported by Rizki et al. (2014) for sesame seed oils but lower than 412.33 mg KOH/g reported by Enemor et al. (2021). More so, the SV of African oil bean seed oil (AB100) (208.67 mg KOH/g) was higher than 193.120 mg KOH/g reported by Ordu & Yingobo (2021), 152.72 mg KOH/g reported by Okpo & Evbuomwan (2014) but corresponds with 207.54 mg KOH/g reported by Okoye (2016). The variation in results between the results of the present study and other reports may be attributed to difference in extraction solvents, variety used, geographical location, seed maturation among others. The SV of the oil blends, AB100, SS100 satisfies the minimum levels set by Codex Alimentarius Commission for oilseeds (FAO, 2001) (189.0 to 198.0 mg KOH/g), and FAO/WHO (2009) international standard for edible oil (181.0 mg KOH/g).

Unsaponifiable Matter (USM)

Unsaponifiable fractions of edible oils are defined as those components with sparring solubility in acqueous solvents but highly soluble in organic solvents when subjected to alkaline hydrolysis commonly referred to as saponification. Huang et al. (2014) reported that less than 2% of oil's content is generally unsaponifiable. Above 2%, the oils ability to produce soap that forms leather easily will be negatively affected, however, it has been reported that unrefined (crude fat) oils may contain higher percent of unsaponifiable fraction (Huang et al., 2014). Unsaponifiable matter of crude oils are majorly the minor components. These unsaponifiable fraction include hydrocarbons, terpene alcohols, sterols, pigments, higher alcohols and tocopherols. Farhoosh & Mohammad (2010) reported that unsaponifiable matter makes up to 0.5 to 2.5% and can rose up to 5.0 to 6.0 % in some vegetable oils. Findings from this study showed that all oil samples, have unsaponifiable fraction below 2%. AB100 had the highest value while control had the lowest. AB100 had higher unsaponifiable fraction than SS100. The values obtained in this study for sesame seed oil (SS100) (1.47%) was lower than 1.85% and 1.76% reported by Benítez-Benítez et al. (2016) but is in agreement with 1.50% reported by Dim et al. (2012). Unsaponifiable fraction of the oil blends decreased from 1.94% in AB100 to 1.62% in SS100 as the proportion of sesame seed oil increased, which signified that different oil sources affect their unsaponifiable matter content depending on the presence of minor components and impurities. Reportedly, sterols dominate the unsaponifiable fraction in many oils. Sterols such as tocopherols are important because of their antioxidant activity and their cholesterol-lowering effect (Calpe-Berdiel et al., 2009). However, they are mostly lost to a high extent, due to refining process (sodium hydroxide and activated bleaching clays) or the extreme physical conditions (high temperature and low pressure) commonly applied in the edible oil industry (Rouyanne et al., 2014) which explain why control sample had the lowest unsaponifiable fraction (0.84%). Based on the results obtained in this study, it could be inferred that oil blends containing higher proportion of African oil bean seed oil would have a higher amount of pigments, hydrocarbons, higher alcohols, plant sterols and other unsaponifiable materials that influence oil quality and stability.

Ester Value

Ester value gives a representation of the acidity of edible oils, measured as the ester index (Hama, 2017). African oil bean seed oil (AB100) had higher ester content than sesame seed oil (SS100), indicating its high acidity. Ester value in the oil blends suggest decreasing acidity as the proportion of sesame seed oil increased. Control sample with the lowest ester value suggest the lowest acidity. Findings of the present study for sesame seed oil was higher than 188.80 – 193.70 mg/g reported by El-Beltagi et al. (2022).

Quality parameters of pure oils and binary blends

Results of quality parameters of pure oils and binary blends are presented in Table 3. Peroxide values ranged from 2.12 – 3.12 meq O_2/kg fat. African oil bean seed oil (AB100) had the highest peroxide value while control had the lowest value. Also, AB100 had higher peroxide value than sesame seed oil (SS100). Peroxide values of oil blends decreased as the proportion of sesame seed oil increased. Free fatty acid (FFA), para anisidine value (p-AV), acid value (AV) and totox value ranged from 0.48-4.04%, 0.05-0.57, 0.96-8.08 mg KOH/g and 4.28-6.81 respectively. Control had lower free fatty acid, para-anisidine, acid and totox values than other oil samples while AB100 had the highest values. In comparison to SS100, AB100 had higher values. The quality parameters of the oil blends improved with increased substitution of African oil bean seed with sesame seed oil.

Table 3. Quality parameters of pure oils and binary blends

Oil samples	PV (meq O_2/kg fat)	FFA (% Oleic acid)	pAV	AV (mg KOH/g)	TOTOX
Control	2.12 ± 0.02^g	0.48 ± 0.04^g	0.05 ± 0.01^g	0.96 ± 0.04^g	4.28 ± 0.04^h
AB100	3.12 ± 0.03^a	4.04 ± 0.02^a	0.57 ± 0.01^a	8.08 ± 0.06^a	6.81 ± 0.07^a
SS100	2.50 ± 0.01^f	2.87 ± 0.07^f	0.05 ± 0.01^g	5.76 ± 0.16^f	5.05 ± 0.03^g
AB90:SS10	3.03 ± 0.02^b	3.93 ± 0.01^b	0.53 ± 0.01^b	7.79 ± 0.08^b	6.58 ± 0.04^b
AB80:SS20	2.94 ± 0.02^e	3.81 ± 0.01^c	0.47 ± 0.01^c	7.64 ± 0.01^b	6.34 ± 0.04^c
AB70:SS30	2.86 ± 0.01^d	3.65 ± 0.02^d	0.42 ± 0.01^d	7.30 ± 0.05^c	6.14 ± 0.01^d
AB60:SS40	2.81 ± 0.02^e	3.38 ± 0.02^e	0.37 ± 0.01^e	6.73 ± 0.01^d	5.99 ± 0.04^e
AB50:SS50	2.79 ± 0.01^e	2.99 ± 0.01^f	0.31 ± 0.01^f	5.99 ± 0.02^e	5.88 ± 0.02^f

Means of duplicate samples ± standard deviation. Means with different superscripts (a-h) within each column are significantly different (p<0.05). PV=Peroxide value. FFA= Free fatty acid value. pAV= para-Anisidine value. AV=Acid value. AB100= 100% African oil bean seed oil. SS100= 100% Sesame seed oil. AB90:SS10= 90% African oil bean seed oil: 10% Sesame seed oil. AB80:SS20= 80% African oil bean seed oil: 20% Sesame seed oil. AB70:SS30= 70% African oil bean seed oil: 30% Sesame seed oil. AB60:SS40= 60% African oil bean seed oil: 40% Sesame seed oil. AB50:SS50= 50 %African oil bean seed oil: 50% Sesame seed oil.

Peroxide Value (PV)

Peroxide value (PV) measures the level of hydro peroxide form via lipid oxidation which ascertain the freshness of edible oils (Potocnik et al., 2018). Oils with high amounts of peroxides oxidizes faster (Suri et al., 2019b), more so, high peroxide value suggest absence or low levels of antioxidant in the oil sample. These peroxides decreases when they condense to form secondary oxidation products. Consequently, low PV does not always indicate freshness of the oil sample, it could suggest the occurrence of advanced oxidation (Suri et al., 2019a). Therefore, a low PV does not indicate that the oil is good, it only gives an indication of the current state of oxidation of an oil sample (Goszkiewicz et al., 2020). The peroxide results in Table 3, revealed that there was significant ($p<0.05$) differences among the oil samples. Control had the lowest PV which may be due to its refined nature. High peroxide value in African oil bean seed oil (AB100) compared to sesame seed oil (SS100) suggest the presence of high hydro peroxide level and low antioxidant level. Lower PV in SS100 influences positively the peroxide level of the oil blends such that, the PV of the oil blends significantly reduced from 3.12 meq O_2/kg fat to 2.79 meq O_2/kg with increasing substitution of African oil bean seed with sesame seed oil from 0 to 50%. Similar trends was reported by Aditya et al. (2015) on blends of different grades of olive oil with sesame seeds, Ngassapa et al. (2016) on blends of sesame seed oil with palm oil and sunflower oil, Fareshteh et al. (2022) on blends of sesame seed oils with other vegetable oils, and Garg et al. (2021) on blends of sesame seed oil and soybean oil blends. Previous studies on the peroxide values of African oil bean seed oil and sesame seed oil showed that African oil bean seed oil (AB100) of the present studies has lower PV than 18.00 meq O_2/kg reported by Ordu & Yingobo (2021), 20.06 meq O_2/kg reported by Akinlabu et al. (2019) and 16.00 meq O_2/kg reported by Okoye (2016). Also, sesame seed oil (SS100) of the present study had higher PV than 2.00 meq O_2/kg reported by Dim et al. (2012) but lower than 5.30 meq O_2/kg reported by Chakraborty et al. (2017). According to the CODEX Alimentarius standard for vegetal oil, the maximum allowable limit of PV is 10 meq O_2/kg fat (CODEX, 1999). Reportedly, a rancid taste and odour often begins to be noticeable or more pronounced when the PV is above 20 meq O_2/kg (Adelaja, 2006), while Ekwenye (2010) placed this value between 20 and 40 meq O_2/kg of oil. The PV of the present study are below the recommended maximum limit and may still be considered fresh. More so, no objectionable odour was perceived in the different oil samples.

Free Fatty Acids

The suitability of a vegetable oil for any direct consumption or industrial application depends on its free fatty acid value, FFA (Visioli et al., 2018). From the industrial perspective, high FFA level in oil are undesirable and unacceptable because they cause large losses of the natural oil during refining while from health perspective, ingestion of FFA increase blood cholesterol (Bazina & He, 2018). Hence, the overall quality of edible oil can be ascertain by the quantity of FFA present. Causes of high concentration of FFA value may be attributed to high extraction temperature, moisture in oil and supremely, lipases coming from the source or contaminating microorganisms (Atinafu & Bedemo, 2014). High free fatty acids accelerates oxidation of oils by decreasing the surface tension of the oil thereby, increasing the diffusion rate of singlet oxygen from the headspace into the oil (Lozano-Castellon et al., 2022). Results in Table 3 showed that control had the lowest FFA value because it is a refined oil. Crude African oil bean seed oil (AB100) had higher value than sesame seed oil (SS100) and control. Blending of sesame seed oil with African oil bean seed oil resulted to lower FFA in the oil blends which suggest beneficial properties against oxidation as well as beneficial health properties, which agrees with the report of Aditya et al. (2015) on blends of different grades of olive oil with sesame seeds, Ngassapa et al. (2016) on blends of sesame seed oil with palm oil and sunflower oil, Fareshteh et al. (2022) on blends of sesame seed oils with other vegetable oils, Garg et al. (2021) on blends of sesame seed oil and soybean oil blends and Evangelia et al. (2023) on blending extra virgin olive oil with sesame seed oil. Variation in the FFA values of AB100 and SS100 could be attributed to the different extent of lipase activity in response to cell damage in vegetable tissue during initial processing and handling (Hammond, 2003). In comparison to previous reports, SS100 with an FFA value of 2.87% corresponds with 2.82% reported by Dim et al. (2012) while AB100 with an FFA value of 4.04% had higher value than 0.70% reported by Ordu & Yingobo (2021) and 2.92% reported by Okpo & Evbuomwan (2014) but corresponds with 4.09% reported by Akinlabu et al. (2019). According to the requirement of Codex, <0.05 to 0.5% has been stipulated as the maximum permissible level for FFA content in edible oil (CODEX, 1999) while Commission Delegated Regulation (EU 2015/1830) established a legally accepted limit of 0.80%. Control (0.48%) was the only sample that satisfies this limit, inferring good and edible quality. This values suggests that the crude oil samples and their blends would have a higher rate of hydrolytic rancidity compared to the control sample, suggesting the need for refining.

Para-Anisidine Value

The secondary stage of oxidation occurs when the hydro peroxides decompose to form carbonyls and other compounds, particularly aldehydes. This gives the oil a rancid smell and they are measured by the para-anisidine, pAV value being a quality marker for evaluating the quality of oils and fats. The lower the pAV, the better the quality of the oil. The test is particularly useful for oils of low peroxide value (PV) and for assessing the quality of highly unsaturated oils (Orthoefer et al., 2006). The results obtained revealed significant differences ($p<0.05$) among the oil samples. Control and sesame seed oil (SS100) had the lowest value while African oil bean seed oil (AB100) had the highest value. Higher para-anisidine level of AB100 reflects the level of secondary oxidation products such as aldehydes and ketones that may possibly be present. However, substituting AB100 with SS100 influences the reduction of para-anisidine level from 0.57 to 0.31 as the proportion of sesame seed oil increased from 10% to 50%. This findings is in agreement with the findings of Fareshteh et al. (2022) on blends of sesame seed oils with other vegetable oils and Evangelia et al. (2023) on blending extra virgin olive oil with sesame seed oil. Para-anisidine value of the oil samples are considerably low compared to standard. The allowable permissible para-anisidine bvalue in edible oil is 8 (Agnieszka & Joanna, 2013), hence, the secondary oxidation parameter of all oil samples was below the permissible level which suggests low concentration of secondary oxidation products.

Acid Value (AV)

The quality of fatty acids in the oil samples in expressed in terms of acid value (AV) (Enengedi et al., 2019). The acid value accounts for the free fatty acids (FFA) produced from triacylglycerol hydrolysis (Akil et al., 2015). It accounts for the presence of free fatty acids in the oils which is a reflection of the presence and extent of hydrolysis by lipolytic enzymes and oxidation. Oils with high acid value are not suitable for cooking but may find use in the production of paints, liquid soap and shampoos (Aremu et al., 2006). The AV obtained in this study showed significant differences among the oil samples with values ranging from 0.96 to 8.08 mg KOH/g. Control sample had the lowest acid value (0.96 mg KOH/g) while AB100 had the highest value (8.08 g KOH/g). Lower acid value recorded in control sample indicated lower FFA which could possibly result to a higher tendency of being stable over a long period of time (Enengedi et al., 2019). SS100 had lower acid value than AB100 and may be hydrolytically more stable stable which could be due to natural antioxidants such as sesamin, sesamolin, sesamol and γ-tocopherol (Sadeghi et al., 2009) that could be retarding formation of FFA through oxidative pathway. The acid value decreases with increasing proportion of sesame seed oil (SS100). This observation corresponds with the findings of Ngassapa et al. (2016) on blends of sesame seed oil with palm oil and sunflower oil, Fareshteh et al. (2022) on blends of sesame seed oils with other vegetable oils, Evangelia et al. (2023) on blends of sesame seed oil and extra virgin oil blends and Garg et al. (2021) on blends of sesame seed oil and soybean oil blends. Lower acid value recorded in blends containing higher amount of sesame seed oil indicated lower level of free fatty acids which translates into better oil quality and stability (Katkade et al., 2018). The acid value obtained in this study was lower than 19.21 mg KOH/100 g reported for soybean oil but higher than the value (4.63 mg KOH/100g) reported for groundnut oil (Amos-Tautua et al., 2013). More so, the acid value of sesame seed oil (SS100) of the present study is 5.76 mg KOH/100 g which is higher than 2.99 mg KOH/g and 4.44 mg KOH/g reported by Enemor et al. (2021) and Benítez-Benítez et al. (2016) respectively, while the acid value of African oil bean seed oil (AB100) of the present study is 8.08 mg KOH/g which is higher than 1.40 mg KOH/1g, 5.84 mg KOH/g and 1.23 mg/KOH/g reported by Enemor et al. (2021), Benítez-Benítez et al. (2016) and Okoye (2016) respectively but lower than 8.18 mg KOH/g reported by Akinlabu et al. (2019). Furthermore, the acid values of the oils except control exceeded the CODEX standard for acid value of edible oil (<1.0 mg KOH/100 g) (Codex, 2011), thus, inferring high amount of FFA and recommendation for refining process.

Totox Value

The Totox value is calculated by the formula AV + 2PV to indicate an oil’s overall oxidation state. The lower the Totox value, the better the quality of oil (Suri et al., 2019a). Table 3 showed that control sample had the lowest totox value, inferring better quality due to refining. African oil bean seed oil (AB100) had higher value than all oil samples including control and sesame seed oil (SS100). Totox value is significantly affected by the acid value which accounts for the concentration of fatty acids in oils, hence, AB100 with higher acid value than SS100 had higher totox value. Also, higher totox value has been reported for oils with higher polyunsaturated fatty acid, PUFA levels (Potocnik et al., 2018). Consequently, substituting African oil bean seed oil with sesame seed oil resulted to reduced totox value from 6.81 in AB100 to 5.88 in AB50:SS50, thereby indicating that the oil blends had better stability.

Viscosity Properties of Pure Oils and Binary Blends

The result for viscosity of control oil, African oil bean seed oil, sesame seed oil and blends of African oil bean seed oil and sesame seed oil are presented in Table 4. The viscosity was determined at 5°C and 37°C which corresponds to refrigeration and body temperature, to understand the viscous nature of each oil samples at the measured temperature. Viscosity values ranged from 152.50 to 660 mPa.s at 5°C and from 40.00 to 103.00 mPa.s at 37°C. Control sample had the lowest viscosity values at 5°C and at 37°C while sesame seed oil (SS100) had the highest viscosity values at both temperature. Also sesame seed oil (SS100) had higher viscosity values than African oil bean seed oil (AB100) which consequently, increased the viscosity values as the proportion of sesame seed oil increased. After blending, the viscosity values of the oil blends at both temperatures were higher than AB100 but lower than SS100.

Table 4. Viscosity properties of pure oil and binary blends

Oil Samples	Viscosity (mPa.s) at 5^{o}C	Viscosity (mPa.s) at 37^{o}C
CONTROL	152.50±0.53^{h}	40.00±0.00^{f}
AB100	560.00±0.01^{g}	91.00±1.41^{e}
SS100	660.00±0.01^{a}	110.00±0.00^{b}
AB90:SS10	575.00±0.01^{f}	93.50±0.12^{de}
AB80:SS20	587.50±0.53^{e}	95.00±0.41^{d}
AB70:SS30	605.00±0.07^{d}	96.70±0.41^{c}
AB60:SS40	622.50±0.53^{c}	99.00±0.41^{b}
AB50:SS50	635.00±0.01^{b}	103.00±0.82^{a}

Values are means + standard deviation of duplicate determination. Mean values in the same column with different superscrip t(a-h) are significantly different (p<0.05) AB100= 100% African oil bean seed oil. SS100= 100% Sesame seed oil. AB90:SS10= 90% African oil bean seed oil: 10% Sesame seed oil. AB80:SS20= 80% African oil bean seed oil: 20% Sesame seed oil. AB70:SS30= 70% African oil bean seed oil: 30% Sesame seed oil. AB60:SS40= 60% African oil bean seed oil: 40% Sesame seed oil. AB50:SS50= 50 %African oil bean seed oil: 50% Sesame seed oil.

The viscosity values of the oil samples differ significantly (p<0.05) from each other. Triglycerides (TGs) are major components of edible oils. The nature and arrangement of the fatty acids on the glycerol backbone of the triglyceride determine viscosity. Therefore, the oil viscosity has a direct relationship with degree of unsaturation and chain length of the fatty acids in lipids. Its value increases with increasing degree of saturation (Fazal et al., 2015). Oil viscosity depends on the nature of the triacylglycerol present in the oils, and changes due to the different arrangement of the fatty acids on the glycerol backbone of TAG molecules (Kim et al., 2010). Viscosity is affected by the degree of unsaturation, chain length of fatty acids, minor component and impurities especially in crude oils. A longer carbon chain and a decreasing degree of unsaturation results in an increase in viscosity (Hoekman et al., 2012). Similar observation was obtained in this study such that, with reference to Table 2, SS100 had higher saturation than AB100, and the higher the amount of SS100 the higher the saturation level in the oil blends, thereby increasing their viscosity. Additionally, the higher viscosity values of oil blends might be as a result of suspended particles still present in the oil sample as stated by Nangbes et al. (2013) since they are unrefined. Huaping et al. (2006) stated that the molecular weight of vegetable oil are inversely proportional to their saponification value. Lower SV signifies presence of long chain fatty acid which in turn results in higher molecular weight and higher viscosity. Similar observation was obtained in this study. The oil blends had decreasing SV (Table 4.4) as sesame seed oil increased, which may have increased the oils viscosity. The control sample had lower viscosity irrespective of their lower SV than other oil samples. The absence of high level of minor components such as carotenoids, chlorophyll, FFA, in the refined control sample may also have contributed to lower viscosity (Nangbes et al., 2013). Notably, viscosity of edible oil is closely dependent on temperature. At higher temperature of 37°C all oil samples exhibited similar characteristics, such that, an increase in temperature from 5°C to 37°C corresponds to a non-linear reduction in viscosity (Falkovich, 2011).

Conclusion

This study successfully evaluated the chemical properties, quality parameters and viscosity of edible oils extracted from African oil bean seed oil and sesame seed oil and their blends. The study showed that sesame seed had higher oil content than African oil bean seed with better oil quality and higher viscosity. Blending African oil bean seed oil with sesame seed oil improved the quality of the binary blends, the unsaturation level as evidently observed in the iodine values and the oxidative stability as revealed by the totox value while the viscosity properties increased. However, the free fatty acid value of the experimental samples were beyond the recommended limit, hence, the need for refining. Conclusively, binary oil blends had better oil quality and stability, two important features required for an edible oil to achieve balance between nutrition and processing stability.

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