Extraction and Comparative Characterization of Oils from Edible Seeds of *Glycine max* and *Sesamum indicum*

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Authors' contributions

This work was carried out in collaboration among all authors. Author VHAE designed and supervised the study. Authors CLI and OFN managed and performed the experimental and statistical aspects of the study. Authors UCO wrote the protocol while ECO wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aim: The incidence of heart-related disease conditions due to consumption of cholesterol containing oils and the increasing global demand for oil for domestic and industrial purposes have necessitated the need for scientific evaluation of other neglected indigenous plants for potential quality oil yield. This study thus aimed at extracting and comparing physicochemical and nutritional properties of seed oils from *Glycine max* and *Sesamum indicum* with a view to diversifying alternative sources of oil to meet teeming industrial and health needs and for food security.
Methodology: Solvent extraction method was employed to extract oil from seed samples which were further subjected to estimation of physicochemical indices such as free fatty acid, saponification value, iodine value, peroxide value, specific gravity, refractive index, density, pH, melting temperature and viscosity according to methods described by using titration method.
Results: Findings indicated higher saponification (412.33 mgKOH/mg), acid (2.99 mgKOH/g), free fatty acid (1.49 mgKOH/g), viscosity (0.13 Pas) and melting point (5.66 $^{\circ}$C) values for sesame seed oil than for soybean seed oil. However, soybean seed oil showed higher density (0.837 g/ml),

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specific gravity (0.842 Kg/m^3), pH (6.21), iodine (47.25 wij's or g/iodine/g) and peroxide (40.80 mEq/Kg) indices than that obtained for sesame seed oil though mean values were not significantly different.

Conclusion: From observed measured parameters, sesame seed may be suitable for industrial purposes such as the production of soap and paint owing to its high saponification, free fatty acid, viscosity and melting point values while soybean seed oil may be excellent source for domestic and nutritional consumption in addition to industrial use.

Keywords: Sesame; soybean; free fatty acid; saponification value; nutritional; heart-related.

1. INTRODUCTION

More recently, scientific statistics have revealed a significant incidence in the onset and progression of cardiovascular diseases (CVD). In 2016, CVD accounted for approximately one-third of all deaths globally as reported by Moraga [1] and Amini et al [2] with an increase in number of deaths by 42.4% from 1990 to 2015 noted by Mensah et al [3] and Amini et al [2]. According to World Health Organization [4], representing 31% of global deaths, an estimated 17.9 million people died from CVDs in 2016. In 2019 alone, mortality linked to CVDs increased from 12.1 million in 1990 to 18.6 million with trends for disability adjusted life years (DALYs) significantly increasing from 17.7 million to 34.4 million over the years, indicated by a study conducted by Roth et al [5] to determine the global burden of CVDs from 1990 to 2019. Similarly, it is projected that CVD would be the cause of more than 23 million deaths by 2030. The World Health Organization (WHO) [4] has also estimated that over three-quarters of CVD deaths, a greater than 75% of all deaths, reside in low- and middle-income countries, which is a growing epidemic problem in recent years in a study documented by Roth et al. [6], raising serious concerns for the potential risk of poor, unhealthy diet and lifestyle choices prevalent in the areas. The escalating incidence of cardiovascular diseases linked to the high intake of saturated lipids due to the presence of blood low-density lipoprotein cholesterol (hyperlipidemia) has markedly indicated a deteriorating health status of individuals predisposed to heart-related diseases with debilitating effects linked to their consumption, noted by Eneh et al. [7] who indicated hyperlipidemia as connected to poor fatty diets. With these existing stark cases of CVDs, it then becomes urgent to profile other sources of plant oils for dietary management of heart-related diseases.

It was projected by the United Nations in 2013 that the world population would reach 9.7 billion by 2050 from the current 7.4 billion [8], thus increasing food demand with the rising world population [8]. It was also estimated that oil production may increase by 133 million tonnes to reach 282 million tonnes as reported by [9] in order to meet the oil demand. Oil is a very essential part of food today. The demand for oil increases every day as the population of the world increases, and present sources of it will definitely not be sufficient to meet increasing demand. Oil palm, soybean, rape, and sunflower have been noted to account for approximately 83% of the global oil production [9]. In the tropics, the most important oil crops include coconut, oil palm, groundnut, and cotton. Nonetheless, there are many other traditional oil seeds in tropical Africa that are grossly under-neglected and under-exploited, as their nutritional and economic values are scarcely known [10]. There is a need to explore other sources of oil and compare their nutritional and industrial values.

Plants provide edible oils which have applications both in food and industries [11]. As Morrison et al [12] noted, they can also serve as a source of oleochemicals. Gaydon et al [13], Grosso et al [14] and Aremu & Akinwumi [15] variously concluded that vegetable oils have made important contributions to diets in many countries; serving as a good source of protein, lipid and fatty acids for human nutrition including the repair of worn-out tissues, new cells formation as well as a useful source of energy. Ajala and Adeleke [16] added that conventional seed oils include groundnut, soybean, palm kernel, cotton seed, olive, sunflower, rapeseed, sesame, linseed and safflower seed and worldwide, these oils are increasingly becoming important with quite a number of analysis being carried out on these oils primarily because of extensive demands both for human consumption and industrial applications. According to Aremu et al [17], Evwierhoma and Ekop [18] and Mohammed and Jorf-Thomas [19], the characteristics of oils from different sources

depend mainly on their compositions and no oil from a single source can be suitable for all purposes, thus the need to diversify sources.

This work thus focused on the comparative study of the oils extracted from seeds of two indigenous seed plants namely *Glycine max* (Soybean) and *Sesamum indicum* (sesame) with a view to identifying and expanding alternative sources of oil for domestic and industrial uses.

2. MATERIALS AND METHODS

2.1 Collection and Processing of Seeds

Dried Soybean (*Glycine max*) and Sesame (*Sesamum indicum*) seeds were purchased in the month of June, 2019, from the Eke Awka market, Awka South Local Government Area, Anambra State, Nigeria. The seeds were identified by a taxonomist at the Department of Botany, Nnamdi Azikiwe University, Awka, Anambra state. The soybean and sesame seeds were pulverized to very fine texture using a mechanical grinder.

2.2 Extraction of the Oil

Extraction was according to method reported by Tsado et al [20]. Exactly 80 g each of the pulverized seeds (soybean and sesame) was weighed and wrapped with filter papers and then introduced into the extraction tube. It was firmly placed on flask containing 150mL of *n*-hexane in the Soxhlet extraction unit and allowed for a period of five hours as the hexane evaporates, condenses, washes out the oil and refluxes back into the extraction flask. The used samples were removed from the extraction unit to enable recovery of the hexane. The process was repeated for the rest of the samples. The extracted oil was kept on the heater for few minutes to enable the removal of traces of hexane and were cooled in a desiccator to cool and then weighed.

2.3 Determination of Acid Value and Percentage Free Fatty Acid

The method reported by Akintola et al. [21] and Enyoh et al. [22] was used. About one gram of the oil sample was weighed into a conical flask and 50 mL of freshly neutralized ethanol was added. Two or three drops of phenolphthalein indicator were added and swirled. The sample was titrated with the standard solution of sodium hydroxide until a faint pink colour which lasts for

at least 15 seconds was obtained. This marked the end point.

$$\text{Acid value (\%)} = \frac{\text{Titre (mL)} \times 5.61}{\text{Weight of sample used}}$$

The FFA is usually acid, (1mL 0.1M) sodium hydroxide = 0.0282g oleic acid, in which case the acid value = 2×FFA. Thus FFA = Acid value/ 2.

2.4 Determination of Saponification Value of the Oil

The oil sample of 2 g was weighed into a conical flask and 25 mL of alcoholic potassium hydroxide solution was added. It was attached to a condenser and heated in boiling water for 1 hour with frequent shaking. The solution turns green which indicates the presence of soap. Exactly 1 mL of 1% phenolphthalein was added. This was titrated with 0.5M HCl solution until a light-yellow colour which persists was observed (titration = a mL). A blank was also carried out at the same time (titration = b mL).

Saponification value (mg KOH/g) = (B-S) x M x 56.1/W

Where

(B – S) is the difference between the volume of HCl solution used for the blank run and for the tested sample, in mL; M is the molarity of HCl solution, in mol/L, 56.1 is the molecular weight of KOH, in g/mol; W is the weight of sample, in g, in a method reported by Akintola et al [21].

2.5 Determination of Peroxide Value of the Oil

The method reported by Akintola et al. [21] in their work was used. The oil sample (1 g) was weighed into a dry tube, 1 g of powdered potassium iodide and 20 mL of solvent mixture (2 volume glacial acetic acid + 1 volume chloroform) were added to it. The tube was placed on boiling water so that the liquid boils within 30 seconds and also allowed to boil vigorously for not more than 30 seconds. The contents were quickly poured into a flask containing 20 mL of 5% potassium iodide solution. The tube was washed twice with 25ml of water and titrated with 0.002 M sodium thiosulphate using starch. The peroxide value was reported as the number of mL of 0.002 M sodium thiosulphate per g of sample. If the value obtained is multiplied by 2, the figure equals milliequivalent of peroxide oxygen per g of sample, which has greater international recognition.

2.6 Determination of the Iodine Value of the Oil

The method specified by ISO 3961 (1989) was used, that is Wijs/Hanus method. About 0.4 g of the sample was weighed into a conical flask and 10 mL of carbon tetra chloride added to dissolve the oil. Exactly 20 mL of Wijs's solution was added to the flask, vigorously swirled and left in the dark for 2 hours and 30 minutes. Afterwards, 15 mL of 10% potassium iodide solution and 100 mL of water were added and titrated with 0.1 M sodium-thiosulphate solution until the yellow colour almost disappeared. Titration continued with addition of exactly 3 drops of 1% starch indicator and drop-wise thiosulphate until the blue coloration disappeared after vigorous shaking. A blank with 10 mL of carbon tetrachloride was determined.

Iodine value (g I_2/100 g) = (b – a) x N x 12.69/W

(b – a) is the difference between the volume, in mL, of sodium thiosulphate require for the blank run and for the tested sample respectively, N is the normality of sodium thiosulfate in Eq/L; 12.69 is the conversion factor from meq sodium thiosulfate to grams of iodine (the molecular weight of iodine 126.9 g/mol); W is the weight of sample, in grams.

2.7 Determination of the Refractive Index of the Oil

The method outlined by Cocks and Rede [23] was used to determine the refractive index (^{o}C) of the oil samples.

2.8 Determination of the ph Value of the Oil

The method as described by APHA [24] was used. Exactly 2 mL of the sample was poured into a clean dry 25 mL beaker and 13 mL of hot distilled water was added to the sample in the beaker and stirred slowly. It was then cooled in a cold-water bath to $25^{0}C$. The pH electrode was standardized with buffer solution and the electrode immersed into the sample and the pH value was read and dried.

2.9 Determination of Melting Temperature of the Oil

About 2 mL of oil extract was frozen in a beaker using a refrigerator overnight and inserting a simple laboratory thermometer into the frozen oil, the setup was heated at $40^{0}C$ in water bath. The temperature (^{o}C) at which the oil completely melted was recorded as the melting point of the oil.

2.10 Determination of the Specific Gravity of the Oil

The analysis was carried out according to the method reported by Morris [25]. A 50 mL pycometer bottle was washed thoroughly with detergent water and petroleum ether, then dried and weighed. The bottle was filled with water and weighed. The bottle was also filled with the oil sample and weighed.

Specific gravity = density of oil / density of water

2.11 Determination of the Density of the Oil

The densities of the oils were determined using the method reported by Morris [25]. A 50 mL density bottle was thoroughly washed with water and petroleum ether and dried. The bottle was filled with sample seeds and weighed. After drying the bottle, it was filled with the oil and weighed.

Density (kg/m^3) = weight of oil / volume of oil

2.12 Determination of Viscosity of the Oil

About 2 mL of the oil was suspended in distilled water and stirred for 2 hours at room temperature. The viscosity was measured in ^{o}C using the Oswald type viscometer.

2.13 Data Analysis

Data was analyzed using IBM SPSS Statistics version 21 and results were expressed as Mean ± Standard Error of Mean of triplicate determinations. Students' *t*-test was used to determine the level of significance at 95% level of confidence between means of equal variances where $p < 0.05$ was considered significant.

3. RESULTS

Fig. 1 shows that the Acid value (2.992%), FFA (1.4959%) and melting point ($5.67^{o}C$) of sesame oil differ significantly from those of soybean oil being $1.496^{o}C$, $0.7479^{o}C$ and $5.0^{o}C$ respectively. The differences between the values of their

density, specific gravity, viscosity and refractive index is not significant, thus making both oil similar in terms of these parameters.

Fig. 2 shows the saponification value of sesame oil (412.33 mgKOH/kg) is higher than that of soybean oil (401.115 mgKOH/kg), whereas the iodine (47.25 g/iodine/g) and peroxide (40.8 mLequ/kg) values of soybean is higher than those of sesame oil; 8.7999 g/iodine/g and 26.47 mLequ/kg respectively, differing greatly in iodine value than in peroxide value.

4. DISCUSSION

The study aimed at comparing the physiochemical properties of the oil extracted from sesame seeds and soybean seeds. Determination of oil content in plants is important because it predicts the profitability of given plants as potential source of oil. From the research work, the percentage yield of oil from sesame

seed is higher than that of soybean, indicating that in terms of oil yield, sesame seed is more profitable than soybean seed. The colour of the oil from sesame seed was clear/pale yellow but that of soybean oil was golden brown, this shows that, soybean oil undergoes greater length of bleaching to clear oil than sesame, which gives sesame another advantage over soybean.

From the Figs 1 and 2 the following inferences can be made: Soybean oil has a better shelf life compared to sesame oil, this is because acid value indicates the age and quality of the oil. Codd [26] noted that the lower the acid value of an oil, the higher the shelf life of the oil. The acid value obtained from soybean oil is 1.496 mg KOH/g while that obtained from sesame oil is 2.992 mg KOH/g. Also, the FFA values of soybean oil (0.7499%) is lower than that of sesame oil (1.4959%) which still makes soybean oil a better oil than sesame oil.
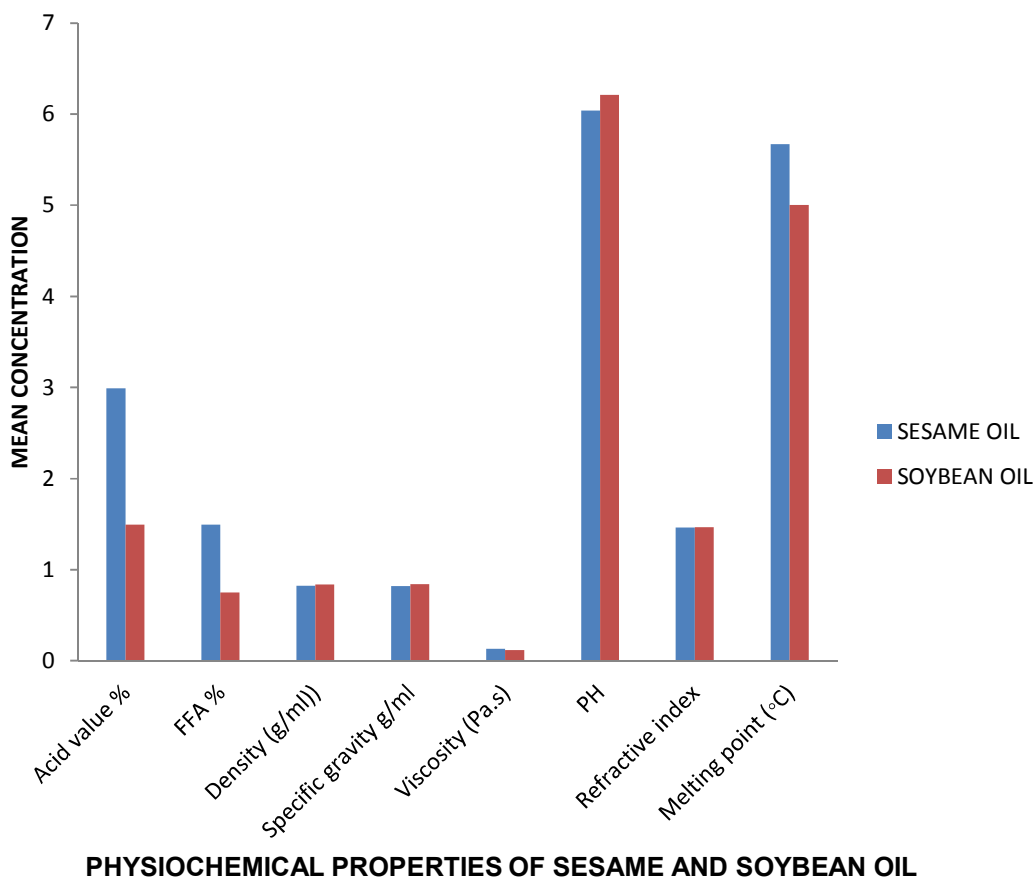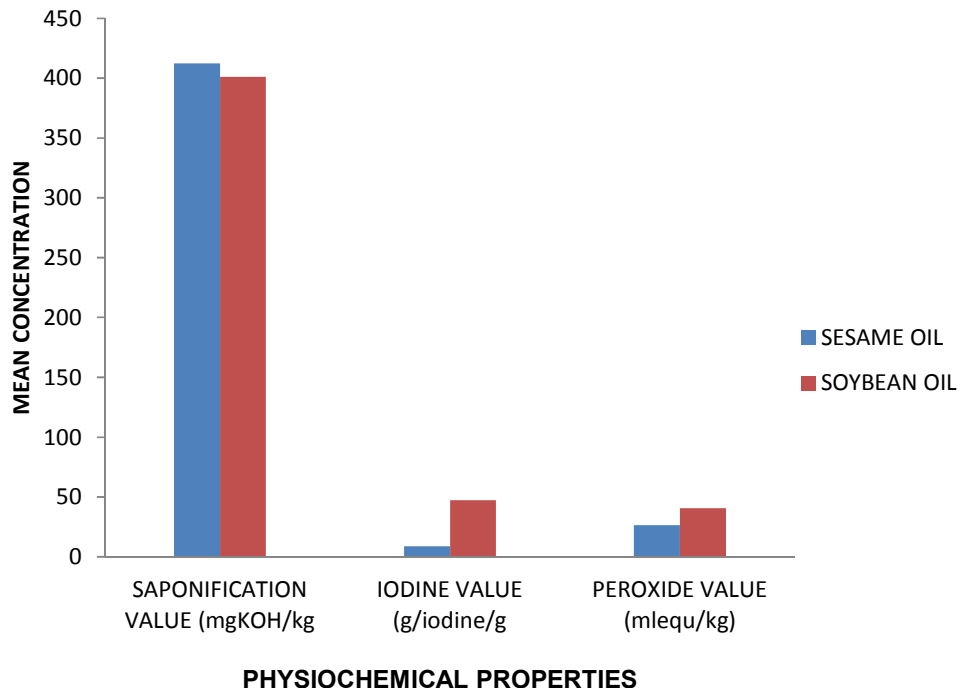

PHYSIOCHEMICAL PROPERTIES OF SESAME AND SOYBEAN OIL

Fig. 1. Physiochemical properties of *Sesamum indicum* and *Glycine max* (Data presented as mean ± S.E.M = Significantly different at *p* < 0.05)

Fig. 2. Physiochemical properties of S*esamum indicum* and *Glycine max* data presented as mean ± S.E.M = Significantly different at *p* < 0.05

Alfred [27] discussed that the higher the iodine value in a given vegetable oil, the more C=C bonds (unsaturation) present in the oil. The iodine value obtained from sesame seed oil is 8.7999 g I_2/100 g, while that of soybean oil is 47.257 g I_2/100 g and when compared with the value of soybean oil given by a literature which is within the range of 124-139 g I_2/100 g, according to CODEX [28], and it was discovered that the iodine content for the oil is lower. Hence the degree of unsaturation of soybean oil is greater than that of sesame oil. This makes soybean a good drying oil usable in cosmetics than sesame oil.

Most popular plant oils have saponification value ranging from 180 - 200 mg KOH/g which are pretty good values for the production of soaps as Minxangi et al. [29] identified. The saponification value determined from sesame seed oil was (412.33 mg KOH/g) which is higher than that of soybean seed oil (401.11 mg KOH/g) and they are both higher than that of soybean oil (189 - 195 mg KOH/g) given by a literature in SON [30] and those of palm kernel oil (245 - 255 mg KOH/g) SON [30]. This indicates that the sesame seed oil is very good for industrial manufacture of soaps than soybean oil.

The best test for the rancidity of a vegetable oil is determination of the peroxide value (PV). The higher the peroxide value of an oil, the more rancid the oil becomes [26]. The value obtained from sesame seed oil was 26.47 meq O_2/kg which was lower when compared with soybean oil at 40.8 meq O_2/kg. Hence sesame oil is less rancid than soybean oil. Sesame oil is more slightly acidic than soybean oil. This was determined from their pH values which are 6.02 and 6.21 respectively, inferring good nutritional quality of oil. The specific gravity of sesame seed oil was obtained at 0.82 g/ml while that of soybean seed oil was 0.84 g/ml. This indicates the unsaturation of an oil because specific gravity increases with higher degree of unsaturation. The differences in terms of pH values and specific gravity of both oils is almost the same. Both oils thus have same quality in terms of these parameters.

Also, from the results obtained from the *t*-test, the iodine value, peroxide value and the viscosity of sesame oil and soybean oil are significantly high (*p* < 0.05) being 37.46 ± 0.00, 14.33 ± 0.02 and 0.015 ± 0.018 respectively. Iodine value is used to determine the amount of unsaturation in fats or oil [31]. High iodine value has health

implications. The higher the iodine value, the less stable the oil and the more vulnerable to oxidation and free radical production [32]. Soybean oil with higher iodine value is more harmful than sesame oil.

As Enyoh et al [22] highlighted, the peroxide value is an indicator of the level of lipid peroxidation or oxidative degradation. It is also used to indicate early stages of rancidity occurring under mild conditions and a measure of primary lipid oxidation. This shows that oil with high degree of unsaturation is more susceptible to autoxidation, a free radical reaction involving oxygen which leads to spoilage of fat and oil to form off-odours. From the findings of the work, soybean oil with higher peroxide value is rancid compared to sesame oil hence sesame oil would offer better flavour than soybean oil.

Viscosity increased with the molecular weight and decreased with increasing unsaturated level and high temperature and this was in support of a study by Nourrechni et al. [33]. From the findings of the study, sesame oil had higher viscosity than soybean, thus formed better hydrogen bonds between carboxyl groups. The more viscous oil is, the better its use as lubricant, as noted by Belewa et al. [34] and these properties portend both oils to be potential good nutritional sources of oil as it cannot clog arteries. Hence, in this regard, sesame seed oils will have better lubricating properties than soya bean oil.

5. CONCLUSION

In Nigeria, the demand for vegetable oil has ever been widening as industrialists rely mostly on the popular vegetable oil such as palm kernel oil, soya bean oil, cotton seed oil and coconut seed oil for preparation of various products. Sesame seed can as well be used basically for industrial purposes for the production of soap and paint because of its high oil yield and very high saponification value. Soybean seed though with lower yield of oil still serves better for domestic use in addition to industrial usage. From the findings of the work, summarily, the physicochemical properties tend to offer better attributes to potentially serve as excellent dietary sources of oil in the dietary management of CVDs. However, the nutritional values of the oils still remain to be determined.

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