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Assessment of Physicochemical Properties of *Helianthus annuus* and *Sesamum indicum* Seed Oils at Varying Temperatures

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ABSTRACT

This study evaluated the effect of temperature on the physicochemical properties of whole and blended *Helianthus annuus* and *Sesamum indicum* seed oils for their industrial potential. The seeds were collected from Wukari, ground into pastes and the cold maceration method was adopted for the extraction of oil. The oils were analyzed for their physicochemical properties using standard methods. The percentage yield of *Helianthus annuus* and *Sesamum indicum* oil was 14.97 and 18.86%, respectively. The results of the physicochemical characteristics for *Helianthus annuus*, *Sesamum indicum* oil and the oil blend respectively were as follows: moisture content (%): 0.058, 0.043 and 0.055; specific gravity (g/cm^3): 0.912, 0.825 and 0.860; viscosity (mPa/s): 41.60, 32.70 and 38.00; iodine value (g/100g): 104.57, 106.59 and 74.41; saponification value (mgKOH/g): 188.64, 201.68 and 54.69, peroxide value (meq/kg): 8.36, 8.75 and 9.00 and acid value (mgKOH/g): 1.80, 1.68 and 3.76. The increase in temperature from 50 to 250 ^{o}C caused a decrease in moisture content, specific gravity, viscosity, iodine, acid values and an increase in the peroxide value of all the oils. The saponification value of *Helianthus annuus* and *Sesamum indicum* oils increased with an increase in temperature while the oil blend recorded a decrease in saponification value. The study recommends that these oils and their blend may find potential applications in the food, cosmetics, pharmaceutical and biofuel industries.

Keywords: Physico-chemical, *Helianthus annuus, Sesamum indicum,* seed oil, temperature, Industrial application.

INTRODUCTION

Oils from plant seeds are essential for industry, medicine, and nourishment. The composition of fatty acids in oil largely determines its suitability for a given usage [1]. Among the most popular oil seeds are sunflower, peanut, soybean, olive, sesame, palm kernel, rapeseed, cotton, linseed, and locust bean seeds. Nut and seed oils are popular due to the high concentration of bioactive lipid components in them, which have been linked to several health advantages [2].

Proteins, carbs, fats and oils, vitamins, and minerals are essential for the human body [2]. The nutritional value of vegetable oils is of primary significance. In many ways, vegetable oils made from plant seeds have significantly contributed to human comfort. Edible oil is a necessary ingredient in cooking and food flavoring. They provide crucial nutritional requirements that humans are unable to achieve on their own, in addition to nutrients including fat-soluble vitamins and unsaturated fatty acids [3].

Edible oil seeds are utilized in the food industry and provide over 80% of the world's vegetable oil output for human consumption. Industrial usage as a feedstock for many industries is gaining attention [4]. The remaining 20 percent is used in the chemical and animal sectors. The potential for usage, production rate, accessibility, and processing ease of an oil seed determine its suitability for growing businesses [2]. Oils are used in the production of soap, detergent, cosmetics, pharmaceuticals, and oil paintings [5]. Industrial and nutritional methods have raised the need for oil, prompting a quest for oils derived from specific types of seeds.

With industries in Nigeria mainly depending on common oils like palm kernel, coconut, cottonseed and soybean oils, to produce various goods, the need for vegetable oil is increasing. Like other oilseeds, sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*) are high in lipids and proteins. Blending multiple oils is a common technique since no single oil can satisfy all nutritional demands and the properties of most oils depend greatly on their chemical compositions. The nutritional shortcomings of individual oils can be addressed by combining oils in different ratios.

The qualities of the extracted oils are greatly influenced by the temperature, storage time, and oil extraction technique. The effects of temperature on the physico-chemical characteristics of oil seeds have not received much attention. This study aims to investigate how temperature affects the physico-chemical characteristics of *Helianthus annuus* and *Sesamum indicum* seed oils and their blend. Additionally, it evaluates their potential functions in various Nigerian sectors.

MATERIALS AND METHODS

Collection and Preparation of Seeds

Helianthus annuus and *Sesamum indicum* seeds were purchased from local vendors in Wukari New Market, Taraba State, Nigeria. The seeds were kept at room temperature until they were needed. The chemicals and reagents utilized were of analytical quality. The seeds were dehulled and winnowed, and then hand-sifted to remove debris. Then, the seeds were gathered, ana an attrition mill was used to grind them into a paste.

Extraction of samples

The cold maceration method described by Nwonye and Priscilla [6] was adopted with slight modification. For full extraction, 200 g of the sample paste (*Helianthus annuus* seed) was put into a 500 ml beaker with 300 ml of n-hexane, and the mixture was shaken periodically for 48 hours. Using cotton wool and a filter funnel, the resulting mixture was filtered. A second extraction was also performed on *Sesamum indicum* seeds.

Preparation of the Oil blend

To prepare the oil blend, 100ml each of *Helianthus annuus* seed oil and *Sesamum indicum* seed oil (1:1) were measured and mixed in a conical flask using a magnetic stirrer at a constant temperature of 40 °C for about one hour.

Determination of the percentage Oil yield

The percentage oil yield was computed as described by Oladipo and Betiku [7].

$$\% \text{ oil yield} = \frac{\text{weight of the oil extracted (g)}}{\text{weight of the paste (g)}} X\ 100$$

Moisture content determination

The moisture content was determined using the method described by Goudoum [4]. Ten grams of a well-mixed oil sample were weighed into a clean Petri dish that had been dried and chilled in a desiccator. After four hours in the oven, the sample was cooled to room temperature in the desiccator for forty-five minutes before being weighed again [8]. The process was repeated until a steady weight was achieved. The following formula was used to calculate the moisture content as a percentage of mass:

$$\% \text{ Moisture Content} = \frac{(\text{Mb} - \text{Md})}{(\text{Mb} - \text{M})} \quad (1)$$

Where, M = Mass (g) of Petri dish, Mb = Mass (g) of Petri dish + sample and Md = Mass (g) of Petri dish + test sample after drying.

Specific gravity determination

The specific gravity was determined by the specific gravity bottle method using IS: 1460-2000. This was conducted at 25 °C [9].

$$\text{The specific gravity of the sample} = \frac{(W3 - W1)}{(W2 - W1)} \quad (2)$$

Where, W_1 = Weight of empty specific gravity bottle, W_2 = Weight of water + specific gravity bottle, W_3 = Weight of test sample + specific gravity bottle.

Viscosity determination

The viscosities of the various oils were measured using a viscometer. In order to determine the force required to overcome the viscosity's resistance to rotation, a concentric cylinder system was immersed in oil. Based on the probe's speed and shape, the viscosity value, expressed in mPa.s, was automatically determined. To conduct the experiment, two milliliters of an oil sample were placed in a concentric cylinder system with a shear rate of 60 sG1.

Iodine Value determination

The iodine content of the oils was assessed using the method described by AOCS [10]. A sample of oil weighing about 0.25 g was placed in a conical flask and dissolved in 10 milliliters of CCl_4. After adding 30 ml of Hanus solution, the mixture was left to stand in the dark for 45 minutes, shaking occasionally. To wash away any remaining iodine on the stopper, 100 milliliters of distilled water and 10 milliliters of 10% KI solution were added. In order to titrate the iodine, a previously standardized $Na_2S_2O_3$ solution was added gradually while being constantly shaken, until the yellow solution became nearly colourless. The titration process was maintained after a few drops of the starch indicator were introduced until the blue hue completely vanished. The container was forcefully shaken in order to allow the KI solution to absorb any iodine that could still be in the CCl_4 solution. For the experiment, the volume of $Na_2S_2O_3$ solution needed was recorded. With the sample, a blank experiment was carried out. The following formula was used to determine the weight percentage of iodine absorbed by the oil sample:

$$\text{Iodine value} = \frac{(B - A) \times N \times 0.127 \times 100}{W} \quad (3)$$

Where, B = ml of 0.1N $Na_2S_2O_3$ required by blank, A = ml of 0.1N $Na_2S_2O_3$ required by the oil sample, N = Normality of $Na_2S_2O_3$, W = Weight of oil in g

Saponification Value determination

The procedure of outlined in the Laboratory Handbook [9] was used. Approximately 2 grams of the specified oil or fat are placed in a conical flask and precisely weighed (w g). In 25 milliliters of 0.5 N alcoholic potassium hydroxide solution, the oil or fat was dissolved. After that, a water condenser was used to reflux the reaction mixture in a water bath for 30 minutes. After cooling, the resultant solution was titrated against a 0.5 N HCl solution with 1 milliliter of phenolphthalein added. The quantity of milliliters of acid needed was recorded (a). An identical blank experiment was conducted, in which the fat or oil was left out. The amount of hydrochloric acid (ml) needed was indicated (b). The saponification value was given by the expression:

$$\text{Saponification value} = \frac{(b-a) \text{ x } 0.02805 \text{ x } 1000}{w} \qquad (4)$$

Peroxide Value determination

About 1 g of the oil sample was combined with 20 ml of a solvent mixture (glacial acetic acid/chloroform, 2/1 by volume) and 1 g of potassium iodide. The mixture was then brought to a boil for one minute. A flask filled with 20 milliliters of 5% potassium iodide was filled with the heated solution. The combination was titrated with 0.025 N sodium thiosulphate after a few drops of the starch solution were added, and the peroxide value was calculated as follows [9]:

$$PV = \frac{SN103}{w} \qquad (5)$$

Where: S – ml of $Na_2S_2O_3$, N – Normality of $Na_2S_2O_3$, W – Weight of oil sample (g).

Acid Value determination

A 250 ml beaker was filled with 25 ml of ethanol and 25 ml of diethyl ether. In a 25 ml conical flask, 10 g of oil was mixed with the resultant mixture, and a few drops of phenolphthalein were added. With constant shaking, the mixture was titrated with 0.1 m KOH to the endpoint, when a dark pink color was seen and the 0.1 m KOH volume was recorded [9].

$$\text{Acid value} = \frac{(V \times N \times 56.1)}{w} \qquad (6)$$

Where: V = volume of potassium hydroxide used, N = normality of Potassium hydroxide, W = weight in g of the sample.

RESULTS AND DISCUSSION

Percentage yield of *Helianthus annuus* and *Sesamum indicum* seed oils

The percentage yield of *Helianthus annuus* and *Sesamum indicum* seed oils obtained from cold maceration is shown in Table 1. It was observed that *Helianthus annuus* and *Sesamum indicum* oils had percentage yields of 18.86 and 14.97 %, respectively. The percentage yield of *Helianthus annuus* seed oil was higher than that of *Sesamum indicum* oil indicating that *Helianthus annuus* seed oil can be used to produce a greater amount of oil on an industrial scale. Oils with high yields indicate that more product (e.g. biodiesel) can be obtained from the same amount of raw material which will in turn improve profitability [11]. In a study by Presson *et al*. [12], it was observed that *Thevetia peruviana* oil was produced with a yield of 25.58% and 66.32% from the press method and Soxhlet method, respectively.

Table 1: Percentage yield of *Helianthus annuus* and *Sesamum indicum* seed oils

	Helianthus annuus oil	*Sesamum indicum* oil
% yield	18.86	14.97

Physiochemical properties of whole and blend of *Helianthus annuus* and *Sesamum indicum* seed oils

The physiochemical properties of whole and blend of *Helianthus annuus* and *Sesamum indicum* seed oils are shown in Table 2.

Table 2: Physiochemical properties of whole and blend of *Helianthus annuus* and *Sesamum indicum* seed oils

	Helianthus annuus oil	*Sesamum indicum* oil	Oil blend
Moisture content (%)	0.058 ± 0.00	0.043 ± 0.00	0.055 ± 0.00
Specific gravity (g/cm^3)	0.912 ± 0.01	0.825 ± 0.01	0.860 ± 0.01
Viscosity (mPa/s)	41.60 ± 0.50	32.70 ± 0.45	38.00 ± 0.40
Iodine Value (g/100g)	104.57 ± 0.80	106.59 ± 0.50	74.41 ± 0.65
Saponification Value (mgKOH/g)	188.64 ± 1.25	201.68 ± 1.40	54.69 ± 0.50

Peroxide Value (meq/kg)	8.36 ± 0.10	8.75 ± 0.12	9.00 ± 0.15
Acid Value (mgKOH/g)	1.80 ± 0.05	1.68 ± 0.04	3.76 ± 0.06

Moisture content

Moisture content is a crucial factor in various industries, especially in food processing, agriculture, pharmaceuticals, and material sciences [13]. The moisture content of the oil produced in this study ranged from 0.058% and 0.043%. The oil from *Helianthus annuus* seeds had the highest moisture content (0.058%) while that from *Sesamum indicum* seeds had the lowest (0.043%). The oil blend had moderate moisture content (0.055%). According to the results, all of the oils' moisture contents exceeded the acceptable limit of 0.29 mg/l by SON standard for edible oil. A study by Presson *et al*. [12] revealed that the moisture content of oil from *Thevetia peruviana* seeds was 0.003% (pressed method) and 0.004% (Soxhlet method) which were lower than the values obtained in this study. The oil from *Sesamum indicum* seeds is expected to have a longer shelf life compared to the other oils produced in this study. Oils with higher moisture content are more valuable for industrial processes such as soap, detergent, cosmetics, and oil painting as well as for texturing, baking, and frying food [14].

Specific gravity

The oils in this study had specific gravity ranging from 0.825 to 0.912 g/cm^3. *Helianthus annuus* oil had the highest specific gravity (0.912 g/cm^3) while *Sesamum indicum* oil had the lowest specific gravity (0.825 g/cm^3). The blend of *Sesamum indicum* and *Helianthus annuus* oils had moderate specific gravity values of 0.860 g/cm^3. These values were lower than the recommended range of specific gravity for sunflower oil (0.919–0.923) by WHO/FAO [15]. Aremu *et al*. [16] reported that the specific gravity of garlic and ginger oil at 15 ^{o}C is 0.97 and 0.90 g/cm^3 respectively. Castor seed oil (*Ricinus communis*) had a specific gravity of 0.948 g/cm^3 [17]. Presson *et al*. [12] reported that *Thevetia peruviana* oil has a density ranging from 855 to 884 kg/m^3. Customers greatly favor oils with lower density levels [18]. Specific gravity ranging from 0.906 to 0.913 g/cm^3 was reported for Cashew nut seed oil (*Anacadium occidentale*) [19]. Oils with this range of specific gravity are suitable for edible oils, ideal as base oils in lotions, creams, and serums and appropriate for light-duty industrial lubricants and biodegradable formulations [20].

Viscosity

The viscosity of oils in this study ranged from 32.70 to 41.60 mPa/s. *Helianthus annuus* oil had the highest viscosity of 41.60 mPa/s while *Sesamum indicum* oil had the least viscosity at 32.70 mPa/s. The oil blend had moderate viscosity of 38.00 mPa/s. This result was similar to those reported by Bwade *et al*. [21] for Pumpkin seed oil (*Telfairia occidentalis*) which ranged from 44.70 to 45.00 mPa/s, while Almond seed oil (*Prunus amygdalus)* had a viscosity of 302.39 mPa/s [22]. The viscosity of the oil from *Thevetia peruviana* was also reported to be 22.25 and 19.91 mm^2/s in a study by Presson *et al*. [12]. These oils have viscosity values lower than 100 mPa/s and are considered low-viscosity oils [23]. This suggests that the oils can be applied where fast-moving parts are involved, such as in light machinery, automotive engines, or hydraulic systems [24]. The moderate viscosity of these oils makes them potentially useful as carrier oils in drug formulations [25] and can facilitate smooth application in skincare and hair care products [26].

Iodine Value

The iodine values of *Helianthus annuus* and *Sesamum indicum* seed oils were 104.57 and 106.59 g/100g, respectively. *Sesamum indicum* seed oil had the highest iodine value among the oil samples analyzed. The *Helianthus annuus* and *Sesamum indicum* seed oil blend had the lowest iodine value (74.41 g/100g). These findings were higher than the 45–53 mg/l SON standard suggested range for edible oil [27]. A study by Hasan *et al*. [28] observed that the iodine values of fresh soybean, rice bran, palm, castor and almond oil were 105.47, 88.07, 44.82, 84.95 and 92.91 $gI_2/100g$, respectively. Similarly, in a study conducted by Evwierhoma and Ekop [29], it was reported that sesame, soybean, avocado and jatropha seed oils had iodine values of 117.45, 126.25. 80.00 and 100.50 $gI_2/100g$, respectively. Aremu *et al*. [16] also reported that the iodine value of garlic and ginger oil are 116.20 and 105.64 mg I_2/g respectively. The oils in this study are classified as non-drying oil because their iodine values are lower than 110 [30]. Apart from being dehydrated before application, the non-drying properties of the oils may make them unsuitable for use in the paint and coatings production sectors [31]. However, these oil can be used in the food industry (margarine and shortening production), as well as the soap and detergents industry [32].

Saponification Value

The saponification value represents the average molecular weight of the triglycerides found in extracted oils [2]. The saponification values of *Helianthus annuus* and *Sesamum indicum* seed oils were 188.64 and 201.68 mgKOH/g, respectively. *Sesamum indicum* seed oil had the highest saponification value. The oils' saponification levels fell between 195 to 205 mg KOH/g of edible oil, which is the permissible range according to SON [27]. The saponification values in this study were comparable to those reported by Aremu *et al*. [16] for garlic and ginger oil (182.15 and 191.22 mg KOH/g respectively). Hussein *et al*. [33] observed that the saponification values of fresh neem seed oil ranged from 114.09 to 141.11 mg KOH/g oil. In another study, it was reported that neem seed oil had saponification value of 213.18 mg KOH/g [34]. The oils in this study have saponification values within the range of 180 to 200 mg KOH/g and have the potential to be used soap and cosmetics production [35].

Peroxide Value

The peroxide value is a measure of the degree to which rancidity reactions have occurred during the storage of extracted oil [36]. *Helianthus annuus* seed oil had the lowest peroxide value (8.36 meq/kg)while the highest peroxide value was found in a blend of *Helianthus annuus* and *Sesamum indicum* seed oils (9.00 meq/kg). The peroxide values of the oils are below 10meq/kg oil specified by NIS [37] and SON [27]. In a study conducted by Evwierhoma and Ekop [29], sesame, soybean, avocado and jatropha seed oils had low peroxide values of 0.60, 0.95. 3.30 and 3.50 meq/kg, respectively. Aremu *et al*. [16] also reported peroxide values of garlic and ginger oil to be 2.42 and 2.61 meq/kg respectively. A study by Hasan *et al*. [28] noted that fresh soybean, rice bran, palm, castor and almond oil had lower peroxide values of 1.17, 1.43, 1.05, 6.02 and 5.08 meqO_2/kg, respectively. Reduced stability to oxidative rancidity is indicated by a high peroxide value, whereas increased strength to oxidative rancidity is shown by a low peroxide value [34]. The low peroxide value of these oils makes them potentially useful in pharmaceuticals, manufacture of long-lasting cosmetic products and are suitable for food storage and frying [38].

Acid Value

The acid values of *Helianthus annuus* and *Sesamum indicum* seed oils were 1.80 and 1.68 mgKOH/g, respectively. The highest acid value was observed in the blend of *Helianthus* *annuus* and *Sesamum indicum* seed oils(3.76 mgKOH/g). These oils' acid values were too high for consumption since it was higher than the SON standard tolerable limits of 0.7 max mg/l for edible oil. The acid values of fresh soybean, rice bran, palm, castor and almond oil were 0.36, 1.11, 0.94, 1.89 and 1.4 mgKOH/g, respectively [28]. Hussein *et al.* [33] found that neem seed oil had an acid value ranging from 11.34 to 18.01 mg KOH/g. Aremu *et al.* [16] reported that the acid values of garlic and ginger oil are 2.60 and 4.52 mg KOH/g respectively. An oil's acid value indicates the amount of free fatty acid it contains and the extent of hydrolysis that has occurred [39]. Low acid values suggest that the seeds were not aged before extraction [40]. These low acid values make the oils suitable for use in the food industry due to their high quality,in biodiesel production to reduce corrosion risks, skincare formulations to minimize skin irritation [41, 42].

Effect of temperature on the physico-chemical properties of whole and blend of *Helianthus annuus* and *Sesamum indicum* seed oils

The effect of temperature on the physico-chemical properties of whole and blend of *Helianthus annuus* and *Sesamum indicum* seed oils is shown in Tables 3, 4 and 5, respectively.

Table 3: Effect of temperature on the physicochemical properties of *Helianthus annuus* seed oil

Physico-chemical Properties	Temperatures (°C)				
	50	100	150	200	250
Moisture content (%)	0.056 ± 0.00	0.047 ± 0.00	0.044 ± 0.00	0.038 ± 0.00	0.033 ± 0.00
Specific gravity (g/cm^3)	0.876 ± 0.01	0.874 ± 0.01	0.866 ± 0.01	0.860 ± 0.00	0.852 ± 0.01
Viscosity (mPa/s)	38.90 ± 0.50	38.76 ± 0.48	37.98 ± 0.50	37.55 ± 0.15	37.30 ± 0.45
Iodine Value (g/100g)	77.92 ± 0.90	76.69 ± 0.85	74.62 ± 0.80	72.84 ± 0.10	71.32 ± 0.20
Saponification Value (mgKOH/g)	137.73 ± 1.50	147.26 ± 1.75	166.2 ± 2.00	175.87 ± 1.60	194.25 ± 1.75
Peroxide Value (meq/kg)	7.93 ± 0.20	4.64 ± 0.12	13.68 ± 0.15	14.26 ± 0.32	15.65 ± 0.30
Acid Value (mgKOH/g)	0.81 ± 0.05	0.62 ± 0.06	0.91 ± 0.01	0.76 ± 0.00	0.67 ± 0.01

Table 4: Effect of temperature on the physico-chemical properties of *Sesamum indicum* seed oil

Physico-chemical Properties	Temperatures (°C)				
	50	100	150	200	250
Moisture content (%)	0.048 ± 0.00	0.045 ± 0.00	0.039 ± 0.00	0.032 ± 0.00	0.027 ± 0.00
Specific gravity (g/cm^3)	0.823 ± 0.01	0.820 ± 0.01	0.818 ± 0.01	0.817 ± 0.01	0.814 ± 0.00
Viscosity (mPa/s)	32.66 ± 0.35	32.61 ± 0.40	32.59 ± 0.30	32.54 ± 0.15	32.47 ± 0.25
Iodine Value (g/100g)	74.62 ± 1.00	81.22 ± 0.70	79.19 ± 1.20	69.54 ± 0.92	67.76 ± 0.90
Saponification Value (mgKOH/g)	73.63 ± 1.20	50.49 ± 0.70	102.38 ± 0.75	61.71 ± 1.00	104.49 ± 1.30
Peroxide Value (meq/kg)	8.38 ± 0.15	12.19 ± 0.10	13.79 ± 0.05	14.60 ± 0.00	16.03 ± 0.20
Acid Value (mgKOH/g)	10.78 ± 0.30	10.35 ± 0.20	10.21 ± 0.50	9.28 ± 0.05	9.00 ± 0.20

Table 5: Effect of temperature on the physico-chemical properties of *Helianthus annuus* and *Sesamum indicum* oil blends

Physico-chemical Properties	Temperatures (°C)				
	50	100	150	200	250
Moisture content (%)	0.054 ± 0.02	0.050 ± 0.01	0.048 ± 0.01	0.043 ± 0.00	0.040 ± 0.00
Specific gravity (g/cm^3)	0.852 ± 0.20	0.850 ± 0.10	0.847 ± 0.00	0.843 ± 0.00	0.839 ± 0.01
Viscosity (mPa/s)	36.90 ± 0.25	36.86 ± 0.30	36.82 ± 0.05	36.79 ± 0.10	36.70 ± 0.15

Iodine Value (g/100g)	76.64 ± 0.90	80.2 ± 0.80	74.36 ± 0.50	68.02 ± 0.50	66.75 ± 0.70
Saponification Value (mgKOH/g)	333.8 ± 5.10	251.05 ± 4.45	211.5 ± 5.00	220.5 ± 3.90	226.65 ± 3.75
Peroxide Value (meq/kg)	9.5 ± 0.15	12.25 ± 0.50	13.81 ± 0.10	14.88 ± 0.20	16.19 ± 0.35
Acid Value (mgKOH/g)	5.5 ± 0.10	5.39 ± 0.09	5.27 ± 0.10	5.17 ± 0.15	5.02 ± 0.06

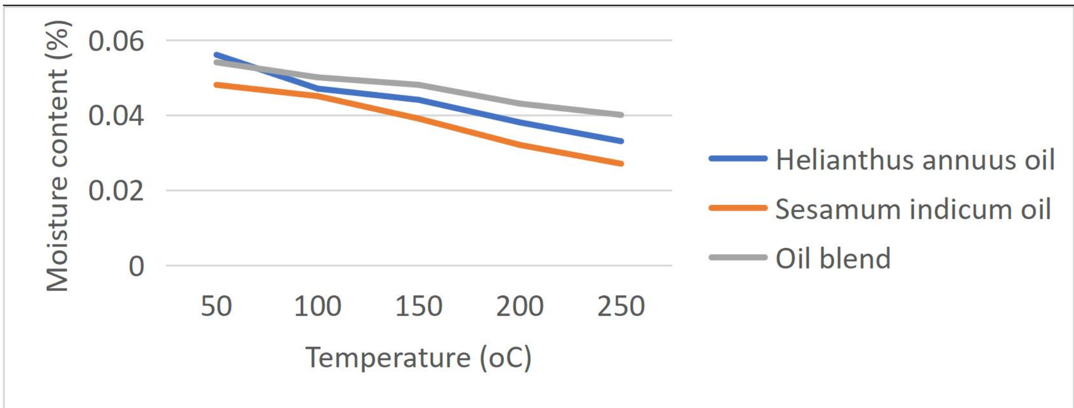

Figure 1: Effect of temperature on the moisture content of the oils

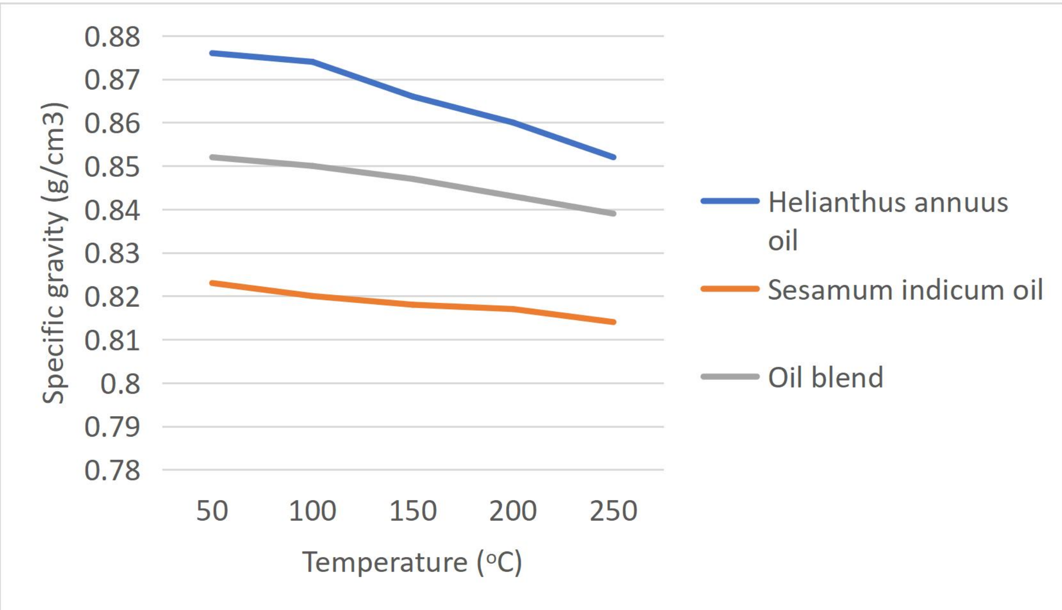

Figure 2: Effect of temperature on the specific gravity of the oils

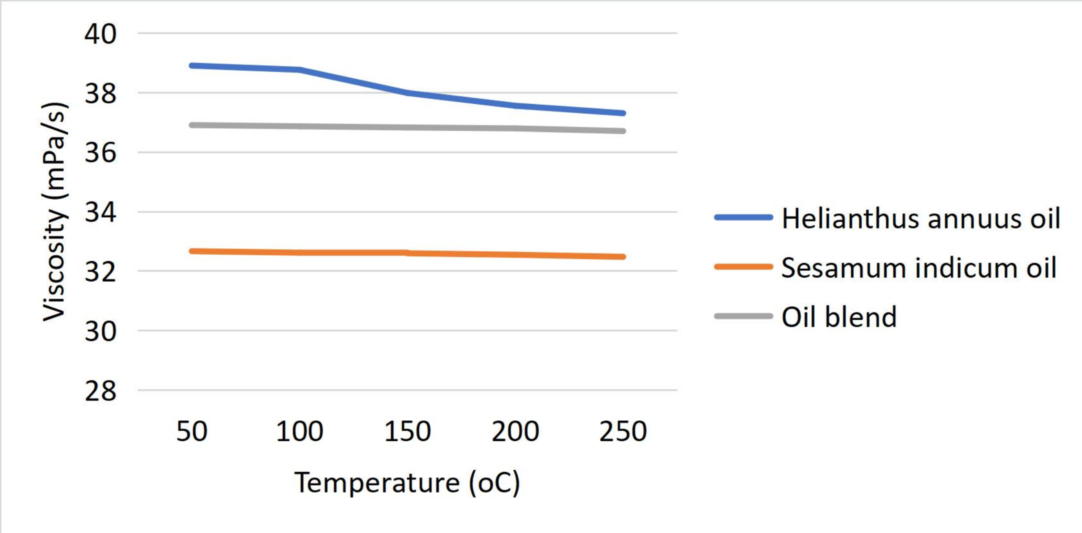

Figure 3: Effect of temperature on the viscosity of the oils

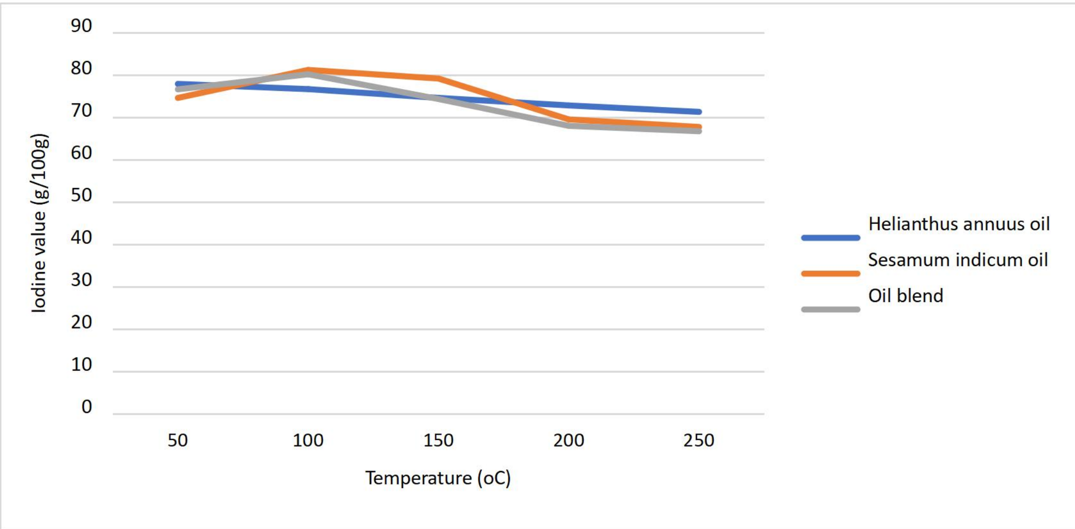

Figure 4: Effect of temperature on the iodine value of the oils

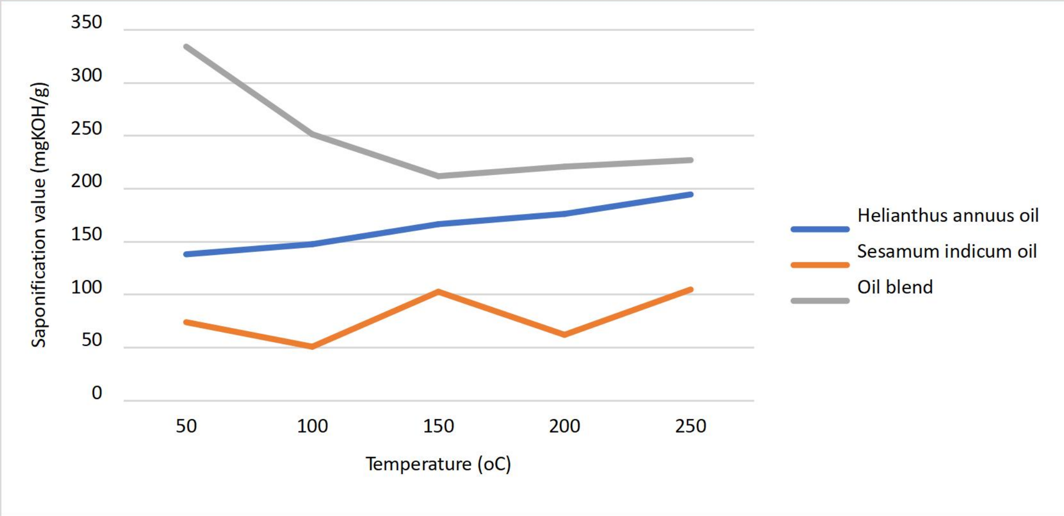

Figure 5: Effect of temperature on the saponification value of the oils

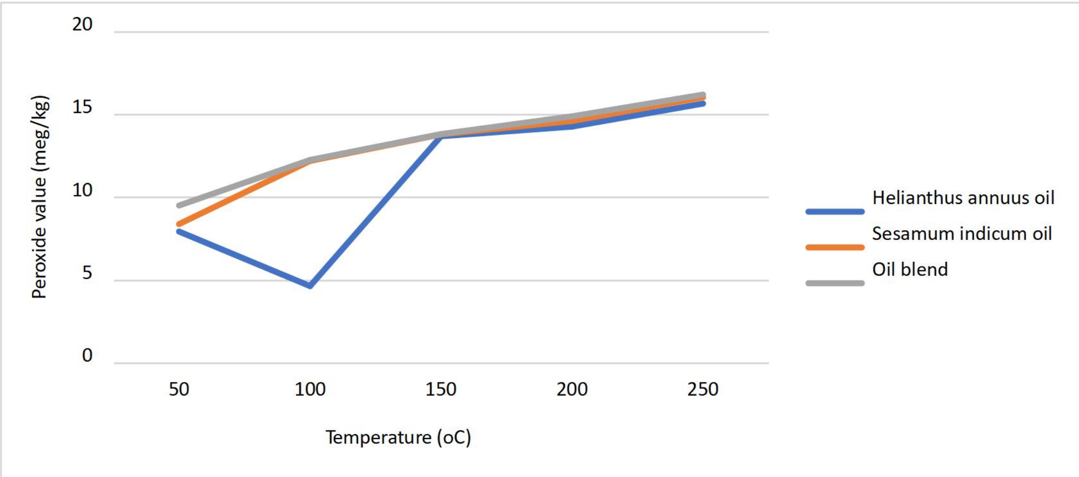

Figure 6: Effect of temperature on the peroxide value of the oils

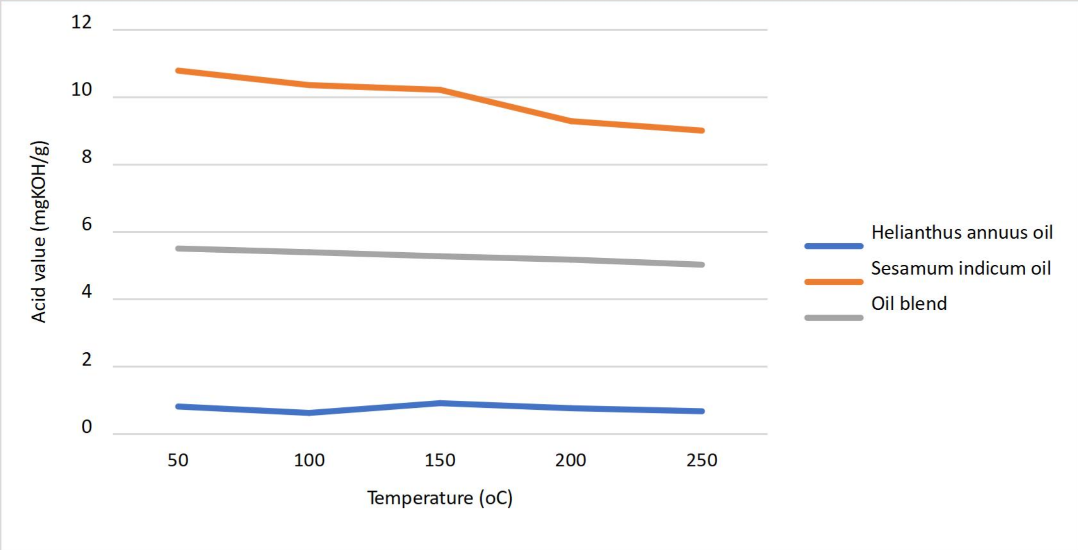

Figure 7: Effect of temperature on the acid value of the oils

One of the factors known to degrade oil quality is temperature [43]. The moisture content of *Helianthus annuus* oil, *Sesamum indicum* oil and the oil blend decreased from 0.056 to 0.033%, 0.048 to 0.027% and 0.054 to 0.040%, respectively with increase in temperature from 50 to 250 ^oC. When oil is heated, the water molecules within it gain kinetic energy, leading to increased evaporation. As a result, higher temperatures typically reduce the oil's moisture content [44], making it useful for baking, snack production, seed treatments, capsules and ointments.

The specific gravity of *Helianthus annuus* oil, *Sesamum indicum* oil and the oil blend decreased from 0.876 to 0.852 g/cm^3, 0.823 to 0.814 g/cm^3 and 0.852 to 0.839 g/cm^3, respectively with increase in temperature from 50 to 250 ^oC. As temperature increased and specific gravity decreased, oil that might barely sink at a lower temperature could float at a higher temperature and cause the oil to expand [45]. These oils can be used for high-temperature cooking, cosmetic products and food coatings.

The viscosity of *Helianthus annuus* oil, *Sesamum indicum* oil and the oil blend decreased from 38.90 to 37.30 mPa/s, 32.66 to 32.47 mPa/s and 36.90 to 36.70 mPa/s, respectively with increase in temperature from 50 to 250 ^oC. At elevated temperatures, the molecules in the oil move more rapidly, reducing the intermolecular forces that contribute to viscosity. In food processing, the viscosity of oils affects mixing, coating, and frying processes. Oils with the correct viscosity at frying temperatures ensure even cooking and proper texture, making them useful for deep frying, baking and blended oil for salad dressings or cooking [46].

The iodine values of *Helianthus annuus* and *Sesamum indicum* seed oil decreased from 77.92 to 71.32 g/100g and 74.62 to 67.76 g/100g, respectively with increase in temperature from 50 to 250 °C. The oil blend also recorded a decrease in iodine value from 74.64 to 66.75 g/100g with increase in temperature from 50 to 250 °C. This finding is in line with the work of Dawodu *et al*. [47] who reported a decrease in the iodine values of peanut, soybean, sunflower, olive and palm kernel oils with increase in temperature. This shows that the oils heated at 250 °C is more suitable for high-temperature cooking (like frying) compared to oils heated at lower temperatures (those having higher iodine values). They can also be used for baking, soap making, cosmetics formulations, margarine and shortening production [48].

The saponification values of *Helianthus annuus* and *Sesamum indicum* seed oil increased from 137.73 to 194.25 mgKOH/g and 73.63 to 104.49 mgKOH/g, respectively with increase in temperature from 50 to 250 °C. The oil blend however recorded a decrease in saponification value from 333.80 to 211.5 mgKOH/g with increase in temperature from 50 to 250 °C. Nwokocha and Adegbuyiro [(2017) reported that the saponification value of Jatropha curcas Kernel oil was highest in the water extracted oil at 200°C (233 mg KOH/g) and lowest in cold hexane extracted oils (221 mg KOH/g). The low saponification values of all the oils indicate that there are less ester linkages than usual, which will lead to good use of the oil in the manufacturing of soaps and shampoos [35].

The peroxide values of *Helianthus annuus* and *Sesamum indicum* seed oil increased from 7.93 to 15.65 meq/kg and 8.38 to 16.03 meq/kg, respectively with increase in temperature from 50 to 250 °C. The oil blend also recorded an increase in peroxide value from 9.50 to 16.19 meq/kg with increase in temperature from 50 to 250 °C. These oils can be used for salad dressings, marinades, and dips, flavoring oils, skin care formulations like moisturizers, massage oils, and serums because oxidation rates are lower at room or skin temperatures [49]. Reduced antioxidants lead to an increase in peroxide value (loss in oxidative stability) and may be caused by microstructural changes in seeds or thermal degradation that occurs at high temperatures [50]. The increase in extractability of tocopherols (or other antioxidants) due to the heat breakdown of cellular structure is typically credited with the improvement in oxidative stability [51]. Zahir *et al*. [52] also reported an increase in the peroxide values of corn oil (0.538 to 2.994 meq/kg) and mustard oil (0.388 to 2.720 meq/kg) with increasing frying temperature from 0 to 140 ^{o}C and 0 to 170 ^{o}C, respectively.

The acid values of *Helianthus annuus* and *Sesamum indicum* seed oil decreased from 0.81 to 0.61 mgKOH/g and 10.78 to 8.65 mgKOH/g, respectively with an increase in temperature from 50 to 350 ^{o}C. The oil blend also recorded a decrease in acid value from 5.50 to 4.89 mgKOH/g. These oils can find use in cooking and frying, biodiesel production, lubricants and hydraulic fluids, skin care products, coating and preservatives, paints and varnishes. This finding varied from that of Dawodu *et al*. [47] who observed an increase in the acid values of peanut, sunflower, soybean, olive and palm kernel oils with increase in temperature. A high acid value is indicative of a high level of free fatty acids, which turn oil rancid and appear to raise blood cholesterol levels, particularly the ratio of low-density lipoproteins to high-density lipoproteins, when consumed [53].

CONCLUSION

This study investigated the impact of temperature on the physico-chemical properties of *Helianthus annuus* and *Sesamum indicum* seed oils. The results indicate that both seed oils and their blend undergo changes in chemical composition and physical properties at different temperatures. The decrease in viscosity and density as temperature increases can improve the flowability of the oils in industrial processes. These properties make the oils suitable for use in skin care products and soaps. Additionally, the oils could be utilized as feedstock for biodiesel production, offering a renewable energy source. The application of these oils in food processing (salad dressings, margarine), cosmetics (skin care products), and bio-lubricants should be encouraged. It is recommended to maintain temperatures below the threshold where significant degradation occurs to help preserve the oils' beneficial properties and ensure longer shelf life.

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