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The Comparative Assessment of Nutritive Values of Dry Nigerian Okra (*Abelmoschus esculentus*) Fruit and Oil

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Abstract Okra (*Abelmoschus esculentus*) fruit flour and the oil were analyzed with respect to proximate, physico chemical properties and fatty acid composition. The results showed that okra fruit contained crude protein (23.36%) and carbohydrate (42.68%). Palmitic acid ($C_{I6:0}$) was the most concentrated fatty acid with the value of 32.14% followed by linoleic ($C_{I8:2}$) (30.94%) while oleic acid ($C_{I8.1}$) took the third position with the value of 29.13%. The results of physico chemical properties were: iodine value (112.16mgI_2/100g), saponification value (182.20mgKOH/g), peroxide value (7.31mg Equv.O_2/Kg), cloud point (10^{o}C), pour point (4^{o}C), flash point (242°C) and kinematic viscosity (52.13Cst). These values obtained indicate that okra fruit is a potential source of protein and nutritionally good for consumption.

Keywords Proximate, Physico chemical, Fatty acid, Okra

1. Introduction

Vegetables are important food for the maintenance of health and protection of body from diseases. They contain valuable food ingredients, which can be successfully utilized and repair the body. Okra (*Abelmoschus esculentus*) is also known as lady's finger, it is a common fruit vegetable grown for domestic consumption in the tropical and sub - tropical countries of the world. Okra is commonly grown in West Africa especially in Nigeria, mainly for its fruit but the immature leaves are sometimes used for soup making and flavouring or may be added to salads and stews. The crop grows well in the poor soil with intermittent moisture and hot weather, especially in the warm region with good sun-light (20°C) [1]. It is a drought tolerant vegetable in the world but can be damaged by severe frost [2]. Okra has maximum yield at the period of low rainfall and can produce fruits for a very long time. There is scarcity of information on the detailed nutritional composition of okra fruit and oil; therefore, this work was aimed at determining the proximate composition of flour, physico chemical properties and fatty acid of the oil from Nigerian okra fruit.

2. Materials

Dry okra (*Abelmoschus esculentus*) fruits were obtained from Central market in Akure, Ondo State Nigeria in Africa. The dry okra fruits were further sun-dried for one day. The pods with the seeds were milled into flour using a Marlex grinder. The okra fruit flour was packaged in a poly ethylene bag and kept in freezer at -4°C prior to analyses. The oil from the okra fruit flour was extracted with petroleum ether (British Drug House, London) boiling range 40-60°C using Soxhlet extractor. All chemicals used were of analytical grades.

3. Methods

3.1. Proximate Analysis

The moisture and ash contents were determined using the air oven and Muffle furnace according to methods of Pearson [3]. The sample was analysed for crude fat, crude fibre and crude protein according to the methods described by AOAC [4]. Nitrogen was determined by micro-Kjedahl method described by AOAC [4] and the percentage nitrogen was converted to crude protein by multiplying by 6.25.

3.2. Physico Chemical Properties

3.2.1. Saponification Value

A 2.0ml of the oil sample was added to the 20ml of ethanolic potassium hydroxide in 500ml round bottom flask. The flask with its content was refluxed for 30 minutes. 2ml of phenolphthalein indicator was added and the hot solution was allowed to cool and later titrated against the 0.5M hydrochloric acid. A blank titration was carried out using the same procedure [5].

$$Saponification\ value = \frac{56.1M\left(V_1 - V_2\right)}{W} \quad (1)$$

Where:

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M = Molarity of hydrochloric acid.
V_1 = volume of HCl used in the test.
V_2 = volume of HCl used in the blank.
W = weight of sample oil.

3.2.2. Peroxide Value

A 2.0g of the oil sample was weighed into the 200ml conical flask containing 20ml of petroleum ether and heated for 30 seconds in a water bath. 20ml of 50% aqueous solution of potassium iodide and 25ml of distilled water were added. The resulting mixture was titrated with 0.002M sodium thiosulphate solution. During the titration a milky white precipitate was observed and the total disappearance of the precipitate indicated the end point of the titration. The peroxide value of the sample oil was estimated on the basis of the equation below. The same procedure was repeated for the blank [6].

$$Peroxide\ value = \frac{100\ (T_B - T_S)}{Weight\ of\ sample\ oil}\ mg\ Eqiv.O_2/kg \quad (2)$$

Where:

M = Molarity of thiosulphate
T_S = volume of thosulphate used in the sample test.
T_B = volume of thiosulphate used in the blank.

3.2.3. Acid Value

A 5g of the sample oil was weighed into a 250 ml conical flask. 50 ml of hot neutralized alcohol was measured into the flask. The content in the flask was boiled on a water bath, after which 5 drops of phenolphthalein indicator was added into the content of the flask. The mixture was then titrated with 0.1M sodium hydroxide using a burette until a pink colour was observed, indicating the end point [5].

$$Acid\ value = \frac{M \times T_B - T_S}{Weight\ of\ sample\ oil} \quad (3)$$

Where:

M = Molarity of sodium hydroxide.
T_S = Titre value of the sample.
T_B = Titre value of the blank

3.2.4. Iodine Value

A 0.2g of the sample oil was transferred into a flask containing 10ml carbon tetrachloride. 25ml of Wijs solution was added into the flask containing the sample (Wijs solution consists of iodine monochloride in glacial acetic acid). Blank was prepared. The mixture was stored in a dark place for 30 minutes at temperature of 25°C after which 15ml potassium iodine solution was added along with 100ml of distilled water. The resulting mixture was titrated with 0.1M sodium thiosulphate solution using 2ml of 1% starch indicator. The titration was continued until the blue colour just disappeared, indicating the end point [6].

The iodine value was calculated on the basis of the following equation:

$$Iodine\ value = \frac{12.692\ (T_B - T_S) \times M}{Weight\ of\ the\ sample\ oil} \quad (4)$$

Where:

M = Molarity of the solution.
T_S = Titre value of the sample.
T_B = Titre value of the blank

3.2.5. Unsaponifiable Matter

After saponification, 300ml of the mixed solvent of ethanol (70%), toluene (25%) and 5ml oil was added to the packed glass column. It was allowed to run through the column at the rate of 12ml / minute. The glass column was washed with 150ml of the solvent mixture at the same rate. It was concentrated to 25ml using rotary evaporator and then transferred to the tarred dish for evaporation in oven at 105°C for 15 minutes. The dried sample was weighed and titrated for the remaining acids; the weight was corrected for the unsaponifiable matter [4].

3.2.6. Specific Gravity

The sample (40ml) was homogenized and poured into a 500ml measuring cylinder gently to avoid air bubbles. The temperature was controlled to avoid drifting in the temperature value. Hydrometer was dipped into the oil carefully to avoid resting on the wall of the cylinder and the reading was recorded [6].

3.2.7. Refractive Index

The oil was dried to make it free of moisture. Two drops of the oil was put on the lower prism of the equipment and the prism was closed up. The water was allowed to pass through the jacket at 45°C, and the jacket was adjusted until the equipment read temperature of 40°C. The light was also adjusted and the compensator was moved until a dark border line was observed on the cross wire. The reading on the equipment was recorded [6]

3.2.8. Kinematic Viscosity

The capillary viscometer was used for kinematic viscosity determination. The sample was filtered to remove impurities; then introduced into the viscometer and allowed to stay in a regulated water bath long enough to reach the desired temperature. The head level of the test sample was adjusted to a position in the capillary arm of the equipment to about 5mm ahead of the first timing work. As the sample was flowing freely, the time required for the meniscus to pass from the first time mark to the second was read [7].

The equation used was:

$$V = C\ T \quad (5)$$

V - Kinematic viscosity
C - Calibration constant
T - Flow time in seconds

3.2.9. Flash and Fire Points

The dried sample was poured into the cup of the tester to the mark and placed the cup cover with the left hand pointing toward the left front corner of the test compartment. Stirrer driver was fixed into the tester properly and the resistance thermometer probe connected. Flame and the pilot light were carried out by lighting and the drought screen was closed. The tester was put on and the heater temperature was regulated. The stirrer was switched on simultaneously with the tester for homogeneity. A flash occurred when a large flame was observed on the cup and the temperature at which this occurred was recorded as the flash point for the oil sample. The fire point was temperature observed when the oil combustion was sustained after the flash point of the sample oil was recorded [8].

3.2.10. Pour Point

The sample was homogenized and poured into the test jar to mark level. The jar was closed tightly with the cork carrying the high pour thermometer that was placed 3mm below the surface of the oil. The disc was placed in the bottom of the jacket and the ring gasket was placed around the jar at the 25mm from the bottom. The test jar was then placed in the jacket. The oil was allowed to cool without disturbance to avoid error and the test jar from the jacket was removed carefully; tilted to ascertain whether there is a movement of the oil. The procedure continued in this manner until a point was reached at which the oil in the test jar showed no movement when the test jar was held in a horizontal position for 5 minutes [8].

3.2.11. Cloud Point

The determination of cloud point was done using a high precision cloud meter (wave guide sensor total - reflection type), the wave guide sensor has an incidence channel, emergence channel and a detector surface that intersect along the detection surface. The incidence optical fibre was connected to the exit of the emergence channel, and a heating / cooling of the wave guide sensor was done within a desired temperature range. The sample oil was placed on the detection surface and light introduced into the incidence optical fibre. The emergence light from the optical fiber was detected. The wave guide sensor was heated / cooled thereby heating / cooling the sample and the temperature wherein the total reflection of light in the emergence optical fibre, was the cloud point of the sample oil [8].

3.3. Fatty Acid Profile

The fatty acid profile was determined using a method described by Hall [9]. The fatty esters analyzed using a PYE Unicam 304 gas chromatography fitted with a flame ionization detector and PYE Unicam computing integrator. Helium was used as carrier gas. The column initial temperature was 150^{o}C rising at 5^{o}C min^{-1} to a final temperature of 200^{o}C respectively. The peaks were identified by comparison with those of standard fatty acid methyl esters.

4. Results and Discussion

4.1. Proximate Composition

Table 1 shows the results of proximate analysis on dry okra fruit. The value of moisture was higher than those of pearl millet, quinoa flour and benniseed [10] and *Parinari curtellifolia* (4.40%) [11]. It is worth nothing that all oil seed samples have low quantity of moisture [5], which makes them not susceptible to microbial attack. The value of moisture is very important when considering food preservation. High moisture reduces the shelf life of foods while low moisture content keeps the spoilage at insignificant level [12]. The value of crude protein (23.4%) in okra fruit was lower than those of *Luffa cylindrica* (32.7%) [13], gourd seed (30.9%), quinoa seed flour (13.5%) [5]. The dry okra fruit crude fibre (8.85%) was higher than those of pigeon pea (3.80%) reported by [14], cowpea (2.6%) [15], pearl millet (3.1%) [10] and pumpkin seed (2%) [16] but lower than quinoa flour (9. 50%) [5]. The high value of fibre reported for okra fruit can improve its digestibility and absorption processes in large intestine, helping to stimulate peristalsis, thereby preventing constipation [13]. The value of crude fat (6.33%) for dry okra fruit was lower than those of raw African mango seeds (54.7%) [17], *Luffa cylindrica* (32.7%) [13], benniseed (44.30%) [5] and soy bean (19.1%) [18], but in agreement with quinoa flour (6.30%) reported by [5]. Thus, the oil can be used for cooking and in the formulation of pomades and margarines [19]. The result of the ash (5.23%) obtained compared favourably with those of legumes like kidney bean (5.68%) [13], but higher than that of six varieties of dehulled African yam bean (AYB) (2.06-2.36%) [20] and fluted pumpkin seed (4.8%) [21]. The results showed that the sample contains fairly high ash content which indicates that the dry okra fruit would provide essential valuable and useful minerals needed for body development. The carbohydrate value of okra fruit was 42.7%. The carbohydrate content in dry okra fruit was lower than that of pearl millet [10]. Carbohydrate is essential for energy production in the human body as a result of oxidation. Tindal [22] confirmed that the edible portion of okra fruit is rich in carbohydrate and fibre. The value obtained for the carbohydrate was also lower than those for great northern bean [23] and Africa yam bean flour (61.66%) [12].

Table 1. Proximate composition of dry Nigerian okra fruit

PARAMETERS	%
Ash	5.23
Crude fat	6.33
Crude fibre	8.85
Moisture	13.6
Crude protein	23.4
Carbohydrate	42.7

4.2. Physico Chemical Properties

Table 2. Physico chemical properties of dry Nigerian okra oil

Parameter	Value
Saponification (mgKOH/g)	182.20
Peroxide value (mgEquiv.O_2/Kg)	7.31
Iodine value (mgI_2/100g)	112.16
Acid value (mgKOH /g)	3.39
Kinematic viscosity (Cst) @ 35^{o}C	52.13
Specific gravity	0.917
Unsaponifiable matter (%)	0.98
Refractive index at 40^{o}C	1.463
Free fatty acids (% Oleic acid)	0.12
Flash point (^{o}C)	242
Cloud point (^{o}C)	10
Fire point (^{o}C)	261
Pour point (^{o}C)	4

Table 2 shows the physico chemical properties of dry okra fruit oil. The results indicated that the saponification value (182mgKOH/g) was lower than those of shea-nut oil (195mgKOH/g), jatropha oil (193.55mgKOH/g) [24], quinoa oil (192.0mgKOH/g) [5], butter fat (220mgKOH/g) [25], coconut oil (253mgKOH/g) and palm kernel oil (247mgKOH/g) reported by [3]. According to Ezeagu *et al.,* [26], a saponification value of (200mgKOH/g) indicates high proportion of fatty acid of low molecular weight. It shows that the dry okra fruit oil have a potential as ingredient in industrial manufacture of soap, cosmetics and for the thermal stability of polyvinyl chloride (PVC). These properties make the okra oil source of essential fatty acids required in the body [27]. However, the saponification value was within the range for edible oils reported [28]. Iodine value is a measure of the degree of unsaturation in oil. The iodine value of okra oil (112.16 mgI_2/100g) reflects the presence of high percentage of unsaturated fatty acids in the seed oil [29]. The iodine value was a little above 100 and so it could be classified as semi drying oil. The iodine value (112.16 mgI_2/100g) was higher than those of quinoa oil (54 mgI_2/l00g) [5] and periwinkle (59 mgI_2/100g) [30]. This property enables it to be employed in the manufacture of soaps, lubricants and candles [31]. Acid value is an index of free fatty acid content due to enzymatic activity. The acid value (3.39mgKOH/g) presently obtained for okra oil was found to be lower than those of benniseed oil (4.76mgKOH/g) [10], calabash seed oil (5.92mg/KOH), lump-in-neck oil (4.59mgKOH/g) and bottle gourd seed (5.21mgKOH/g) [32]. The minimum acceptable value of 4.0mgKOH/g was recommended by Codex Alimentarius Commission for oil seeds [33]. The low acid value indicates that the oil would be suitable for manufacture of soap and it also finds application in cooking [34]. The specific gravity of the dry okra oil was 0.917. This value was lower than those of fluted pumpkin seed oil (0.955) [35], groundnut (0.918) [36], *Citrullus colocynthis* (0.910), *Citrullus linatus* (0.920) [32], neem seed oil (0.939) [35], bottle gourd seed (0.940) and lump-in-neck (0.930) [32]. The value obtained for dry okra oil shows that the oil is less dense than water as expected theoretically. The refractive index of the okra seed oil was 1.463 and this value was lower than those for pumpkin seed oil (1.470) and African star apple seed oil [37]. The refractive index (1.463) obtained for dry okra oil shows that the oil is not as thick as most drying oil whose refractive indices fall between 1.475 and 1.485 [38]. Peroxide value is an index of rancidity, thus, the high peroxide value of oil indicates a poor resistance of the oil to peroxidation during storage [39]. The peroxide value of okra oil (7.31mg Equiv.O_2/Kg) was below the maximum acceptable value of (10mgEquiv.O_2/Kg) set by Codex Alimentarius Commission for oil such as groundnut oil [33]. The low peroxide value further confirms the stability of the oil [40]. It serves as an indicator of the oil to resist lypolytic hydrolysis and oxidative deterioration [27]. The value obtained for okra oil was comparatively higher than those of legume oils (5.63-6.63meq/Kg) [32] and quinoa oil (2.44%) [5]. Free fatty acid is the hydrolytic activity of lypolytic enzymes during preparation of seeds for oil production. Free fatty acid value of okra oil was 0.12%. It is important in determining the use of oil for industrial or edibility purpose. The value obtained is within the allowable limit for edible oil (0-3) [41]. The value obtained was lower than those values for calabash seed oil (2.96%), bottle gourd seed oil (2.60%) and lump- in-neck (2.30%) [32]. Therefore, the oil may be used as edible oil. The unsaponifiable matter obtained for okra seed oil was 0.98%. The flash point (242°C) obtained for dry okra oil was higher than those of palm kernel oil (l40°C) and ghee diesel (l04°C) [42], conventional diesel fuel (55°C) [43], yellow oleander (190°C) and groundnut (270°C) [4]. Liquid fuel with a high flash point can prevent auto ignition and fire hazard at high temperature during transportation and storage periods. Hence, the higher the flash point, the higher is the safety during handling, transportation and storage [43]. Pour and cloud points are two important parameters for low temperature application of a fuel. The cloud point is the temperature at which wax first becomes visible when the fuel is cooled. The cloud point for okra oil (10°C) was lower than those of soybean ethyl ester (15^{o}C) and yellow oleander oil (14°C) but higher than those of soybean oil (9^{o}C) and diesel (7°C) [45] and groundnut oil (9°C) [44]. This value reported for okra oil was within the limits of cloud point suggested for vegetable oil (20°C maximum) [45]. The pour point is the temperature at which the amount of wax from a solution is sufficient to gel the fuel. The pour point of okra oil (4°C) was lower than that palm kernel oil (22 °C) [46] but higher than those of yellow oleander oil (2 °C) and groundnut oil (1 °C) [44]. The reason for the low pour point value obtained for dry okra seed oil may be due to the fact that it has a higher viscosity compared to palm kernel oil [46]. Viscosity is the lowest temperature at which the fuel can flow. Viscosity is the most important property of biodiesel since it affects the operation of fuel injection equipment, particularly at low temperatures when an increase in viscosity affects the fluidity of the fuel [47]. The value of kinematic viscosity

(52.13Cst) at 35 °C obtained for dry okra oil was higher than those values for vegetable oils between 27.2Cst and 53.6Cst and methyl esters between 3.6Cst and 4.6Cst. High viscosity leads to poorer atomization of the fuel spray and less accurate operation of the injectors [48]. Kinematic viscosity decreases with temperature and the viscosity of dry okra seed oil was higher than those of groundnut oil and some other conventional oils such as soybean (31Cst), cotton seed (36Cst) and sunflower (45Cst) at 300 °C [49]. The value of fire point (261°C) obtained was lower than those of heavy duty oil (SAE 40) 300 °C and light duty oil (SAE 30) 290°C [48] but higher than that of palm kernel (251 °C) [46]. It was quite clear that the dry okra oil had good fire point and could be compared with those of conventional lubricants like SAE40, SAE 30 and also yellow oleander oil (250°C) and groundnut oil (280°C) [44].

4.3. Fatty Acid Composition

Table 3 shows the fatty acid composition of dry okra oil. The results indicated that the most prominent of fatty acid in okra seed oil were: linoleic acid ($C_{I8:2}$) (30.94%) and oleic acid ($C_{I8:1}$) (29.l3%). linoleic acid ($C_{I8:2}$) was the most concentrated fatty acid with the value of 30.94% followed by oleic acid (29.13%). The value of linoleic acid was higher than that of periwinkle (27.9%) [30], but lower than those of pigeon pea oil (54.8%) [50] and soy bean oil (52.0%) [25]. The value of oleic acid in the sample was also higher than those of cat fish oil (11.1%), snake fish oil (13.7%) and tilapia fish oil (12.5%) [51].The high content of monounsaturated fatty acid (MUFA) especially oleic acid ($C_{I8:1}$) is associated with a low incidence of Coronary Heart Disease (CHD) because it decreases total cholesterol and low-density lipoprotein cholesterol [52]. Polyunsaturated fatty acids are also more prone to oxidation. In contrast, dietary intake of certain unsaturated fatty acid, in particular conjugated linoleic and fat - soluble antioxidants has been linked to potential health benefits [53].

Table 3. Fatty acid composition of dry Nigerian okra oil

FATTY ACID	CONCENTRATION (%)
Behenic acid ($C_{20:4}$)	0.339503
Lauric acid ($C_{12:0}$)	0.000000
Myristic acid ($C_{14:0}$)	0.278732
Palmitic acid ($C_{16:1}$)	0.267287
Margaric acid ($C_{17:0}$)	0.347652
Stearic acid ($C_{18:0}$)	5.390857
Oleic acid ($C_{18:1}$)	29.133627
Linoleic acid ($C_{18:1}$)	30.936392
Linolenic acid ($C_{18:2}$)	0.325445
Arachidic acid ($C_{18:3}$)	0.835694

High dietary intakes of saturated fatty acids (SFA) are risk factor for development of obesity, cardiovascular disease [53]. The total saturated fatty acid (TSFA) (38.98%) obtained was in agreement with (TSFA) of winged termite (39.9%) [54] but was higher than those of unroasted (17.8%) and roasted (17.5%) cashew kernel [54]. High levels of total blood cholesterol are associated with the incidence of CHD as well as high intakes of saturated fatty acids [55]. The (TSFA) of dry okra oil was higher than those cotton of seed oil (25.73%), peanut (18.38%), soybean (15.10%) and sun flower (12.36%) [56] but lower than those of palm (49.45%), palm kernel (80.34%) and coconut (90.69%) [56]. The major saturated fatty acid was palmitic acid ($C_{I6:0}$) (32.14%) which was also higher than those of coconut (10.08%), soybean (9.90%) and lower than that of palm (42.7%) [56]. The monounsaturated fatty acid (MUFA) (29.40%) of main interest is oleic acid ($C_{18:I}$) which was lower than those of African yam bean (0.69%) [20], cowpea bean (6.9%) [57], pigeon pea (10.0%) [50] and comparably related to the value of soybean (26.2%) [25], com (26.11%) and borage (25.25%) [56]. The MUFA was also higher than those of coconut (7.51%), palm kernel (16.90%), [56], while it was lower than those of peanut (50.33%) and rice bran (44.51) [56].

The result obtained from dry okra oil indicate that linoleic acid ($C_{I8:2}$) dominates the polyunsaturated fatty acid (PUFA) (31.26%). The value was slightly lower than those reported for soyabean (59.4%) [25], cowpea (59.6%) [57], pigeon pea [(59.8%) [50] and calabash seed (59.9%) [32]. PUFA of okra oil was lower than that African yam bean oil (32.85%) [20] and higher than those obtained for winged termites (8.6%), cashew kernel (unroasted) (16.0%) and cashew kernel (roasted) (17.5%) [54]. Oleic and linoleic acids were the major unsaturated fatty acid present in dry okra oil. The total unsaturated fatty acid (TUFA) (60.66%) was lower than those of rubber seed oil (76.80%), cashew seed oil (63.28%), pumpkin oil (83.90%) and castor oil (97.70%) [58]. The saturated fatty acids elevate serum cholesterol while polyunsaturated fatty acids lower serum cholesterol [59,60]. Polyunsaturated are the most important essential fatty acid required for growth, physiological functions and body maintenance [61]. However, the consumption of polyunsaturated fatty acid PUFA and MUFA have been recommended to improve the lipid profile in relation to the saturated fatty acids that increase the plasmatic cholesterol and obesity [62]. TUFA /TSFA of okra oil (60.66 / 38.98) was lower than those of pigeon pea (68.7 / 31.3), cowpea (66.5/32.3) [57] and cashew seed oil (63.28 /36.71) [58] but higher than those obtained for African yam bean (38.4 / 50.8) [20], soybean (84.4 / 14.0) [25], pumpkin oil (83.90 / 16.20), rubber seed oil (76.80 / 23.12) and groundnut oil (79.7 / 20.3) [58]. The total essential fatty acid (TEFA) of the oil was 31.26%. This value was lower than those of African yam bean oil (38.2%) [20], kidney bean oil (50.3%), soy bean oil (53.2%) [25], lima bean oil (41.0%) and pigeon oil (54.8%) [50,57]. The oleic / linoleic acids *(O/L)* ratio of dry okra oil (0.94) was higher than calabash seed oil (0.35), bottle gourd seed oil (0.39%), *Citrullus lunatus* oil (0.27) and *Citrullus colocynthis* oil (0.30) [32]. This ratio helps in determining the detrimental effects of dietary fats. The higher the ratio,

the more nutritionally useful is the oil [54].

5. Conclusions

It can be inferred from the present results that dry okra oil is rich in essential fatty acids and is a good source of edible oil. It also exhibits good and quality physico chemical properties which are comparable with some conventional oils.

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