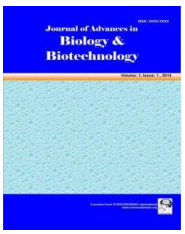

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Comparative Physical Characterization, Physio-Chemical and Fatty Acid Composition of Some Edible Vegetable Oils

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Authors' contributions

This work was carried out in collaboration between all authors. Author NME designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors OEO and SCB managed the literature searches, executed the experimental protocol and editing of the manuscript. Author OEO performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Edible vegetable oils which include red palm oil, coconut oil, groundnut oil, sesame oil (Beniseed oil), soybean oil, palm kernel oil, etc. are derived from seeds or fruits of different plants. These oils are consumed not only for their supply of lipids in the diets but for their distinct aromas, colours, palatability and availability. Vegetable oils are rich in essential nutrients such as vitamins and anti-oxidant compounds. The type of diet and in particular the nature of dietary fats has been found to raise or lower the blood cholesterol in man. This study was therefore necessary as it will assess and ascertain the physiochemical and fatty acid characteristics of the various vegetable oils available in the Nigerian markets. The various physiochemical and fatty acid parameters were estimated using standard procedure. Results indicate that red palm oil had high levels of palmitic and oleic acids as well as peroxide and iodine values, with high fire and boiling points. Coconut oil had high peroxide, saponification and acid values, high concentrations of capric, lauric, palmitic, myristic, stearic and linoleic acids with high smoke point. Palm kernel oil had high iodine, saponification and acid values, high contents of capric, lauric and myristic acids with high flash, fire and boiling points. Oleic and stearic acids were in turn very high in soybean,

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sesame. In conclusion, results indicate that red palm oil, soybean and sesame oil would be safer for consumption since there are less atherogenic compared with the other vegetable oils.

Keywords: Edible vegetable oils; physio-chemical and fatty acid compositions.

1. INTRODUCTION

Vegetable oil is derived from seeds or fruits of plants which grow in different parts of the world. Several hundreds of varieties of plants are available and the dietary consumption of seeds and fruits has been on the increase in the past years period. Due to the growing importance of vegetable oil in human nutrition, there has also been an increase in the production and consumption of edible oil, although some of these vegetable oils are inedible, (example, linseed oil, fungi oil, castor oil).They are used for paints, as lubricants, pharmaceutical components and other industrial purposes. Edible oils include red palm oil, coconut oil, groundnut oil, sesame oil (Beniseed oil), soybean oil, palm kernel oil, etc. [1].

These oils are consumed not only for their supply of lipids in the diets but for their distinct aromas, colours, palatability and availability. These oils are rich in essential nutrients such as vitamin sand anti-oxidant compounds [2]. Dietary oils serve as the major source of lipid in the diet, the type and amount of dietary lipid has been strongly linked to the incidence of several degenerative diseases [3,4]. Polyunsaturated fats have been recommended to reduce coronary heart disease [5]. Epidemiological investigations have also shown that the frequency of coronary heart disease and blood cholesterol level are related to eating habits [6]. The type of diet and particularly the nature of dietary fat have been found to raise or lower the blood cholesterol in man.

The role played by vegetable oils and the various fractions in atherosclerosis is not clear. It has also been reported that palm oil was atherogenic in rabbits [7]. Furthermore, the important physiological role played by the minor components present in palm oil is becoming apparent [8]. It is therefore necessary to continually evaluate the type of lipids that are in our diets.

This study was necessary as it would assess and ascertain the physiochemical and fatty acid characteristics of the various vegetable oils available in the Nigerian markets.

2. MATERIALS AND METHODS

2.1 Chemicals and Reagents

All the chemicals used in this study were of analytical grade. The chemical were obtained from the British Drug House (BDH) Chemical Limited Pole, England and Sigma Chemical Company, St. Louis, MD USA.

2.2 Collection of Experimental Samples

Vital feed (palletized grower feed) were purchased from vital feed depot in Calabar, Cross River State Nigeria. Red palm oil, palm kernel oil and soybean oil were purchased from a

ocal market (Watt Market) in Calabar South Local Government Area of Cross River State, Nigeria, while coconut oil and beniseed oil (sesame oil) were extracted from their fruits.

2.3 Physiochemical Property of Vegetable Oils

The physiochemical property was carried out on the different vegetable oils: red palm oil, palm kernel oil, Soybean oil, coconut oil, and sesame oil using a standard recommended method [9].

2.3.1 Determination of Iodine value

To determine the iodine equivalent of these vegetables oils, about 5ml of chloroform was placed in a dry conical flask and 5ml of Dam's iodine solution added to it from a burette set up in the fume cupboard. After 35minutes, 5ml of 100 percent of freshly prepared potassium iodide and 20ml of water were added and stirred gently so as to mix well. The solution was titrated with 0.025N standard sodium thiosulphate, solution with constant agitation to ensure thorough mixing of the two layers. When the solution was added, pale yellow colouration was obtained, few drop of starch solution were added and titration continued until both phases were colourless [9].

2.3.2 Determination of saponification value

In a 50ml quick fit flask 1.0g of the oil sample was weighted to the nearest 0.001g.Using a pipette 25ml of 0.5ml ethanolic potassium hydroxide solution was added and the reaction mixture shaken briefly on electric shaker. A reflux condenser was then attached to the flask and the solution was refluxed for 60minute using heating mantle. After refluxing, 0.05ml percent of phenolphthalein indicator was added. The solution was then titrated to a colourless end point with 0.5molar solution of hydrochloric acid. A blank determination was carried out simultaneously under the same condition. Three determinations were carried out for each sample [9].

2.3.3 Determination of peroxide value

In a 250ml conical flask 5.0g of the oil sample was weighted to the nearest 0.001g and 10m of chloroform was added. The flask was gently swirled to dissolve the oil. Glacial acetic acid (15ml) was added followed by addition of 1ml of saturated potassium iodide solution using a pipette. The flask was immediately stopped shaken for one minute and placed in a cupboard away from light for a minute. Later 75ml of distilled water was added and vigorously shaken followed by addition of 2 drops of 1 percent starch solution. The liberated iodine was titrated to the end point. (The disappearance of the last trace of the initial blue colour with 0.01 molar solution of sodium thiosulphate run from a burette serves as the end point).

2.3.4 Determination of acid value

1 gram of the oil sample was dissolved in exactly 150ml of V/V 95% ethanol and benzene solvent mixture. The solution was titrated to the end point (pink colour of phenolphthalein) persisting for at least 10second with oil methanolic potassium hydroxide solution run from the burette.

2.3.5 Determination of refractive index

The oil was rendered optically clear and free from water before the determination. The space between the two prisms was filled with the oil and the thermometer of the instrument (refractometer) was allowed to have a constant temperature for 10minutes before the reading was taken. This was done at room temperature. Three determinations were carried out for each sample [10].

2.3.6 Determination of physical property of the vegetable oils

The melting point of the vegetable oil was determined using capillary method. 1g of the oil was placed in a thermometer so that the column of the material was well beside the bulb of the thermometer. The thermometer was carefully clamped and its bulb was inserted in a beaker of paraffin oil. The paraffin oil was heated, the temperature which the solid collapsed was noted and the temperature at which a clear liquid form was also noted. The melting point was taken as the range between the two values [11].

2.3.7 Determination of smoke point

The smoke point is the temperature of which smoke is first detected in the laboratory apparatus from drafts and provided with special illumination the temperature at which oil smokes freely is usually somewhat higher [12].

2.3.8 Determination of flash point

Flashpoint is the temperature at which the volatile products are evolved at such a rate that they are capable of being ignited but not capable of supporting combustion.

2.3.9 Determination of fire point

25ml beaker was filled with the oil sample and place on a heating source (electric heater). A thermometer was vertical suspended in the center of the beaker from the bottom of the bulb appropriately 6.35mm from the bottom of the bulb. The sample was then heated rapidly to about 42ºc and there after the heat was regulated at 60ºc increase per minute. A flame was continuously passed on top at the beaker until the oil cut fire. And the temperature indicated by the thermometer was recorded [10].

2.4 Determination of Fatty Acid Profile

2.4.1 Principle

Triacylglycerol esters of fats and oils are converted into more volatile esters which are then subjected to separation using GLC and aliquot detected using a flame ionization detector or thermal conductivity detector [9].

2.4.2 Procedures

Weight about 350mg of the oil into a 50ml flask add 6ml of approximately 0.5M methanol, sodium hydroxide and some boiling granules and boiled under reflux for 5-10minute or until the droplets of oil disappear. Through the condenser by means of a graduated or automatic pipette add 7ml of commercially prepared 14 percent BF_3 (Boron trifluoride) in methanol and

continue boiling for a further 2 minute. Add through the condenser 2-5ml of heptane and continue boiling for 1 minute cool and add saturated sodium chloride (NaCl) solution with swirling. Transfer about 1ml of the heptane layer into a small-stoppered test tube, or vial and add a little anhydrous Na_2SO_4 (disodium sulphate).This solution will contain about 100mg/ml of methyl esters suitable for GLC. (The heptane layer is aspirated with syringe and needle for GLC injection [9].

3. RESULTS

3.1 Physiochemical Properties of the Experimental Oil

3.1.1 Peroxide value (mg/g)

Red palm oil recorded the highest peroxide value followed by coconut oil, sesame oil, soy bean oil and palm kernel oil respectively, Table 1.

Table 1. The result of physicochemical properties of the different experimental oils (mg/g)

Parameters	RPO	PKO	CCO	SBO	SSO
Peroxide value	1.14±0.006	0.21±0.004	0.45±0.003	0.28±0.003	0.33±0.008
Iodine value	19.43±0.008	12.39±0.04	3.15±0.005	6.33±0.006	7.23±0.008
Saponification value	2.66±0.008	28.04±0.01	98.53±0.07	13.47±0.06	3.29±0.05
Acid value	0.67±0.006	0.17±0.005	0.17±0.006	0.045±0.005	0.22±0.006
Refractive index	1.36±0.009	1.44±0.01	1.42±0.006	1.44±0.008	1.47±0.007

Values are mean ± SEM.
RPO = red palm oil, PKO = palm kernel oil,
CCO = coconut oil, SBO = soybean oil, SSO = sesame oil.

3.1.2 Iodine value

Red palm oil and palm kernel oil recorded high iodine values of19.43 and 12.39 mls respectively. Sesame oil, soy bean oil and coconut oil recorded iodine values of 7.23, 6.33 and 3.15 mls respectively. Coconut oil recorded the least.

3.1.3 Saponification value

Coconut oil recorded the highest saponification value of 98.53. This was significant ($P<0.05$) when compared to a value of 28.04 recorded by palm kernel oil. Soy bean oil, sesame oil and red palm oil recorded the lowest saponification values of 13.47, 3.29 and 2.66 respectively.

3.1.4 Acid value

All the experimental oil recorded acid values which were less than 1. Soy bean oil recorded the lowest acid value of 0.05. Red palm oil recorded an acid value of 0.67, palm kernel oil, coconut oil and sesame oil recorded acid values of approximately 2.

3.1.5 Refractive index

The refractive index of the various oils ranged from 1.36 in red palm oil to 1.47 mg/g in sesame oil.

3.2 The Result of Fatty Acid Composition of the Different Experimental Oils (% Composition)

3.2.1 Cupric acid

Soybean oil, sesame oil and red palm oil did not contain any amount of cupric acid. However, coconut oil and palm kernel oil contained 7.12±0.04% and 3.41±0.01% of cupric acid, while that of coconut oil was significantly higher ($p<0.05$) than that of palm kernel oil (Table 2).

Table 2. Result of fatty acid composition of the different experimental oils (% composition)

Parameters	SBO	SSO	CCO	RPO	PKO
Alphalinolenic acid[c]	6.29±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Stearic acid[a]	3.51±0.04	5.19±0.005	5.35±0.004	4.61±0.005	2.51±0.005
Cupric acid[a]	0.00±0.00	0.00±0.00	7.12±0.004	0.00±0.00	3.41±0.006
Oleic acid[b]	23.14±0.04	40.02±0.006	7.05±0.004	38.65±0.02	13.31±1.99
Palminoleic acid[b]	0.00±0.00	0.51±0.005	0.00±0.00	0.00±0.00	0.00±0.00
Linoleic acid[c]	56.70±0.05	1.01±0.007	0.00±0.00	10.51±0.02	2.31±0.008
Linolenic acid[c]	0.00±0.00	43.21±0.04	4.16±0.004	0.00±0.00	0.00±0.00
Caprylic acid[a]	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Eicosanoid acid[c]	0.00±0.00	1.00±0.004	0.00±0.00	0.00±0.00	0.00±0.00
Lauric acid[a]	0.00±0.00	0.00±0.00	45.02±0.004	0.00±0.00	48.32±0.08
Myristic acid[a]	0.00±0.00	0.00±0.00	18.46±0.007	1.00±0.004	16.18±0.02
Palmitic acid[a]	10.48±0.04	9.30±0.06	9.84±0.005	44.35±0.04	8.41±0.005
Total fatty acid	100.12±1.39	100.24±1.32	97.00 ±1.07	99.12 ±1.32	94.45±1.16

Values are mean ± SEM. a = saturated; b = monosaturated; c = polysaturated.
RPO = red palm oil, PKO = palm kernel oil,CCO = coconut oil, SBO = soybean oil, SSO = sesame oil.

3.2.2 Caprylic acid

All the oils did not contain any caprylic acid.

3.2.3 Lauric acid

Coconut oil and palm kernel oil samples contained 45.02±0.07% and 48.32±0.08% of lauric acid respectively. Soy bean oil, sesame oil and red palm oil lacked lauric acid.

3.2.4 Palmitic acid

Red palm oil had the highest amount of palmitic acid (44.35±0.04%). The palmitic acid content of soy bean oil, sesame oil, palm kernel oil and coconut oil oils ranged from between 8-12%.

3.2.5 Myristic acid

While red palm oil contained approximately 1% of myristic acid, palm kernel oil and coconut oil contained 16% and 18% myristic acid respectively. Soy bean oil and sesame oil did not contain any myristic acid.

3.2.6 Palmitic acid

Palmitic acid (0.5%) was only recorded in sesame oil. Other oils did not contain palmitic acid.

3.2.7 Oleic acid

Coconut oil contained about 7% of oleic acid, this was low when compared to 15% in palm kernel oil, 23% in soy bean oil, 38% in red palm oil and 50% in sesame oil.

3.2.8 Stearic acid

Palm kernel oil, sesame oil, red palm oil, coconut oil and soy bean oil respectively contained 2%, 3%, 4%, 5% and 6% of stearic acid.

3.2.9 Linolenic and and alpha-linolenic acid

Sesame oil and coconut oil contained 50% and 4% of linolenic acid respectively. Soy bean oil was the only oil that contained alpha-linolenic acid (6%).

3.2.10 Linoleic acid

Soy bean oil contained 56% of linoleic acid while red palm oil contained 10%. Palm kernel oil and sesame oil contained 2% and 1% respectively.

3.2.11 Ecosanoic acid

Apart from SSO which had 1% ecosanoic acid, all other oils did not contain ecosanoic acid.

3.2.12 Total fatty acid extracted from each oil

Soybean and sesame oils had the highest total fatty acid of 100.12±1.39% and 100.24±1.32% respectively. The least total fatty acid was recorded of palm kernel oil as 94.45±1.16%, while coconut and red palm oils had total fatty acids of 97.00±1.07% and 99.12±1.32% respectively.

3.3 Comparison of Physical Properties of the Different Experimental Oils (ºC)

3.3.1 Flash point

Palm kernel oil recorded a flash point of 244.86±0.51ºC which was the highest compared to soy bean oil, red palm oil, sesame oil and coconut oil which recorded values of 233.00±0.84ºC, 223.14±0.74ºC, 223.86±0.72ºC and 202.86±0.51ºC respectively (Table 3).

3.3.2 Fire point

Palm kernel oil recorded the highest fire point of 376.61±0.21ºC which was significantly higher when compared to red palm oil, soy bean oil, sesame oil and coconut oil which recorded values of 265.86±1.13ºC, 264.57±0.72ºC, 262.83±0.81ºC and 257.32±1.00ºC respectively.

Table 3. Physical properties of experimental oils (ºC)

Parameters	RPO	PKO	CCO	SBO	SSO	F-test
Boiling point	134.10±0.41	138.27±0.29	122.56±0.51	125.23±0.18	116.86±0.67	380.8736 (p<0.001)
Smoke point	197.43±0.57	191.29±0.42	213.71±0.75	195.86±0.51	184.86±0.51	364.5453 (p<0.001)
Flash point	223.00±0.72	244.86±0.51	202.86±0.51	233.57±0.84	223.14±0.74	525.8145 (p<0.001)
Fire point	265.86±0.61	376.71±0.61	255.57±1.13	266.86±0.80	264.57±0.68	4176.115 (p<0.001)
Melting point	35.62±0.005	38.60±0.05	13.39±0.06	13.63±0.07	12.66±0.06	62292.85 (p<0.001)

Values are mean ± SEM. RPO = red palm oil, PKO = palm kernel oil, CCO = coconut oil, SBO = soybean oil, SSO = sesame oil.

3.3.3 Boiling and melting points

Palm kernel oil recorded the highest boiling point of 138.2±0.41ºC. Red palm oil, sesame oil, coconut oil and sesame oil recorded boiling points of 138.27±0.29ºC, 125.23±0.18ºC, 122.56±0.51ºC and 116.86±0.67ºC respectively.

Palm kernel oil also recorded that highest melting point of 38.60±0.05, followed by red palm oil, 35.62±0.005. Sesame oil had the least melting point of 12.66±0.06.

3.3.4 Smoke point

Coconut oil had the highest smoke point of 213.71±0.75ºC followed by soy bean oil and red palm oil which recorded smoke point of 197.43±0.57ºC, and 195.86±0.51ºC respectively. Palm kernel oil and sesame oil recorded smoke points of 191.29±0.42ºC and 184.86±0.51ºC respectively.

4. DISCUSSION

The word vegetable oil is quite common and familiar to most people because oil is widely identified as an important ingredient for food preparation. But fat is not a common terminology, although oils are referred to as fat especially those of plant origin like red palm oil, soya bean oil, palm kernel oil, beniseed or sesame oil, as well as coconut oil are liquid at room temperature while the animal fats which are commonly referred to as fats are solid at room temperature, Fats and oil are collectively called lipids which are defined as water-insoluble organic bio-molecules found in plants and animal. There are simple and complex lipids. The simple lipids do not contain fatty acid and so are non-saponifiable. They are hydrocarbons which the body cannot absorb or metabolize and so are not edible. The complex lipids, which are fat and oil just as protein and carbohydrates are broken down by the body into simpler units (fatty acid) before they are utilized [5].

Fatty acid are carboxylic acid obtained from hydrolysis of esters of mainly glycerol and cholesterol is also described as the building blocks of complex lipids, they differ from one another not only by the number of carbons in their chain, but by the number of double bonds between the carbon atom [13]. All fatty acid possess a long hydrocarbon (CH) chain and a carboxyl group (COOH) at the end.

The carbon and hydrogen chain may be saturated when all the available space for linkage is taken by hydrogen ions, leaving one single bonds. Polyunsaturated fats have been recommended to reduce coronary heart disease [5]. All saturated fat do not have the same effect on cholesterol synthesis in the liver. Only the saturated fat of chain-length 12,14 and 16 (lauric, myristic and palmitic acid) have been shown to elevate blood cholesterol and of these fatty acids, on the other hand, myristic acid (as found in high coconut and palm oils) elevates cholesterol the most [14]. Stearic acid (18 carbon saturated) has been shown to lower cholesterol by 21% even more than oleic acid (18-carbon mono unsaturated) which lowers LDL by 15% [15].

Studies in 1991 by Hayes et al. [8] indicate that among the long chain saturated fatty acid, stearic acid appears to have a neutral effect on total cholesterol and low density lipoprotein (LDL) otherwise known as bad cholesterol.

Other studies have also confirmed that palmitic acid, lauric acid and myristic acid increase total blood cholesterol, LDL cholesterol, high density lipoprotein and LDL/HDL ratio in both non-human primate, and normo-cholesterolemic men and women who consumed a typical western diet. In this study, lauric acid, palmitic acid and myristic acid have been most in palm kernel oil and coconut oil, an indication that these oils would have more adverse effect on the body compared to other vegetable oils. On the other hand, red palm oil, soybean oil and sesame oil had low levels of these fatty acid hence would cause less problems to the body. Red palm oil for instance has been reported as a potent anti-cancer, anti-atherogenic and blood pressure stabilizing agent [16,17].

Oleic acid is a monounsaturated fatty acid, studies have found that oleic acid has beneficial effect on total cholesterol, LDL, and HDL compared with saturated fats [15,18]. Our study also provides evidence that oleic acid was high in sesame and red palm oils, which further justifies the protective nature of red palm oil.

The dramatic increase in soybean oil sales is largely credited to the Food and Drug Administration's [19] approval of soybean oil as an official cholesterol lowering food; along with other heart and health benefits. A 2006 literature review argued that these health benefits were poorly supported by the available evidence, and noted that disturbing data on soy's effect on the cognitive function of the elderly exists [20].

In conclusion, palm kernel oil and coconut oil have high levels of lauric, palmitic and myristic acids, these acids were low in soybean, sesame and red palm oil. Oleic and stearic acids were in turn very high in soybean, sesame and red palm oils. The results indicate that red palm oil, soybean and sesame oils would be less atherogenic compared with the other vegetable oils. Hence, red palm oil, soybean and sesame oils appear to be safer than other edible vegetable oils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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