Comparative Study of the Physicochemical Characterization and Quality of Edible Vegetable Oils

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ABSTRACT

The comparative study of physicochemical characterization and quality of edible vegetable oils was done in this work using standard analytical techniques. These oils include: Elaeis guineensis jacquin (palm oil), Glycine max (L.)Merr. (soybean oil),Cocus nucifera (coconut oil), Arachis hypogaea L.(groundnut oil), Olea europaea (Olive oil), Sesamum indicum. L. (sesame seed oil),Brassica campestris L. (mustard seed oil), and palm kernel oil (PKO). The range of the values obtained are as follows: saponification value (SV): 5.58 - 249.90 mgKOH/g, peroxide value (PV): 0.45 -290.00 mEqO$_2$/kg of sample, acid value (AV): 0.34 - 68.88 mgKOH/g, iodine value (IV): 0.45 - 16.37g I$_2$/100g sample, density (Ds): 908.9 - 919.6kg/m^3, viscosity (Vs): 20.58– 77.97 mm^2/sec, specific gravity (SG): 0.9089- 0.9196, and refractive index (RI): 1.4578 – 1.4773. The studied characteristics of the oil samples in most cases compared favorably with; FAO/WHO (CODEX Alimentarius) values. There were some observed levels of significant differences in the values at $p \leq 0.05$. The data also showed that the oil quality is good and edible inferring from their low AV. Their IV values which were inconsistent with standard values may have been affected by storage conditions and exposure to air and light. On the other hand, their low PV serves as indicators of the presence or high levels of anti-oxidants in the oils. The result of the work confirms these edible oils to be of good quality..

Keywords: *Edible oil, physicochemical, vegetable oils*

1. INTRODUCTION

Edible vegetable oils are "foodstuffs which are composed primarily of glycerides of fatty acids being obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, of unsaponifiable constituents and of free fatty acids naturally present in the fat or oil" (CODEX-STAN2005).

Oil characterization is the basis for further nutritional and food technological investigations such as adulteration detection (Sarojam, P. 2009). The most common adulteration is the addition of a cheaper vegetable oil to expensive oil. Oil authenticity is a very important quality criterion for vegetable oil and fats because there is a big difference in prices of different types of oil and fat products. Adulteration detection is possible by determining the ratio of the contents of some chemical constituents and assuming these ratios as constant for particular oil.

Oil quality is the physical and chemical properties of fats or oils that are necessary for any specific purpose as stated in a product specification or certificate of analysis. A number of factors have been reported to affect oil quality and include pre-processed factors such as growing season, soil fertility, post-harvest storage conditions such as temperature and post process factors such as heat-thermal degradation and air contact (Turner, 2010).The quality of the vegetable oil therefore is a measure of its identity and edibility.

Oils are known to decompose over time producing unpleasant taste and odour. This is called rancidity. It is caused by the presence of free fatty acids and by atmospheric oxidation. Therefore, a number of parameters have been used

to characterize the identity and edibility of vegetable oils. The basic parameters are colour, odour, and taste. Others include, moisture content, insoluble impurity, iron (Fe), copper (Cu), fatty acid content and antioxidants; acid value (AV), peroxide value (PI), iodine value (IV), refractive index (RI), relative density (RD), and microbial content (Ronald and Ronald, 1989, Williams, 1990, BP, 1993; Prescott *et al*. 2002). The microbial content parameters consist of moulds, coliform, *E. coli* and aerobic mesophillic bacteria, etc. (Robertson, 2005; Alo, 2005).
In this work, the characterization and quality assessment of eight types of vegetable oils was done. This is to ascertain their authenticity, freshness, storability and toxicity. This will provide information that will encourage routine quality monitoring of the sources of these types of edible oils obtained from retailers. The objectives of this study are to determine the quality characteristics of the selected edible vegetable oil samples and to assess quality of the oils by comparison with FAO/WHO (CODEX Alimentarius) and other literature values.

2. MATERIALS AND METHODS

2.1 Sampling

For the purpose of this analysis, samples of 8 different types ofimported refined and locally produced vegetable oils were considered. Popular brands of these products were all obtained from retailers in Enugu, Nigeria. These samples were kept in polyethylene bags and taken to the Chemical Analysis Laboratory of Materials and Energy Technology Department of Projects Development Institute (PRODA) Enugu. They were stored in a cool dry place prior to further analysis.

2.2 Methods

The following chemical determinations were carried out according to the methods described in the A. O. A. C.21st edition, 2011:

- **Iodine number:** A.O.A.C. 21stedn, 2011, Official Method 923.2, Iodine Value of Fats and Oils, Wijs (Carbon tetrachloride solvent) Method.
- **Acid Value:** A.O.A.C. 21st edn, 2011, Official Method 969.17, Acid Value of Butterfat.
- **Peroxide value:** A.O.A.C. 21st edn, 2011, Official Method 965.33, Peroxide Value in Oils and Fat.
- **Saponification Number:** A.O.A.C. 21st edn, 2011, Official Method 920.16, Saponification Number (Koettstorfer number of Oils and Fats).
- **Refractive Index: AOAC.** 21st edn, 2011, Official Method 921.08, Index of Refraction of Oils and Fats using are fractometer (Mettler Toledo RM 40/ RM 50 refractometer).
- **Specific Gravity:** AOAC. 21st edn, 2011, Official Method 920.212, Specific Gravity (Apparent) of Oils: Pycnometer Method.
- **Kinematic Viscosity:** The kinematic viscosity (υ, mm^2/s) was determined with Cannon-Fenske viscometers (Cannon Instrument Co., State College, PA) at 25° C in accordance to ASTM D 445.
- **Density:** The densities (ρ) of the oil samples were determined by multiplying the values of the specific gravity by 1000.

2.3 Data Analysis

Results obtained from each determination are presented as mean ± SD (standard deviation). Test for significance in variations was conducted by analysis of variance (ANOVA) using IBM SPSS Statistics version 20. Variations were considered significant at $p<0.05$.

3. RESULTS AND DISCUSSION

Table 1 shows a summary result of the physicochemical characterization of edible oils determined in this work.

Table 1: Some Typical Quality Parameters of Edible Oils

Sample	Refractive Index (n_D 25°C)	Iodine Value (gI_2/100g)	Peroxide Value ($MeqO_2$/kg)	Acid Value (mg KOH/g)	Saponification Value (mgKOH/g)	Specific Gravity (25°C)	Kinematic Viscosity (40°C)(mm^2/s)	Density (kg/m^3)
G.nut Oil	1.4707±0.00	0.45±0.09	4.40±0.57	0.85±0.13	195±1.98	0.9114	35.28	911.40
Mustard Oil	1.4762±0.00	5.71±0.54	10.20±0.28	0.56±0.11	230±7.90	0.9136	27.80	913.60
Soya Oil	1.4773±0.00	6.47±0.54	1.20±0.00	0.35±0.06	196±0.00	0.9170	26.32	917.00

Coconut Oil	1.4578±0.00	7.59±0.50	3.00±0.28	0.31±0.00	252±15.7	0.9196	20.58	919.60
P.K.O	1.4585±0.00	5.40±0.09	1.50±0.14	2.75.±0.11	188±11.9	0.9159	26.90	915.90
Olive Oil	1.4706±0.00	16.37±0.18	2.30±0.14	0.48±0.00	192±1.60	0.9089	32.01	908.90
Sesame Oil	1.4739±0.00	15.48±1.80	0.80±0.00	1.34±0.11	185±0.00	0.9172	27.30	917.20
Palm Oil	1.4684±0.00	6.10±0.36	1.30±0.14	2.67±0.00	160±3.97	0.9163	77.97	916.30

3.1 Refractive Index

The result of the refractive indices RI of the oil samples in Table 2, indicated that soya oil had the highest RI at 1.4773 while the least value was observed in coconut oil at 1.4578.

Table 2: Refractive Index and FAO/WHO (Codex) values

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	1.4707	1.4578	1.4762	1.4684	1.4585	1.4739	1.4773	1.4706
CODEX 2005	1.460-1.465	1.448-1.450	1.461-1.469	1.454-1.456	1.448-1.452	1.465-1.469	1.466-1.470	1.468-1.471

The variation observed in these values is significant since $p<0.05$.This variation is understandable since different oils have characteristic refractive indices. Refractive index of an oil is the ratio of speed of light at a defined wavelength to its speed in the oil/fat itself. This value varies with wavelength and temperature, the degree and type of unsaturation, the type of substitutions of component fatty acids and with accompanying substances. Refractive index is widely used in quality control to check for the purity of materials and to follow hydrogenation and isomerization (Hoffman, 1986).When vegetable oils are contaminated with particulate matters and chemical adulterants such as potassium hydroxide, a chemical reaction takes place. This reaction takes place between fatty acids of vegetable oils and potassium hydroxide produces soap (carboxylic acid ester). This alters the optical activity of the vegetable oils and increases the susceptibility of the vegetable oils to become rancid or spoiled (Williams, 1990).

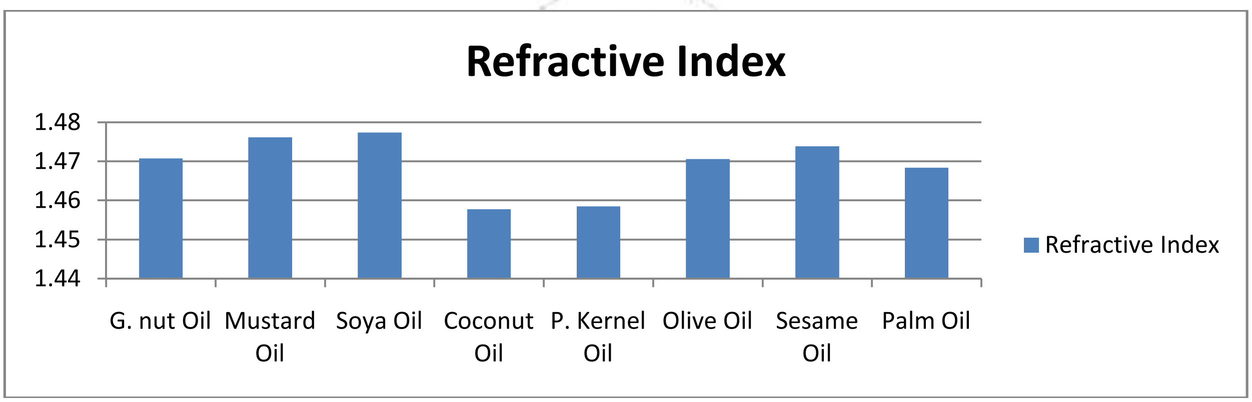

Figure 1: Refractive Indices of Edible Oils

3.2 Density

The density, like the refractive index is also physical measure of adulteration of vegetable oils. Each oil sample is identified by its characteristic density. The density of the oils varies with each type and temperature. Density of vegetable oils is dependent on their fatty acid composition, minor components and temperature (Fakhri & Qadir, 2011). The difference in the density of the oils may be due to the refined and unrefined characteristics of the oils. The range is from 908.9 - to 919.6 kg/m^3 at 25 °C. When compared to water, whose density is 1.00 kg/m^3, edible oils are less dense.

Table 3: Densities of edible oil and literature values

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work Kg/m^3	911.4	919.6	913.6	916.3	915.9	917.2	917.0	908.9
Literature Data*	913.0	919.0	850.0	9.119	1.448-1.452	1.465-1.469	1.466-1.470	918.0

*Ullmann's encyclopedia of industrial chemistry, Vol A 10, Fats and oils, VCH, Weinheim 1995, Bailey's Industrial oil & fat products, 6th edition 2005,Wiley-Intersience New York, Physical and chemical characteristics of oils, fats, and waxes, Champaign, Illinois, AOCS Press, 2006, Manuel des corps grass, AFCEG, Paris 1992

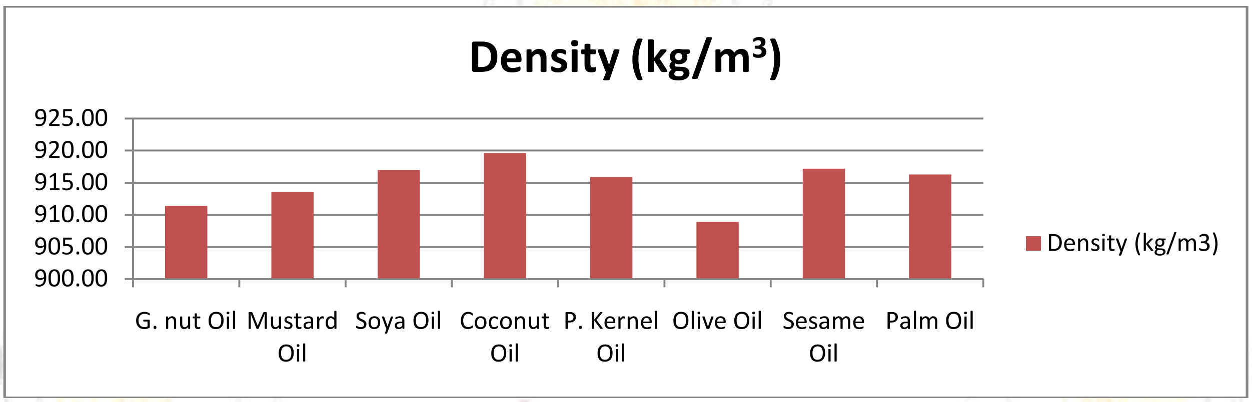

Figure 2: Densities of edible oils

The values obtained show that the densest oil is coconut oil at 919.6 kg/m^3 while the least dense oil is olive oil at 908.9kg/m^3.

3.3 Kinematic Viscosity

Viscosity increased with the molecular weight and decreased with increasing unsaturated level and high temperature (Nourrechni *et al.*, 1992). The viscosity of the investigated oils ranges from 20.58mm^2/s to 77.97mm^2/s in coconut and palm oils, respectively. The more viscous oil is, the better its use as lubricant (Belewa *et al.*, 2010). This implies that palm, groundnut and olive oils will have high lubricating properties. Oils with low viscosity values indicate that they are light and so probably highly unsaturated; the high value might be as a result of suspended particles still present in the crude oil sample (Nangbes *et al.*, 2013).

Table 4: Kinematic viscosity values of edible oils

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	35.28	20.58	27.8	77.97	26.90	27.30	26.32	32.01
Literature Data	42*	29.8- 31.6*	44.1**	42*		39.6*	35.4*	47.8*

*https://www.engineersedge.com/fluid_flow/kinematic-viscosity-table.htm

**Sobahan, M and Nobuyoshi, O.Prospect of Mustard and Coconut Oil as Environment Friendly Lubricant for Bangladesh Proc. of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, Sept. 2010

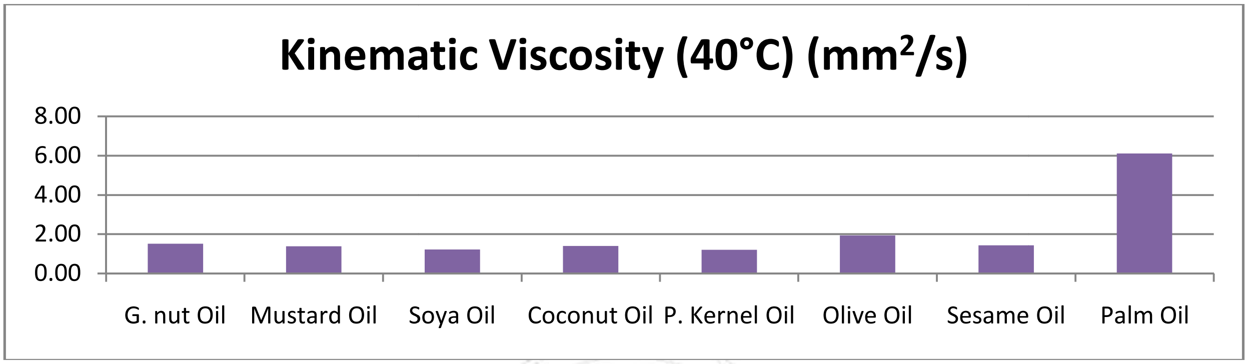

Figure 3: Kinematic viscosity of edible vegetable oils

3.4 Specific Gravity

According to Yahaya *et al*. (2012), specific gravity is commonly used in conjunction with other figures in assessing the purity of oil. This is a dimensionless unit defined as the ratio of density of the substance to the density of water at a specified temperature. It is a physical quality parameter of edible oils. Edible oils have characteristic specific gravities which are used for their identification.

Table 5: Specific Gravity of edible oils

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work @ 25°C	0.911	0.920	0.914	0.916	0.916	0.917	0.917	0.909
Literature Data*	0.92	0.925	0.908	0.924	0.919	0.920-0.923	0.915-0.928	0.915-0.928

*Ullmann's encyclopedia of industrial chemistry, Vol A 10, Fats and oils, VCH, Weinheim 1995, Bailey's industrial oil & fat products, 6th edition 2005,Wiley-Intersience New York, Physical and chemical characteristics of oils, fats, and waxes, Champaign, Illinois, AOCS Press, 2006, Manuel des corps gras, AFCEG, Paris 1992.

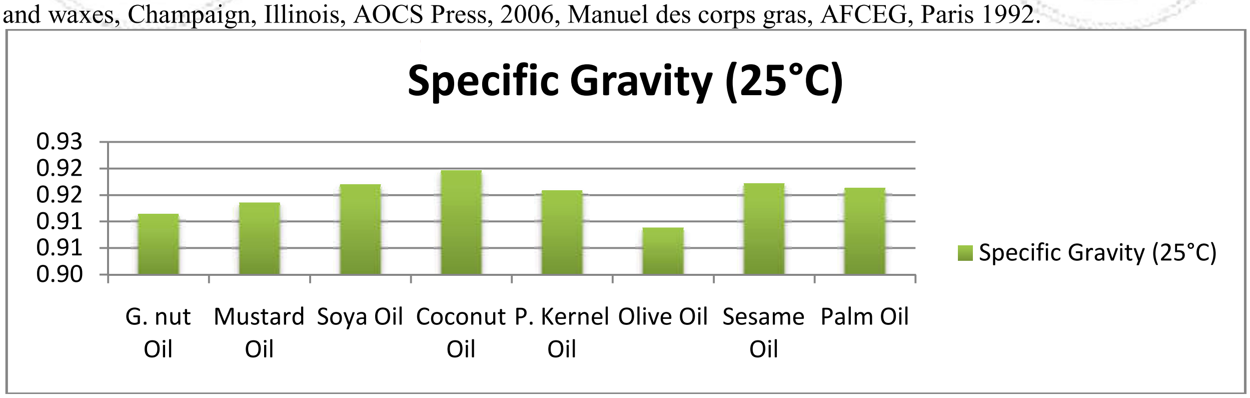

Figure 4: Specific Gravity of edible oils

3.5 Acid Value/Number

Acid value gives an indication of the quality of fatty acids in oil. From Table 1, the acid values range from 0.31mgKOH/g to 2.75 mgKOH/g in coconut and palm kernel oils, respectively. The acid value of oil accounts for the presence of free fatty acids in the oil and is an indicator of the presence and extent of hydrolysis by lipolytic enzymes and oxidation (Gordon *et al*., 1993). Low acid value in oil indicates that the oil will be stable over a long period of time and protect against rancidity and peroxidation. This could be attributed to presence of natural antioxidants in the oils such as vitamins C and A as well as other possible phytochemical like flavonoids. Also appreciable acid value of oils is an indication that the plant might be poisonous for livestock (Aremu *et. al*.2006). Its maximum acceptable level in refined oils is 0.6 mgKOH/g oil, while for cold pressed and virgin oils it is 4.0mgKOH/g oil (CODEX 2005). The variations observed in the values obtained from this study were statistically significant since $p<0.05$.

Table 6: Acid values of edible vegetable oils and FAO/WHO (Codex) standards

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	0.85	0.31	0.56	2.67	2.75	1.34	0.35	0.48
CODEX 2005	0.6	0.6	0.6	10.0	10.0	0.6	0.6	0.6

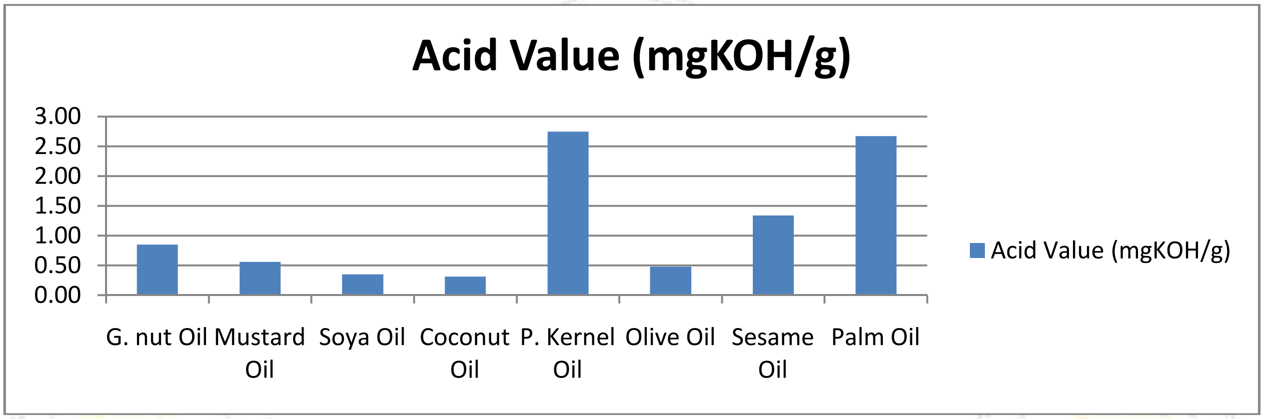

Figure 5: Acid values of edible vegetable oils

3.6 Saponification Value

The saponification value is in the range of 160mg/KOH/g to 252mg/KOH/g for palm and coconut oils respectively. Saponification value is a measure of oxidation during storage, and also indicates deterioration of the oils. An increase in saponification value in oil increases the volatility of the oils. It enhances the quality of the oil because it shows the presence of lower molecular weight components in 1g of the oil which will yield more energy on combustion (Engler & Johnson, 1983). It has been reported by Pearson (1976) that oils with high saponification values contain high proportion of lower fatty acids. High values normally over 200 are obtained with fats and hydrogenated oils, while oils tend to have values below 195.

Table 7: Saponification values and CODEX standards

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	195	252	230	160	188	185	196	192
CODEX 2005	187-196	248-265	168-184	190-209	230-254	186-195	180-200	184-196

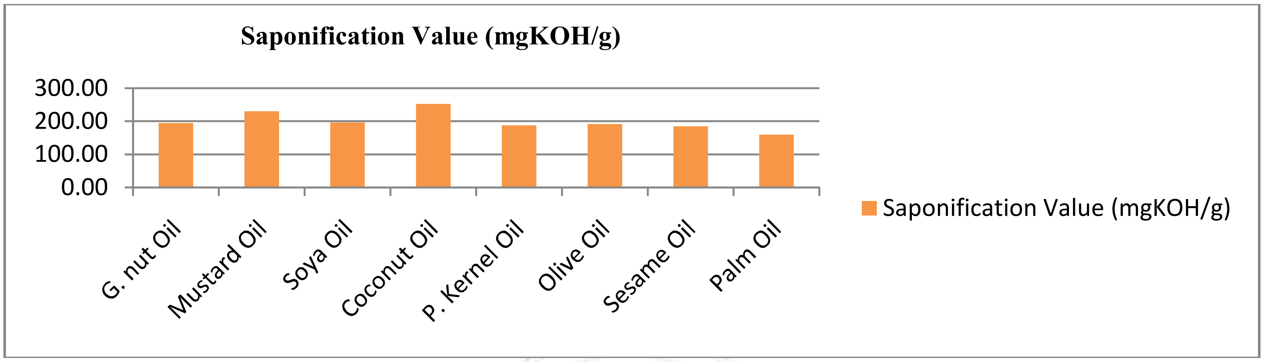

Figure 6: Saponification of edible vegetable oils

3.7 Iodine Value (Wijs)

The iodine value measures the degree of unsaturation of a particular vegetable oil. It is the weight of iodine absorbed by 100 parts by weight of the sample. Studies have shown that the greater the degree of unsaturation, the higher the iodine value and the greater the liability of the vegetable oil to become rancid by oxidation (Ronald and Ronald, 1989). The iodine values of all the oil samples do not agree with literature data except for the iodine value of coconut oil. In explaining this observation, other researchers have commented that oil quality is dictated by several physical and chemical parameters that are dependent on source of oil, processing and storage conditions (Shahidi, 2005).

Table 8: Iodine values of edible oil

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	0.45	7.59	5.71	6.10	5.40	15.48	6.47	16.37
Literature Data*	85-107	6-11	92-125	50-55	16-23	104-120	125-128	75-94

*Ullmann's encyclopedia of industrial chemistry, Vol A 10, Fats and oils, VCH, Weinheim 1995, Bailey's industrial oil & fat products, 6th edition 2005,Wiley-Intersience New York, Physical and chemical characteristics of oils, fats, and waxes, Champaign, Illinois, AOCS Press, 2006, Manuel des corps grass, AFCEG, Paris 1992

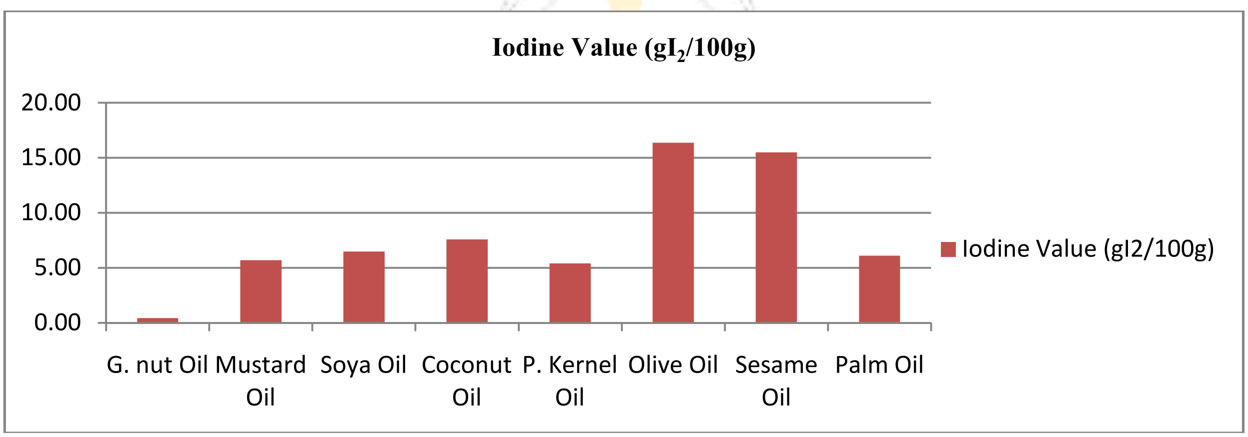

Figure 7: Iodine values of edible vegetable oils

3.8 Peroxide Value

Peroxide value (PV) is the most common indicator of lipid oxidation/rancidity. Peroxides are formed when the triglycerides in the oil oxidize in the presence of moisture. Their content is commonly expressed as the "peroxide value" in milli equivalents peroxidic oxygen per kg of sample. The PV of the oils studied ranges from 0.80meq/kg in sesame oil to 10.2 meq/kg in mustard oil. High values of PV are indicative of high levels of oxidative rancidity of the oils and also suggest absence or low levels of antioxidants; certain antioxidants may, however, be used to reduce rancidity such as propygad late and butyl hydroxyl anisole (Kyari, 2008). The CODEX (2005) stipulated a permitted maximum peroxide level of not more than 10 milli equivalent of oxygen/kg of the oils. Peroxide values higher than 10 to 20 meq/kg are commonly interpreted as rancidity. The variations observed in these values are significant since $p<0.05$.

Table 9: Peroxide values of oils and CODEX standards

S/No	Groundnut Oil	Coconut Oil	Mustard Oil	Palm Oil	P.K.O	Sesame Oil	Soya Oil	Olive Oil
This Work	4.40	3.00	10.2	1.30	1.50	0.8	1.20	2.30
CODEX 2005	10	10	10	10	10	10	10	10

The peroxide values of the oil samples are all within the CODEX 2005 maximum limit 10meq/kg.

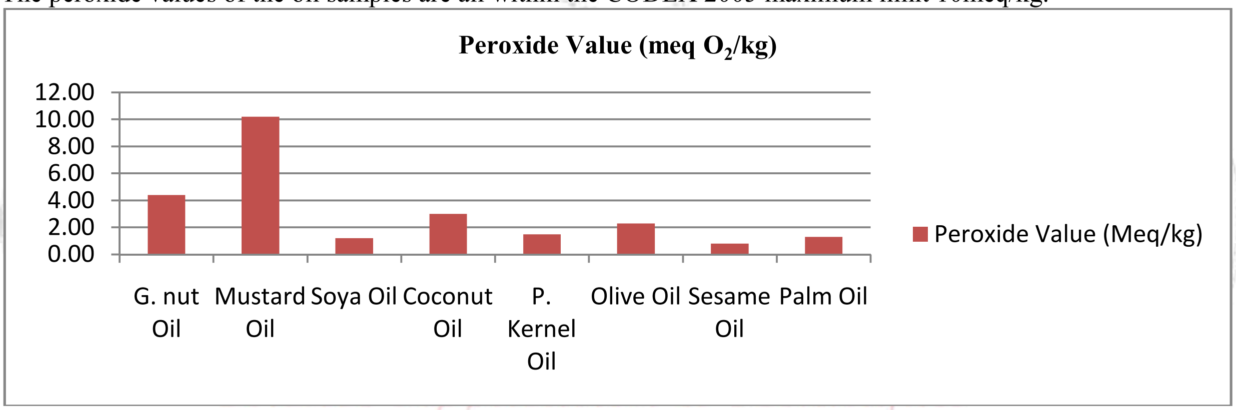

Figure 8: Peroxide values of edible vegetable oils

4. CONCLUSION AND RECOMMENDATIONS

The physicochemical characterization and quality assessment of the edible oils studied show a consistency in most of the parameters with FAO/WHO values. The quality assessment show that these oils show that the oils are of good quality and fit for consumption. However routine checks should continue to ensure that vegetable oils sold to the public are of high quality.

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