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Cameroon Green Energy Potentials: Field Survey of Production, Physico-Chemical Analyses of Palm Kernel Oil for Industrial Applications

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Abstract

This paper reports a field survey undertaken to determine the availability of raw material for palm kernel oil commercial production for industrial applications. Both industrial and artisanal wastes from palm kernel oil production were also surveyed as raw material (palm kernel seeds) for green energy production. Results of the field study show that 22% of palm kernel seeds (which represents tons of waste) resulting from palm oil processing plants are dumped while at the artisanal level, 80% of palm kernel seed waste is dumped. Analysis of field study data shows that large amounts of waste palm kernel seeds are available to enable large scale production of palm kernel oil (PKO) for desirable industrial applications in green energy production. The paper also reports on the physical and chemical properties of Cameroon palm kernel oil (PKO). Palm kernel oil was extracted using mechanical press and solvent extraction. The palm kernel oil (PKO) from Cameroon was analyzed by standard physico-chemical methods. Results of the physical measurements show a specific gravity of PKO of 0.92 kg/L, viscosity of 26.03 cSt and at 5.93 cSt at 40˚C and 100˚C respectively, viscosity index of 185, pour point of 20˚C, cloud point of 29˚C, flash point of 200˚C, aniline point of 105˚F, diesel index of 23, cetane number of 27 and ASTM (American Standards for Testing and Materials) color of less than 2.5. Results of chemical analyses showed an acid value of 17.95 mg KOH/g, free fatty acid (FFA) content of 8.98 mg KOH/g, iodine value of 2.10 mg I_2/g, peroxide value of 2.10 meq/kg, ester value of 123.0 mg KOH/g, hydroxyl value of 93.4 mg OH/g, saponification value of 140.95 mg KOH/g and a sulfur content of 0.016% w/v, signifying low sulfur content. Gas chromatography-mass spectrometry (GC-MS) showed the palm kernel oil to be predominantly made up of glycerides of various fatty acids with higher proportions of C12 to C16 fatty acid residues. Cameroon PKO therefore has a broad spectrum of industrial applications by virtue of its rich physical and chemical properties.

Keywords

Field Survey, Palm Kernel Oil, Raw Material, Energy Production, Physical and Chemical Properties, Fatty Acids, Iodine Value, GC-MS

1. Introduction

Palm kernel oil is a vegetable oil extracted either locally by artisanal methods or at the industrial scale from waste products of palm oil processing [1]. At the artisanal level, the oil finds applications in soap making, cosmetic and pharmaceutical related uses. The palm kernel oil is not edible, reason why the waste products are accumulating and threatening environmental sanity. Previous works on palm kernel oil have concentrated on its extraction, purification and evaluation for potential application [2] with little focus on its characterization and studying the effects of soil type on chemical composition and physico-chemical properties. These detail statistics are required to properly deduce potential uses of palm kernel oil.

In Cameroon, a lot of palm kernel waste is emitted from palm oil processing plants in the plantations of the coastal regions and from many artisanal production facilities in the North West Region and a good quantity of the waste is dumped into the environment. Transforming these wastes into useful products is the concern of researchers. Nchanji *et al.* [1] and Bakoume and Mahbob [3] reported on artisanal production of palm oil and palm kernel oil in Cameroon. Other reports on palm kernel oil include that of Ezeoha *et al.* [4] who mechanically extracted palm kernel oil by screw pressing. Aladetuyi *et al.* [5] analyzed spent and fresh PKO for biodiesel synthesis and reported such physical characteristics as viscosity, flash point, and density but did not analyze other salient physical properties such as cloud point, pour point, viscosity index, aniline point and cetane number which are required in order to deduce low temperature properties, lubricant properties, product safety and related industrial applications.

The results of a field survey on the availability of palm kernel seeds and the scrupulous analysis of mechanically extracted palm kernel oil from Widikum in Cameroon for its chemical and physical characteristics which can in turn influence its industrial applications are reported herein. The relationship between chemical composition of PKO and the geographical location by comparing the results of Cameroon PKO analysis to literature data obtained from other regions is also examined. This comparative study was driven by reports that soil type may have a bearing on chemical composition thereby affecting the physico-chemical properties [6].

The information obtained from this research survey is aimed at adding impetus to the upsurge of small and medium sized enterprises that can make good use of the byproducts of the palm oil producing sector in Cameroon to create wealth and catalyze economic development through job creation and youth employment. The use of industrial waste for further production of useful materials has the propensity of enhancing production economics, environmental sanitization and climate change mitigation.

2. Materials and Methods

2.1. Materials

The first segment of the research consisted of field trips to industrial and artisanal sites for the purpose of palm kernel seed availability survey. At the industrial level, permission to visit the Palm Oil Processing Factory at Mondoni (Tiko) and Idinau (Limbe) all in the Fako Division of the South West Region of Cameroon, was obtained from the Cameroon Development Corporation (CDC) Head office in Bota – Limbe. Field visits were made to artisanal palm plantations and palm oil production units in Widekum in Momo Division, North West Region for the purpose of surveying palm kernel seed wastes as raw materials for industrial applications. In the course of the field study, palm kernel seeds were collected that were used for palm kernel oil extraction and subsequent analyses. Palm kernel seeds were collected from the dumping sites of the palm oil processing mills in Widekum sub division, North West Region of Cameroon. The shells were mechanically cracked to liberate the seeds which were then washed with water to remove debris. The clean seeds were dried under the sun for one week in order to reduce the moisture content to minimum. Palm kernel oil was extracted from the dry seeds using a mechanical press. Another batch of palm kernel oil was extracted in diethyl ether using a Soxhlet apparatus for 4 hours. This chemical extraction was later used to determine the percentage oil content of palm kernel seeds. The extracted oils were stored in glass jars for subsequent use in physical and chemical analyses.

2.2. Physical Measurements on PKO

The specific gravity of palm kernel oil was determined using the hydrometer method outlined in the American Standards for Testing and Materials (ASTM) D1298 analytical procedure which is applicable to liquids of low vapor pressure [7] and [8]. The kinematic viscosity of palm kernel oil was determined at 40˚C and at 100˚C in conformity with the ASTM D445 analytical procedure for oils and related products using a calibrated Cannon-Fenske viscometer. The kinematic viscosity (η) was obtained by multiplying the average flow time (t) by the viscometer constant, C as shown in Equation (1).

$$\eta = C \times t \tag{1}$$

The viscosity index of PKO was determined using the ASTM D 2270 analytical procedure [7]. The water and sediment content of PKO was determined using the ASTM D1796 centrifuge method [8].

The cloud point was determined following the ASTM D2500 analytical procedure that covers petroleum products that are not opaque with cloud points below 49˚C [8]. The pour point was determined using the ASTM D97 analytical procedure.

The flash point was determined using the Penksy-Martens closed cup test procedure in conformity with the ASTM D93 analytical procedure for petroleum products in the temperature range of 40˚C to 360˚C. The aniline point of palm kernel oil was determined using the ASTM D611 analytical [7] [8].

The diesel index was calculated from previously determined properties of the oil such as specific gravity and in conformity with the IP21 standard analytical method [8]: the specific gravity of the oil at 60˚F (15˚C) was determined according to ASTM D 1298.

The specific gravity was converted into the American Petroleum Institute (API) gravity using Equation (2).

$$API = \frac{141.5}{SG} - 131.5 \quad (2)$$

The diesel index (DI) was then calculated using Equation (3).

$$DI = \frac{\text{Aniline point}\left({}^{\circ}F\right) \times API}{100} \quad (3)$$

The cetane number is an indication of the ignition characteristics of a fuel oil in a combustion engine. It was determined for palm kernel oil by calculation. Data from previous characterizations above were used to calculate the cetane number (CN) as in Equation (4).

$$CN = \left(DI \times 0.72\right) + 10 \quad (4)$$

2.3. Chemical Analysis

Free fatty acids (FFA) are usually derived from triglycerides or phospholipids which are not attached to other molecular backbones. The free fatty acid composition of palm kernel oil was determined by titration with potassium hydroxide (KOH) using phenolphthalein as indicator [9]. The acid value was calculated using Equation (5) [10].

$$AV = \frac{V \times C \times 56.10}{m}, \quad (5)$$

where V is the average titre of KOH solution, C the concentration of KOH solution, m the mass of PKO used, and 56.10 the equivalent mass of KOH.

The free fatty acid content was calculated as oleic acid in which case 1 mL of 0.1 MKOH is equivalent to 0.0256 g of oleic acid [9]. Hence, the acid value or total acid value is twice the free fatty acid value.

$$FFA = \frac{AV}{2} \quad (6)$$

The free fatty acid number was expressed as a percentage.

The saponification value of palm kernel oil was determined using the ASTM D94 analytical method [10]. Titration data were used to calculate the saponification value (SV) of Cameroon PKO using Equation (7) [9].

$$SV = \frac{\left(V_B - V_T\right) \times C \times 56.10}{m} \quad (7)$$

where V_B is the blank titre, V_T the sample titre, C the concentration of titrant (HCl) and 56.1 the equivalent mass of KOH.

The Ester Value is the mass (mg) of KOH required to saponify all the esters in 1 g of the palm kernel seed oil and it was calculated as the difference between the Saponification Value and the Acid Value [10].

$$EV = SV - AV \quad (8)$$

The iodine value was determined using the ASTM D2078 analytical procedure [9]. The iodine number was determined using the Wij's method. The iodine value (IV) was calculated from titration data using Equation (9) [11]:

$$IV = \frac{\left(V_B - V_S\right) \times N \times 12.69}{m} \quad (9)$$

The hydroxyl value is the mass of KOH (in mg) equivalent to the hydroxyl content of 1 g of an oil sample. The hydroxyl number was determined using the ASTM D 1957 procedure outlined by Nadkarni [7]. The peroxide value, which is a measure of the peroxides formed in the oil, was determined by titration using thiosulfate in the presence of potassium iodide KI and starch indicator. The peroxide value was determined using the analytical procedure of the American Oil Chemists Society (AOCS) official method [10] [12]. The sulphur content was determined using the technique of energy-dispersive X-ray Fluorescence Spectrometry in accordance with the ASTM D4294 method using the Sulphur-in-Oil Analyser-SLFA-2800 machine [8].

2.4. Determination of the Oil Content of PKO

The Soxhlet extracted oil was used to determine the oil content of the palm kernel seeds. The oil content was obtained using the formula in Equation (10).

$$\%\,\text{Oil content} = \frac{\text{mass of oil extracted}}{\text{dry mass of crushed seeds taken}} \times 100 \quad (10)$$

2.5. Determination of Chemical Composition of Palm Kernel Oil Using GC-MS

The gas chromatography coupled with a mass spectrometer (GC-MS) was used to investigate and identify the chemical entities present in palm kernel seed oil. The analysis was carried out on 2 μL of PKO using the Gas Chromatography-Mass Spectrometer-GCMS-QP2010 Plus model with 99.995% pure helium gas as the mobile phase at a volumetric flow rate of 1.2 mL/min. The oven temperature was programmed at 50˚C for 1 min, then a heating rate of 10˚C/min up to 250˚C, and then left at 250˚C for 10 minutes. The operating temperature range had an upper limit of 280˚C. The mass spectrometer conditions were as follows: ionization voltage was above 50 eV; ion source temperature more than 120˚C; electron ionization mass spectra were acquired over the mass range of m/z = 40 - 560 and the percentage chemical composition was calculated from the mass spectra obtained using the formula represented in Equation (11).

$$\%\text{ chemical composition} = \frac{x_i}{\sum x_i} \times 100 \quad (11)$$

where x_i represents the intensity of a chemical species i and $\sum x_i$ is the sum of intensities of all molecular species found in the 2 μL sample of PKO analyzed.

3. Results and Discussion

3.1. Field Survey Statistics

The data obtained from field survey of palm kernel seeds from three sites for a period of five years at the industrial level where there exists some waste minimization scheme is shown in Table 1. The data was certified by the Manager in charge of palm oil production at the Mondoni Oil Mill. It was observed that some palm kernel seeds are consumed by soap production factories while the rest are dumped and partly act as land pollutants.

Although significant waste minimization from the industrial sector may be noted from Table 1, there are still 1134 tons of waste palm kernel seeds representing an average of 22.73%. Since this waste is readily available, much palm kernel oil can be extracted from the waste seeds for the spectrum of industrial applications and by so doing, sanitize the environment and improve on production economics by making use of free raw materials. Figure 1 and Figure 2 show palm kernel seeds disposed of at the industrial and artisanal levels which form a potential source of raw materials for green energy production and related industrial applications.

The situation of non-utilization of palm kernel seed waste is more serious at the artisanal level. Quantitative data was not available but information obtained from the farmers indicated that more than 80% of palm kernel seed waste from the artisanal sector is just discharged into the environment, into land, rivers, streams and some are burned to provide thermal energy for the cooking of palm nuts for oil extraction.

Table 1. Annual palm kernel production data at the industrial level.

Year	Palm kernel seeds from Mondoni (kg)	Palm kernel seeds from Idenau (kg	Palm kernel seeds from Illoani (kg)	Total palm kernel seeds per annum (kg)	Palm kernel seeds processed into Oil (kg)	Unprocessed palm kernel seeds (kg)	Percentage of Unprocessed palm kernel seeds
2014	654,705	376,240	201,720	1,232,665	951,058	281,607	22.85
2015	985,174	557,260	217,840	1,760,274	1,375,287	384,987	21,87
2016	902,800	138,320	66,980	1,108,100	851,776	256,324	23,10
2017	470,640	444,120	N/A	914,760	703,497	211,263	23.09

N/A = Datum not available.

Figure 1. Industrial and Artisanal Palm Kernel Seeds and Fibers Dumped (Alang, August 2017).

Figure 2. Palm Kernel Seeds Burnt to Provide Energy & Land Space (Alang, August 2017).

Whiles some palm kernel seeds are dumped into the environment on farmlands thus perturbing crop production (Figure 1 and Figure 2); some are discharged into streams and rivers, another fraction is just burnt off to create land space while another fraction is burnt to provide thermal energy (see Figure 2) when boiling palm nuts for palm oil extraction. It is therefore important to note that the palm kernel seeds are laden with much vegetable oil that can be extracted for use in many industrial activities such as green energy production like biodiesel, bio lubricants, cosmetic products, pharmaceutical products, explosives for civil engineering applications amongst others.

3.2. Percentage Oil Content of Palm Kernel Seeds

The percentage oil content of palm kernel seeds gave 45.6% and lies in the propinquity of the range (49.36% ± 2.61%) of PKO content reported in the literature [13]. Of the two extraction methods, mechanical extraction is preferred because it is faster and extraction is quantitative compared to the Soxhlet method. The press cake from mechanical extraction may still contain a non-negligible quantity of the oil in the seed. Soxhlet extraction can however, lead to nearly 100% oil extraction when a suitable solvent is used and is thus preferred for determination of percent oil contents.

3.3. Physical Characteristics of Cameroon PKO

Table 2 displays the physical properties of Cameroon palm kernel oil obtained by standard methods of physico-chemical analyses carried out in the laboratory. The values of Cameroon PKO are compared to literature values reported for Nigeria.

While note is made of the specific gravity, cloud point and pour point which are similar for the two oils, the viscosity and cetane number are significantly different. The sediment content of Cameroon PKO at 0.9% is greater than that of the Nigeria PKO. These differences could probably be explained by variations in soil conditions where plants grow. Generally, the oil palm is not a very demanding crop in terms of soil conditions. Oil palm require a good soil with little gravel, a texture that allows reasonable drainage but still retains plenty of exchangeable cations and contains a good level of soil organic matter [15]. The oil palm can do well on a wide range of soils such as relatively acid ferrallitic and kaolinite soils common in the south west of Cameroon and extending into Akwa-Ibom, Rivers and Cross-Rivers States of Nigeria [16]. The extension of similar soil types from Cameroon into Nigeria, may account for the similarities in the physico-chemical properties from the two regions while differences in rainfall

Table 2. Physical properties of Cameroon Palm Kernel Oil (PKO) compared to values of the Nigerian PKO [14].

Property	Cameroon Values	Nigeria Values
Specific Gravity	0.92 kg/L	0.94 kg/L
Colour	<2.5	N/A
Viscosity at 40˚C	26.03 cSt	33.10 cSt
Viscosity at 100˚C	5.93 cSt	8.10 cSt
Viscosity Index	185	220.7
Water and Sediment content	0.9% v/v	0.31% v/v
Cloud Point	29˚C	25˚C
Pour Point	20˚C	20˚C
Flash Point	200˚C	180˚C
Aniline Point	105˚F	N/A
Diesel Index	23	N/A
Cetane Number	27	60

that cause leaching and other consequences may account for some of the observed differences. Industrialization is another factor that can influence soil composition. The southern and coastal parts of Nigeria such as the Niger Delta and others have more oil and gas or petroleum and other heavy industries and are relatively more industrialized as compared to Cameroon. Hence emission of gases from the manifold industries with subsequent deposition and condensation will possibly influence the composition of the soil [17].

Some of the physical properties of Cameroon palm kernel oil are desirable for industrial and domestic applications [18] [19]. For example, high viscosity renders it apt for domestic lubrication and body lotion to fight skin diseases, high flash point imparts to it, greater thermal stability and reduced propensity to fire hazards. The ASTM color of palm kernel oil (<2.5) is another indicator for the degree of purity. The oil viscosity at 40˚C of 26.03 centistoke (cSt) was also lower than 33.10 cSt reported in the literature for Nigerian PKO while the viscosity of the oil reduced to 5.93 cSt at 100˚C which is also less than 8.10 cSt value reported by [2]. This viscosity at 40˚C is too high for oil to be used in diesel engines and thus it needs to undergo chemical modification like trans-esterification to proffer a lower viscosity [20]. The cloud point and pour point are quite high at 29˚C and 20˚C respectively. These properties render PKO unsuitable for use in internal combustion engines due to its low volatility and high viscosity [5] [21] [22] [23] [24] [25]. Bello *et al.* [26] reported a flash point of 180˚C compared to 200˚C for Cameroon PKO. This is due to the higher aniline point of Cameroon PKO. The viscosity index of the oil was 185 which is not far from 220.7 for the Nigerian PKO [14] [27]. This high viscosity index suggests that the Cameroon PKO is a potential lubricant at lower temperature operations (such as marine uses) though its lubricant properties can be improved upon by replacing the glycerol backbone with trimethylpropane (TMP) [27]. The aniline point is useful as an aid in the characterization of hydrocarbons and in the analysis of hydrocarbon mixtures [28] [29]. Aromatic hydrocarbons exhibit the lowest aniline point values, paraffin exhibit the highest values and cycloparaffins and olefins exhibit intermediate values. The aniline point is most often used to estimate the aromatic hydrocarbon content of mixtures and extrapolate toxicity data therefrom. The aniline point for the Cameroon PKO was high (105˚F) indicating the absence of aromatics and hence the oil is not contaminated, non-toxic and can be used in cosmetic and allied industries. A high diesel index is an indication of the high ignition quality of the fuel. The diesel index of palm kernel oil was low at 23 signifying that it is not very suitable as a fuel in compression ignition engines without appropriate chemical modification. The cetane number of 27 for Cameroon PKO is much lower compared to those of fuel oils like petroleum diesel which has a diesel index of 47 [8]. The higher the cetane numbers the better the fuel. This is another indication of the need for chemical modification of Cameroon PKO in order to diversify its applications especially as green energy source.

3.4. Chemical Characteristics of Cameroon PKO

Table 3 shows the chemical properties of Cameroon PKO. Data for the Nigerian PKO [14], Malaysia [30] and China [13] have been included for comparison.

The results in **Table 3** show agreement between the chemical properties of PKOs from Cameroon, Nigeria and China. The fatty acid content of the PKO from Malaysia almost doubled that of other countries. The saponification, ester, iodine and peroxide values are lower for the Cameroon PKO than for the others. Hence geographical location has a minor but non-negligible influence on chemical composition and hence chemical properties. Higher acid values imply higher amounts of free fatty acids (FFA) which also indicate low quality oil [10] as increased free fatty acids is another pointer to chemical degradation through rancidity and allied reactions.

The percentage of free fatty acid (%FFA) in Cameroon palm kernel oil was 0.9%. If the %FFA exceeds 1%, the oil should be pre-treated before being utilized in some vital industrial processes like biodiesel synthesis so as to evade distractive saponification reactions [26] that lead to lower yields. The quality of Cameroon PKO is therefore good enough for direct industrial applications in cases like biodiesel, biolubricant and cosmetics production without recourse to extensive pre-treatment precautions. The saponification value obtained for Cameroon PKO of 140.95 mg KOH/g was moderately high but lower than 190 for coconut oil [26] [31]. This shows that Cameroon PKO is composed of a mixture of short and long chain fatty acids with a preponderance of short chain fatty acids. The saponification number is inversely proportional to the average chain length or molecular weights of the constituent fatty acids in the oil or fat [32]. Hence the higher the saponification number, the shorter the average chain length [33]. Actually the ester value is also obtained by subtracting the acid value from the saponification value such that; the closer the ester value is to the saponification value, the better the oil sample because this implies the free fatty acid content is low which is desirable for further processing of the oil into other useful products. The ester value obtained in this work, 123.0 was close to the saponification

Table 3. Chemical Properties of Cameroon PKO Compared to Literature Values [13] [14] [30].

Property	Cameroon Value	Nigerian Value	Malaysian Value	Chinese Value
Free Fatty Acids (%)	0.90	0.95	2.01	0.70
Saponification Value (mg KOH/g)	140.95	216.0	191.10	239.43
Ester Value (mg KOH/g)	123.0	214.0	193.2	237.46
Iodine Value (mg I_2/g)	2.67	15.86	17.8	20.15
Hydroxyl Value (mg KOH/g)	93.4	N/A	N/A	N/A
Peroxide Value (meq/kg)	2.10	7.0	1.52	1.48
Sulphur Content (0.016% w/v)	0.016	13.60	N/A	N/A

N/A: Data not available.

value (140.95) and together with other physical properties of PKO, corroborates the fact that the palm kernel oil is a good candidate for industrial transformation by virtue of its flexible chemical properties.

The peroxide value of 2.1 meq/kg was very small compared to 9.2 meq/kg for *Jatropha curcas* oil reported by Baroi *et al.* [34]. However, this value is coherent with the acid value. The palm kernel oil extracted from Cameroon PKO is therefore clean and is a potential raw material for extended industrial applications. The formation of peroxides is a result of rancidity of oil which is a biochemical reaction between fats and oxygen or occasioned by microorganisms in the oil. In the process, long chained fatty acids are degraded and short chained compounds are formed. The peroxide value for Cameroon PKO is much lower compared to a peroxide value of 16 meq/kg for coconut oil [26]. This implies that Cameroon PKO possesses a desirable oxidative stability which is suitable for the cosmetic industry. The iodine value of oil gives an indication of the degree of unsaturation of the oil sample and consequently it is an indirect method of determining oxidative stability of PKO and its products. The iodine value obtained in this work was low (2.67 mg I_2/g). Hence Cameroon PKO is relatively saturated and possesses moderate thermal stability. The higher the unsaturation, the more the product is prone to rancidity-type of reactions with an attendant shorter shelf life. The iodine values of PKO obtained from other countries were higher and consequently, these PKOs are thermally unstable compared to Cameroon PKO. The hydroxyl value was low (93.4 mg KOH/g). Low hydroxyl values of oil samples are desirable as they signify the presence of fewer free hydroxyl groups and consequently low free fatty acid. The sulfur content of PKO was found to be 0.016% w/v, which is far less than 13.60% for Nigerian PKO. This could be due to higher sulfur content of Nigerian soils caused by acid rain due to higher degree of industrialization of the region and which is in conformity with literature reports that variation in soil composition is responsible for chemical polymorphism observed is some plants [35]. High sulfur content in oils is undesirable because of the toxic tendency of sulfur and its oxides on the environment. The high sulfur content in the Nigerian PKO is a function of the type of soil on which the palms grow and this has an effect on chemical polymorphism and bioactivity [35].

3.5. Chemical Composition of Cameroon Palm Kernel Seed Oil

The chemical composition of PKO was investigated using GC-MS analysis. The fatty acid profile of PKO from Cameroon was compared to those of Nigeria, Malaysia, and China (**Table 4**). PKO is made of mostly esters of fatty acids such as palmitic, stearic, oleic, linoleic, lauric, capric, caprylic, myristic acids *inter alia* [2]. **Table 4** shows the fatty acid profiles of PKO from Cameroon, Nigeria [14], Malaysia [30] and China [13]. Some significant variations in chemical composition are observed in the analytical results of Cameroon PKO as compared to the results of analysis of PKO from other parts of the world. This slight variation in

Table 4. Fatty acid profiles of PKO from different geographical locations.

Chemical Species	Cameroon (%)	Nigeria (%)	Malaysia (%)	China (%)
Hexanoic Acid	6.0	0.30	0.30	N/A
Heptanoic Acid	0.2	N/A	N/A	N/A
Octanoic Acid (Caprylic Acid)	5.0	3.3	3.6	4.24
Nonanoic Acid	0.50	N/A	N/A	N/A
Decanoic Acid (Capric Acid)	16.10	3.4	3.3	3.46
Undecanoic Acid	0.60	N/A	N/A	N/A
Dodecanoic Acid (Lauric Acid)	38.5	48.2	47.9	48.01
Tetradecanoic Acid (Myristic Acid)	8.50	16.2	16.7	16.52
Pentadecanoic Acid	2.10	N/A	N/A	N/A
Hexadecanoic Acid (Palmitic Acid)	9.0	8.40	8.50	7.82
Octadecanoic Acid (Stearic, oleic, linoleic Acids)	11.0	20.10	19.50	19.32
Eicosanoic Acid	2.2	N/A	N/A	0.44
Docosanoic Acid	N/A	N/A	N/A	0.03
Tetracosanoic Acid	N/A	N/A	N/A	0.06
Impurities	0.30	0.40	0.20	0.10

N/A: Data not available.

chemical composition is probably due to differences in soil composition where the palm trees (*Elaeis guineensis*) grow.

The principal chemical components of Cameroon palm kernel oil include lauricacid, decanoicacid, octadecanoid acid, hexadecanoic acid, and tetradecanoic acid residues. Some of the fatty acid components occur in smaller proportions. One conspicuous difference between the components of Cameroon PKO and those from other locations is the presence of small amounts of fatty acid molecules with odd numbers of carbon chain atoms. These include heptanoic acid (0.2%), nonanoic acid (0.5%), undecanoic acid (0.6%), and pentadecanoic acid (2.1%). Some fatty acid components are present in PKO of some countries and not in others. For example, C22 and C24 are present only in PKO from China. C20 to C24 are absent in PKO from Nigeria and Malaysia. The impurity level of Cameroon PKO is quite low at less than 0.4% and consequently the product can be used for other industrial activities.

4. Conclusion

A field survey has shown that there exists huge waste of palm kernel seeds in Cameroon laden with vegetable oil which can be collected and the oil extracted for use in various manufacturing operations. We have further shown that Cameroon PKO has the requisite characteristics of raw material for various industrial applications. The high viscosity index and low sulphur content can permit the use of palm kernel oil as a biolubricant in some low temperature marine applications. The chemical content of the palm kernel oil makes it susceptible for use in biodiesel and biolubricant synthesis. The glycerol by-product from the trans-esterification reaction can be used in pharmaceutical and cosmetic industries. The slight variation in chemical composition from one country to another suggests that geographical locations may have a bearing on chemical polymorphism and chemical properties. Cameroon palm kernel oil therefore has a broad spectrum of industrial applications by virtue of its rich physical and chemical properties.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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