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Extraction and Physiochemical Characterization of Oils Obtained from Selected Under-Utilized Oil Bearing Seeds in Nigeria

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ABSTRACT

The oils extracted from selected underutilized seeds in Nigeria; Rubber seeds (RS), African pear seeds (APS) and Cotton seed (CS) using n-hexane were analyzed for their physico-chemical properties viz: melting point, relative viscosity, free fatty acids, saponification value, iodine value, acid value, percentage unsaponifable matter, ester value and heat of combustion, using standard methods. The % oil contents in the seeds were determined to be 42.967 ± 0.59%, 19.427 ± 0.13% and 35.433 ± 0.86% for RS, APS and CS respectively. The extracted oils were liquids at room temperature with oil extracts from APS and CS having pleasant odour with light green and golden brown colour respectively, however oil extract from RS had an unpleasant smell with brownish yellow colour. There was significant difference in the physiochemical properties investigated. The acid value ranged from 6.840 to 32.000 mg KOH/g, the saponification values were high ranging from 173.115 to 185.333 mg KOH/g. The iodine value of (RSO), (139.703 g I_2/100g) classified it as a semi - drying oil. The peroxide value of RSO (14.300 mequiv O_2/kg oil) falls above the Standard Organization of Nigeria (SON) recommended peroxide value (10 mequiv O_2/kg oil) for edible oils and its free fatty acid (16.096 %) is also above the recommended 5% which makes it non-edible oils. The physicochemical properties of the oils suggest that they exhibit edible and industrial potentials.

Keywords: African Pear, Cotton, Oil, Rubber, Seed

INTRODUCTION

Fats and oils belongs to a group of compounds called lipids. Fats are of animal origin and are solids at room temperature, while oils are of plants (vegetable) origin and liquids at room temperature. Edible Fats and oils are the third most important macro nutrient required by the body after carbohydrates and proteins (Youdim, 2019). They are rich sources of vitamins and contain two and a half times the energy provided by carbohydrates. In addition, fats and oils also contain essential fatty acids which are not manufactured by the body and as such must be obtained from diets containing fats and oils (Aremu *et al.,* 2015). With some exceptions and in contrast to animal fats, oils are the lipids that contain predominantly these unsaturated (light) fatty acids of two kinds: monounsaturated (oleic acid mainly in extra virgin olive oil) and polyunsaturated (linoleic acid and linolenic acid in oil extracted from oil seeds) (Thomas, 1991). Therefore, seed oils are sorted for in various food applications as important contributor to healthy diet; they also provide characteristic flavours and textures to foods as integral diet components (Odoemelam, 2005). Globally, an estimated 40 million tons of fats and oils are consumed by man annually (Dhiman *et al.,* 2009) and the demand is on the increase with the increasing population. As a result, there is shortage in the availability of oils with inflated cost as supplies cannot meet the demands.

Therefore, over the years concerted efforts have been made to find alternative sources of oils to augment the existing ones (Aremu *et al.,* 2015; Ikhuoria and Maliki, 2007) and as much as possible find non-edible oil sources for non-edible industrial uses and vice versa in order to reduce the food-non-food clashes of oils. However effective determination of the potential use of oil extracts demands reliable information about the physiochemical characteristics of the oils. It is on these basis that this study was conducted, to extract oil from seeds of Rubber (*Hevea brasiliensis*), African pear (*Decryocles edulis*) and cotton (*Gossypium spp*), and to also investigate their physiochemical characteristics to provide baseline data on their quality in order to give an indication for their suitable uses.

Rubber tree (*Hevea brasiliensis*), belonging to the family *Euphorbiaceae* is one of the major tree crops in Nigeria. It is cultivated on plantations in the tropics and subtropics, especially in Southeast Asia and western Africa. The milky liquid (latex) that oozes from any wound to the tree bark is the most important part of the plant, which can be coagulated and processed into solid products, such as tires. Latex can also be concentrated for producing dipped goods, such as surgical gloves (Sun, 2004; Pillai and Girish, 2014). The tree produces enormous amount of seeds which presently does not have any major applications. An estimate of 20 000 tonnes rubber seed can be produced from 200 000 ha of rubber plantations in Nigeria (Nwokolo, 1996) and an estimate of 1.3kg of seeds (800 seeds) can be produced by each tree yields twice a year.

African pear (Dacryodes eduls) is a well known plant in West Africa. It is a tropical fruit tree which grows in the humid and sub-humid climate of the West African countries. The fruits are edible and are the most important part of the plant. The fruits are mostly consumed alone or with corn after being softened by roasting or putting them in hot water. After eating the pulp the seeds are usually discarded as wastes which are sometimes the seeds eaten by ruminants.

Cotton (*Gossypium spp*) is the most important raw material of textile industry and it is the single largest natural source of fibre. Although some of the seed was used for planting, fertilizer, and animal feed, the majorities are left to rot or indiscriminately disposed.

In the light of this, studies have shown that these seeds contain appreciable amount of oils (Onuegbu *et al*., 2016; Arisa and Lasarus, 2008; Ohikhene, 2006) with nutritional value that could be used to augment the dwindling supply of oil and fats and also provide a useful supplement to animal feeds. Although these seeds are known to contain appreciable amount of oil, studies about their physicochemical properties are few. Therefore, the swaying need to extract oil from these seeds and also determine their physicochemical properties in order to determine their edible, nutritional and industrial attributes.

MATERIALS AND METHODS

Samples Collection and Oil extraction.

Rubber seeds were collected from the Plantation of Rubber Research Institute of Nigeria (RRIN) Iyanomo while already cleaned cotton seeds and fruits of native pear (*Dacryodes edulis*) were bought from New Benin market, Benin City, Edo State, Nigeria. The rubber seeds were cracked (shelled) while the fruits of the native pear were shelled to obtain the seeds after which all the seeds were then washed clean with distilled water and dried at room temperature. The rubber and the African pear seeds were chopped into small pieces and then all the seeds (rubber seeds (RS), African pear seeds (APS) and cotton seeds (CS)) were separately dried in an oven at 50ºC until there was no significant change in their weight. After cooling, the seeds were milled into powder with a blender and stored in air-tight polythene bags before use. Thereafter, 50g each of the milled seeds were loaded separately into a thimble and placed in the refluxing unit of the Soxhlet apparatus with 300 cm^3 of n-hexane as extraction solvent. The extracts were de-solventized with the rotary evaporator to obtain the seed oils.

Physicochemical characteristics

The Physicochemical characteristics of the oils were carried out. The colours and smell of the oils were determined by visual observation and use of the sense of smell while melting points was by the capillary method. Relative viscosity was determined by the use of Oswald U-tube viscometer. Specific gravity was determined using 25ml capacity density bottles according to Pearson (1980) at 29°C. The percentage yield was obtained as ratio of the weight of oil extracted to the weight of sample, multiplied by 100. The saponification values (SV), acid values (AV) and iodine values (IV) were determined using the official method of analysis (A.O.A.C, 1995). Peroxide values were determined using the AOCS Surplus method Cd 8-53 (AOCS, 1992). Unsaponifiable matter was determined using the separation method. Ester value (EV), heat of combustion (HC) and free fatty acid (FFA) values were determined by mathematical expression; EV= SV- AV; HC = 11380 – IV – 9.15(SV); FFA = 0.503(AV) (Akinola *et al*. 2010; Aremu *et al*., 2015).

Statistical Analysis

One way analysis of variance (ANOVA) was carried out to assess the significant differences in the data obtained. The mean of the data was compared using SPSS (Statistical package for Social Scientist).

RESULTS AND DISCUSSION

The Physico-chemical characteristics of the oil samples are presented in Tables 1 and 2. The extracts were all liquid at room temperature, signifying that they can all be classified as oils. This also gives an indication that the oils have some level of unsaturation. The colour of rubber seed oil (RSO) was brownish yellow which is different from the dark brown reported by some authors (Asuquo *et al.,* 2012; Abdulkadir *et al.,* 2014; Ebewele *et al.,* 2010) and golden yellow (Pearson, 1976). Elsewhere, yellow colour was reported (Joseph *et. al.,* 2004), while pale yellow was also reported (Salimon *et al.,* 2012). African pear seed oil (APSO) was observed to be light green which was in line with Ajiwe and Obika (2000) but in disagreement with Ajayi and Oderinde (2002) who recorded dark yellow. Cotton seed oil (CSO) was golden brown in agreement with (Agarwal *et al.,* 2003) but in disagreement with the dark reddish colour observed by Gumuskese and Cakaloz (1992), attributing it to pigmented materials such as gossypol, carotinoids, chlorophyll and various resins present in the crude oil. The properties of crude oils can also be determined by several factors, which include; it's crude colour, the extraction procedures and the color of the oil after extraction. Nevertheless, refining procedures of degumming and decolourisation can significantly improve the appearance (Asuquo *et al.*, 2012). In contrast to APSO and CSO which had pleasant odour, RSO had an unpleasant odour. The physical appearance and odour of rubber seed oil makes it undesirable as edible oil, unlike APSO and CSO which have appearance and odour the makes them desirable as edible oils.

Oil quality and its content are the key determinants of the viability of an oil source. In this study, the percent oil content of all oil bearing seeds were appreciable and showed significant variations, with values; 42.967 ± 0.59%, 19.427 ± 0.13% and 35.433 ± 0.86% for rubber seed (RS), African pear seed (APS) and cotton seed (CS) respectively. The variation is attributed to the fact that the seeds are from different plants. Also, the oil content in the seeds were all within the rang classified as oil bearing viz; 28 - 33.6% for palm oil (Akubugwo and Egbgu, 2007; Ezeoha *et al.*, 2017); 31.7 – 57.0% for groundnuts (Yol *et al.*, 2017); 50.1% for peanuts (Bishi *et al.*, 2015); 15.85 – 19.45% for soybean (Anwar *et al.*, 2016) and 31.28 – 42.37% for coconut (Adeyanju *et al.*, 2016). However, results suggest that RS is the most viable while APS is the least. Also, the 19.427 ± 0.13% oil content recorded for APS was higher than the 15.30% and 11.94% reported respectively by (Akubugwo and Egbogu, 2007) and (Ajayi and Oderinde, 2002) for APS. The oil content for APS recorded in the present study was however lower than the 50.00% reported elsewhere (Arisa and Lazarus, 2008). Low yield could be attributed to genetic factor, seed species and extraction solvent (Table 1)

The melting points; 28.667 ± 0.35 ^{a} for RSO, 31.420 ± 0.30 ^{b} for APSO and 29.000 ± 0.20 ^{a} °C for CSO, were low. These values varied significantly and could be as a result of difference in fatty acid composition. Low melting point for oils has been associated with unsaturated oils (Ikhuoria and Maliki, 2007). The relative viscosities values were comparable with RSO recording the highest relative viscosity (0.420 ± 0.16^{b}) with values significantly different ($P<0.05$) from APSO and CSO, while CSO recorded the lowest relative viscosity (0.357 ± 0.10^{a}) with value not significantly different from APSO degree of saturation (Mengistie *et al.*, 2018). The low viscosities of APSO and CSO would make them useful in many edible and industrial applications such as in frying and cooking oils, in the production of mayonnaise etc. They can also enter into the production of body cream as their low viscosity would prevent the dryness of the skin when used as body cream (Ikhuoria and Maliki, 2007).

RSO recorded the highest specific gravity (0.923 ± 0.10^{c}) which was statistically different from APSO and CSO, while APSO recorded the lowest value (0.886 ± 0.00^{a}). The specific gravity value for RSO and CSO are comparable and similar to values documented by Asuquo *et al.*, 2012, Ebewele *et al.*, (2010) and Kaur *et al.*, (2016) for RSO. These values are comparable to the specific gravities of other edible vegetable oils (Negash, *et al.*, 2019) and within the 0.919-0.925 levels advised by FAO/WHO (2009). The highest specific gravity obtained for RSO could be attributed to the presence of high content of linoleic acid. Previous studies have associated high specific gravity levels to presence of linoleic acid (Mengistie *et al.*, 2018).

Table 1: Physical Properties

Sample/ Physical Properties	Rubber Seed Oil	African Pear Seed Oil	Cotton Seed Oil
State	Liquid	Liquid	Liquid
Colour	Brownish Yellow	Light green	Golden brown
Odour	Unpleasant	Pleasant	Pleasant
Viscosity (Poise)	0.420 ± 0.16^{b}	0.372 ± 0.00^{a}	0.357 ± 0.10^{a}
Specific gravity at 29°C	0.923 ± 0.10^{c}	0.886 ± 0.00^{a}	0.900 ± 0.00^{b}
Melting point (MP) (°C)	28.667 ± 0.35 ^{a}	31.420 ± 0.30 ^{c}	29.000 ± 0.20 ^{b}
% Yield (%)	42.967 ± 0.59 ^{c}	19.427 ± 0.13 ^{a}	35.433 ± 0.86 ^{b}

Results are expressed as mean of triplicate determinations. (The superscripts a, b and c represents statistical significance). Values with the same superscript letters on the same row do not differ significantly at $p< 0.05$

Acid value is a measure of the amount of free fatty acids present in fat and oils. It gives an indication of the deterioration, rancidity, or edibility of the oil. High acid levels imply that the oil will require an excess polyol for its polycondesation reaction. The acid value obtained for RSO (32.600 ± 0.81 ^{c} mg KOH/g) in this study was very high compared to the APSO (8.731 ± 0.45 ^{b} mg KOH/g) and CSO (6.840 ± 0.51 ^{a} mg KOH/g). The acid value of RSO was higher than the 1.68 mgKOH/g recorded by (Asuquo *et al.*, 2012) but lower than values obtained by (Abdulkadir *et al.*, 2014) and (Ebewele *et al.*, 2010) who recorded 34.0 and 37.96 mg KOH/g respectively in similar studies for RSO. High acid value may be due to hydrolytic reaction during processing or due to enzymatic action in the RSO. However, alkali refining can be used to achieve the desired acid content (Aigbodion *et al.*, 2001; Nawar, 1996). The acid values for APSO and CSO suggest that they can be used in different edible applications.

The saponification value gives an indication of the molecular weight of the fatty acid contained in the oil. It also gives an indication of the purity status of the oil or whether the oil is adulterated (Akubugwo and Ugbogu, 2007). High saponification values suggest that the oil has little impurities. In this study the saponification values recorded were high and varied significantly amongst the oils and the highest value was recorded for RSO (185.333 ±3.51 [c] mg KOH/g oil). The saponification value recorded for RSO in this study was lower than the 193.61 mg KOH/g and 226.02 mg KOH/g recorded respectively by (Asuquo *et al.,* 2012) and (Ebewele *et al.,* 2010) but higher then than the 179.6 mg KOH/g oil recorded by (Abdulkadir *et al.*, 2014) in similar studies for RSO. Saponification value recorded for APSO (173.115 ± 0.51 [a] mg KOH/g) was comparable with the finding of (Arisa and Lazarus, 2008) and (Ajayi and Oderinde, 2002) who respectively reported 172.80 and 179.52 mg KOH/g for APSO. Elsewhere, higher values of 246.60mg KOH/g and 213.54mg KOH/g were recorded by (Akubugwo and Ugbogu, 2007) and (Onuegbu *et al.,* 2016). The difference in values may be due to genetic and ecological variations as values fall within the range reported in literatures. The high saponification values obtained suggest that the oils could be good for soap making.

The iodine value is a measure of the degree of unsaturation of oils. High iodine value is attributed to high unsaturation. It is the amount of iodine in grams that will saturate 100 grams of the oil or fat. Saturated oils and fats have zero iodine value because they cannot take up any iodine. Iodine value is also the measure of the drying property of oils. It is used as a basis for the classification of fats and oils into drying (with iodine value higher than 150 g I_2/100g), semi-drying and non-drying (with iodine value of the range 100 - 150 g I_2/100g) and non-drying (with iodine value lower than 100 g I_2/100g) oils (Aremu *et al.,* 2015; Asuquo *et al.*, 2012). This information determines the ability of oils to form solid film on exposure to air. The RSO recorded the highest iodine value (139.703 ± 1.48 [c] g I_2/100g) which is significantly different ($P<0.05$) from CSO and APSO which recorded the lowest (43.849 ± 0.40 [a] g I_2/100g) value. The higher iodine value of RSO could mean that it has higher unsaturated fatty acids. The iodine value recorded for RSO in this study was significantly higher than the 118.8 g I_2/100g reported by (Kaur, 2010) for RSO in a related study. Also, the iodine value of APSO (43.849 ± 0.40 [a] g I_2/100g) was within the range of values reported in literature; 31.50 g I_2/100g by (Ajayi and Oderinde, 2002), 32.40 g I_2/100g by (Arisa and Lazarus. 2008), 40.20 g I_2/100g by (Akubugwe and Ugbogu, 2007) and 48.16 g I_2/100g reported by (Onuegbu *et al.*, 2016) for APSO. The high iodine values of RSO suggest that the oil can be classified as a semi-drying oil (iodine value of 100-150 g I_2/100g) (Asuquo *et al.,* 2012) thus can be used in alkyd resin production and other formulations such as liquid soap and shoe polish. APSO and CSO can be classified as non-drying oil, because of their low iodine values. Therefore, not suitable for ink and paint production due to their non-drying properties but could enter into useful application such as in the manufacture of soaps, body creams, cosmetics, plasticizers and lubricants. The iodine value for APSO and CSO recorded in this study compares favorably with 40.20 g I_2/100g and lower than 32.40 g I_2/100g reported for ASPSO in a similar studies by (Akubugwo and Ugbogu, 2007) and (Arisa and Lazarus, 2008) respectively and suggest that they have higher saturated fatty acid content (that is they contain less unsaturated bonds) and as such the oils will be resistant or less prone to oxidative rancidity.

The peroxide value gives an indication of the quality and stability of oil. It is used to determine the extent to which oil can go rancid as a result of storage, heating or oxidation. Rancid oils have peroxide values of 10- 20 mequiv O_2/kg oil and the Standard Organization of Nigeria (SON) recommended peroxide values for edible oils is 10 mequiv O_2/kg oil (Onoji *et al.*, 2016). In this study RSO (14.300 ±0.43 [c] mequiv O_2/kg oil) recorded the highest peroxide value which was statically different ($P<0.05$) from APSO (6.312 ± 0.38 [b] mequiv O_2/kg oil) and CSO (3.46 ± 0.41 [a] mequiv O_2/kg oil). The peroxide value for RSO in this study was within the 1.6 – 16 mequiv O_2/kg range reported in the literature for RSO (Onoji *et al.,* 2016).The high peroxide value recorded for RSO fall above SON recommended limits thus not suitable to be eaten. However peroxide value can be significantly reduced by the refining process (Bell and Gillattm, 1994). On the other hand, the high peroxide value also suggests that the oil can resist deterioration during storage (Mohammed and Hamza 2008). The low peroxide values recorded for APSO and CSO classified them as edible, more saturated and less prone to rancidity (Asuquo *et al.,* 2012).

The unsaponifiable matter (sterols, phospholipids, waxes, terpanes etc) of all the samples were low, with RSO having the highest value (9.297 ± 0.61 [c] %). This value was statistically different ($P<0.05$) from APSO (3.833 ± 0.08 [b] %) and CSO (1.929 ± 0.38 [a] %). This implies that RSO is less saponifiable while CSO is more. Sterols and phospholipids can be extracted from oils with high unsaponifiable matter for use respectively in the production of drugs in pharmaceutical and production of lecithin, used in the manufacture of margarine, confectionery, shortenings, etc (Dibungi *et al.,* 2002; Ikhuoria and Maliki, 2007).

The free fatty acid is an index for determining the quality of oils. The lower the free acid content, the more desirable is the oil as edible oil (Bell and Gillattm, 1994). It is recommended that edible oil should have free fatty acid values of less than 5% (Ikhuoria and Maliki, 2007) as such oils has lower tendency to go rancid (Roger *et al.,* 2010). Free fatty acid values follows the same trend as the acid value, with RSO (16.398 ± 0.41 [c] %) being significantly higher ($P<0.05$) than APSO (4.392 ± 0.22 [b] %) and CSO (3.441± 0.24 [a] %). The free fatty acid value recorded for RSO compared with the 18.98% and 17.00% recorded by respectively by (Ebewele *et al.,* 2010) and (Abdulkadir *et al.,* 2014) for RSO in similar studies. However, the value was significantly higher than 0.84% and significantly lower than 41.64% reported by (Asuquo *et al.,*2012) and (Kaur *et al.,* 2016) respectively. High acid and free fatty acids values of RSO have been associated to its higher degree of unsaturation (Eka *et al.,* 2010; Kaur *et al.,* 2016*).* Furthermore, the free fatty acid value recorded for APSO was again higher than the 2.78% reported by (Akubugwo and Ugbogu, 2007) for APSO in a similar study. Also, the value recorded for CSO exceeded the 1.7 – 2.80% rang reported in literature (Gumuskese, 1992; Konuskan *et al.,* 2015). Elsewhere, higher free fatty acid values in oils has been associated to increased hydrolytic activities in the presence of moisture, catalysed by some enzymes, acids, bases and heat (Ikhuoria and Maliki, 2007). However, the free fatty acids values for APSO and CSO being lower than 5% makes them desirable as edible oils.

The ester value is the number of milligrams of potassium hydroxide required to saponify the esters present in 1g of the oil. In this study, the ester values were high suggesting high amount of esters and low molecular weight fatty acid content. CSO recorded the highest value (173.503 ± 6.31 [c] mgKOH/g) which was significantly different ($P<0.05$) from APSO and RSO which recorded the lowest value (135.330 ± 2.99[a] mgKOH/g). The high ester value of CSO implies higher amount of ester than fatty acid content. The ester value recorded in this study were comparable with many vegetable oils such as castor oil (174.09 mgKOH/g), avocado pear oil (172.8 mgKOH/g) (Ikhuoria and Maliki, 2007), groundnut oil (173.90 mgKOH/g) (Musa *et al.,* 2012) and soybeans oil (188.02 mgKOH/g) (Akanni *et al.*, 2005). The heat of combustion value were significantly different ($P<0.05$) with the highest value recorded by APSO (9752.149± 5.37 [c] gcal/g) and RSO recorded the lowest value (9544.500± 32.14 [a] gcal/g). The values recorded in this study fall within 8904.25 gcal/g and 11303.35 gcal/g range reported in literature (Aremu *et al.*, 2014).

Table 2: Chemical Properties

Samples/Chemical Properties	Rubber Seed Oil (RSO)	African Pear Seed Oil (APSO)	Cotton Seed Oil (CSO)
Acid Value (AV, mg KOH/g)	32.000 ± 0.81 [c]	8.731 ± 0.45 [b]	6.840 ± 0.51 [a]
Saponification Value (SV mg/ KOH/g)	185.333 ±3.51 [c]	173.115 ± 0.51 [a]	180.343 ± 5.80 [b]
Iodine Value (IV g I_2/100g)	139.703 ± 1.48 [c]	43.849 ± 0.40 [b]	42.660 ± 0.40 [a]
Peroxide Value (PV meqO_2/Kg)	14.300 ±0.43 [c]	6.312 ± 0.38 [b]	3.460 ± 0.41 [a]
Unsaponifiable Matter (USM %)	9.297 ± 0.61 [c]	3.833 ± 0.08 [b]	1.929 ± 0.38 [a]
Free Fatty Acid (FFA %)	16.096 ± 0.41 [c]	4.392 ± 0.22 [b]	3.441± 0.24 [a]
Ester Value (EV mgKOH/g)	135.330 ± 2.99[a]	164.384 ± 0.94 [b]	173.956 ± 6.31 [c]
Heat of Combustion (HC) gcal/g	9544.528± 32.14 [a]	9752.147± 5.37[c]	9687.202± 50.28 [c]

Results are expressed as mean of triplicate determinations. (The superscripts a, b and c represents statistical significance). Values with the same superscript letters on the same row do not differ significantly at $p< 0.05$.

CONCLUSION

Results obtained from this study showed that the oils extract were brownish yellow, light green and golden brown for RSO, APSO and CSO respectively. APSO and CSO had pleasant odour while RSO was unpleasant. The percent oil content of all the oil bearing seeds were appreciable with rubber seed (42.967 ± 0.59%) being the most viable. The extracts were all liquid at room temperature and with low melting point signifying that they can all be classified as oils with some levels of unsaturation. The results suggest that the oils have many edible and industrial attributes. The low viscosities of APSO (0.372 ± 0.00[a]) and CSO (0.357 ± 0.10[a]) would make them useful in frying and cooking oils and in the production of mayonnaise, body cream. Only with some little variation, acid values, saponification values, iodine values, peroxide values and free fatty acid values followed the same trend with RSO recording the highest values. These observations suggest that RSO have higher degree of unsaturation, can be classified as semi-drying oil, it would require an excess polyol for its polycondesation reaction, more prone to rancidity. Its high peroxide value (14.300 ±0.43 [c] mequiv O_2/kg oil) being higher than SON recommended limits for edible oils and also, its free fatty acid (16.096 ± 0.41 [c] %) value being above 5% makes it not desirable as edible oils. Therefore, RSO should be developed for industrial applications such as in the production of alkyd resins and other formulations such as liquid soaps and shoe polish. Also, RSO had the highest unsaponifiable matter thus less saponifiable as a result sterols and phospholipids it contains. However, the sterols and phospholipids can be extracted for use respectively in the production of drugs in pharmaceutical and lecithin, used in the manufacture of margarine, confectionery, shortenings. Although statistically different, APSO and CSO had comparable acid values, saponification values, iodine values, peroxide values and free fatty acid values which were lower than RSO. Their low acid values suggest that they can be used in different edible applications. Their low iodine value classified as non-drying oil therefore, could enter into useful application such as in the manufacture of soaps, body creams, cosmetics, plasticizers and lubricants. Also, their iodine as well as their peroxide values suggests that they have higher saturated fatty acid content and as such the oils will be resistant or less prone to oxidative rancidity.

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