International Journal of the Physical Sciences Vol. 5(6), pp. 826-831, June 2010
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 © 2010 Academic Journals

Full Length Research Paper

Considerations of the extraction process and potential technical applications of Nigerian rubber seed oil

R. O. Ebewele[1], A. F. Iyayi[2]* and F. K. Hymore[3]

[1]Department of Chemical Engineering, University of Benin, Benin City, Edo State, Nigeria.
[2]Valorization Division, Rubber Research Institute of Nigeria, P. M. B. 1049 Benin city, Edo State, Nigeria.
[3]Department of Chemical Engineering, Covenant University, Ota, Ogun State, Nigeria

Accepted 30th April, 2010

Rubber seeds from the rubber tree (*hevea brasiliensis*) are in abundance in Nigeria from which non-edible oil could be obtained. However, the seeds are wasted in the rubber plantations annually even though the extractable oil has potential technical applications. If the full potentials of the oil are to be realized, there is need to have a data base information on the oil extraction process and its properties. Rubber seeds were collected from different rubber clones and extracted first by n-hexane to determine the yield characteristics. Second, the seeds were extracted by a hydraulic press at varied operating conditions: pressure range (5-8MPa), temperatures, 40-90ºC; and moisture content, 7-16%. The effect of particle size and other operating variables on oil yield were studied. The physico-chemical properties of the extracted oil were evaluated. It was found that the percentage oil yield from the seeds of the rubber clone NIG800 at 45.03% was higher than the yield from other clones; GTI (40.21%) and RRIM 707 (38.42%) when the particle size of 1.16 mm was used. Oil yield increased with increase in temperature and pressure. Maximum oil yield was obtained during mechanical pressing at a moisture content of 10% (wt), temperature of 70ºC and pressure of 8MPa. The physicochemical characteristics of the oil showed high incidence of free fatty acid (FFA) of 37.96% (wt) and the high iodine value (IV) of 142.45 is indicative of the presence of high unsaturation. Rubber seed oil could therefore serve as semi-drying oil used in ingredients for surface coating and in the formulation of products where the presence of unsaturation is important.

Key words: Rubber seed oil, extraction, particle size, temperature, moisture content.

INTRODUCTION

The rubber tree (*hevea brasiliensis*) is exploited in Nigeria mainly for latex in view of its economic importance. The ancillary products namely, wood and the seeds are mostly neglected (Hosen et al., 1981). Of these two products, the seeds have the greatest potential and are in abundance in the country (Nwankwo et al., 1985; Achinewhu et al., 1985). The yield of seeds per annum in the plantations is estimated to be from 100 to 150 kg/ha (Abdullah et al., 2009). However, this yield is influenced by factors such as abnormal leaf and phytophora diseases, genetic and weather (George et al., 2000; UNIDO, 1987).

The seeds have been found to be rich in oil. Its content in the dried kernel varies from 35 to 45% (Nwokolo et al., 1988). It is semi-drying and consists of 17-22% saturated fatty acids and 17 - 82% unsaturated fatty acids and is comparable to drying oils commonly used in surface coatings (Aigbodion et al., 2000). Rubber seed oil (RSO) has been found to have potential applications in many areas amongst which are in the production of biodiesel as fuel for compression engines (Ramadhas et al., 2005; Ikwuagwu et al., 2000; Perera and Dunn, 1990), as lubricant (Njoku et al., 1995), foaming agent in latex foam (Reethamma et al., 2005), in the synthesis of alkyd resin used in paints and coatings (Aigbodion et al., 2005; Ikhuoria et al., 2004) and several other uses (Iyayi et al., 2007). RSO has also been used as partial substitute to mineral oil as carrier for copper fungicide in the management of abnormal leaf fall disease of rubber in an attempt to reduce cost without compromising on the efficacy of disease control (Jacob et al., 2007).

As promising as the potentials of RSO are, they are of

*Corresponding author. E-mail: afiyayi@yahoo.com.

no use if there is no viable method for the extraction of the oil from the seeds. The methods commonly used for the extraction of vegetable oil from oilseeds are: mechanical pressing, solvent extraction and most recently the Gas assisted mechanical expression (http://doc.utwente.nl/58041). The first method is simpler to use and the oil obtained via the process is of high quality but the attainable yield is low compared to the oil originally present. The solvent method on the other hand uses inflammable solvent such as hexane for higher oil recovery than the mechanical process but suffers the disadvantage of reduced oil quality (http://doc.utwente.nl/58041). The quality reduction is caused by the solvent co-extraction of undesirable components from the oilseeds. The gas assisted mechanical expression method is a combination of mechanical expression and the use of supercritical carbon dioxide. In this process, carbon dioxide is dissolved in the oil contained in the seeds before pressing. The advantages of the this method are that more oil is recovered without compromising on quality, the mechanical pressure used is much lower than the conventional pressing and the carbon dioxide used has sterilizing effect among others (http://doc.utwente.nl/58041).

To date, no detailed study of the operating conditions necessary for the efficient extraction of Nigerian rubber seed oil has been carried out although small scale production of the oil has been reported (Iyayi et al., 2008). Besides, characterization of the oil so as to establish potential application has not been carried out. Therefore the broad objectives of this study are to evaluate the operating variables such as temperature, pressure, moisture and particle size as they affect oil yield from the rubber seeds and the physicochemical properties of the extracted oil.

EXPERIMENTAL PROCEDURES

Collection of rubber seeds

Three rubber clones in Rubber Research Institute of Nigeria plantations were selected for the purpose of rubber seed collection and subsequent oil extraction. These were: NG800, which is an indigenous clone, G.T.1 and RRIM707 which are exotic clones. These clones have the following yield characteristics in terms of latex production (Omokhafe and Nasiru 2005): NG800 series, 2,600kg/ha/yr; G.T.1, 1,300 kg/ha/yr and RRIM707, 1,346 kg/ha/yr.

Two hundred kilograms of rubber seeds were collected from each of the above rubber clones plantations. They were dried separately in a batch dryer which has an indirect heating process that operates at a temperature range of 60 - 70℃. The seeds were dried to a moisture content of 7% which is safe for storage. The seeds were then packed in jute bags of 25 kg and stored in a warehouse until they were ready to be used.

Oil extraction

Both mechanical expression and solvent extraction were used for the extraction of the oil. Solvent extraction was first used to determine which of the seeds from the rubber clones would yield more oil and also determine the effect of particle size on yield.

Solvent extraction

Fifty (kilograms of the dried rubber seeds from three rubber clones viz: RRIM707, G.T.1 and NIG 800 were decorticated manually to free the kernel from the shell. Five hundred grams of the kernel each were milled to obtain the particles having an average diameter of 1.16, 1.36, 2.36 and 2.36 mm by using standard methods (ASTM E11). Each of these milled kernels was extracted using a soxhlet extractor with n-hexane as the solvent. The extraction was carried for four hours at temperature corresponding to the boiling point of the solvent. The hexane in hexane – oil mixture was evaporated *in vacuo* using rotary evaporator. The oil was then collected and weighed.

The percentage oil yield was calculated for all treatments using the expression below:

$$Y = \frac{Wo\ (100)}{Wm} \qquad (1)$$

Where, Y is the oil yield (%), Wo is the weight of oil expressed (g) and Wm is the weight of the sample of milled rubber seed kernel used in the experiments. The extraction of the oil from each of the clone was carried out for the different particle size.

Mechanical extraction

Five hundred grams of the milled kernel of rubber seeds were put in a mesh bag and placed on a fabricated oil receptor at the lower platen of a laboratory hydraulic press. The lower and the upper platen of the hydraulic press were pre-heated to the desired extraction temperatures. Sample of milled kernel of rubber seeds was extracted at different temperatures: ranging from 40 to 90℃. To extract the oil, the upper and the lower platens of the press were closed on under constant pressure from 5 to 8MPa for each of the temperature above. Oil was expressed from the milled kernel as it was pressed under pressure in between the platens. Thereafter, the effect of moisture content: from 7 to 16% on oil yield was determined at different temperatures and at the optimum pressure. The extracted oil was collected and weighed. The percentage oil yield was later computed from the ratio of mass of oil to the mass of sample before oil extraction.

Characterization of the extracted rubber seed oil

The physico-chemical properties of the oil such as specific gravity (SG), free fatty acid (FFA), peroxide value (PV), iodine value (IV) and saponification value (SV) of the extracted rubber seed oil (RSO) at conditions of maximum oil yield were determined in accordance with methods prescribed by AOCS (Firestone, 1998).

RESULTS AND DISCUSSION

Effect of particle size on oil yield of seeds from different rubber clones

Figure 1 presents the effect of particle size on oil yield of

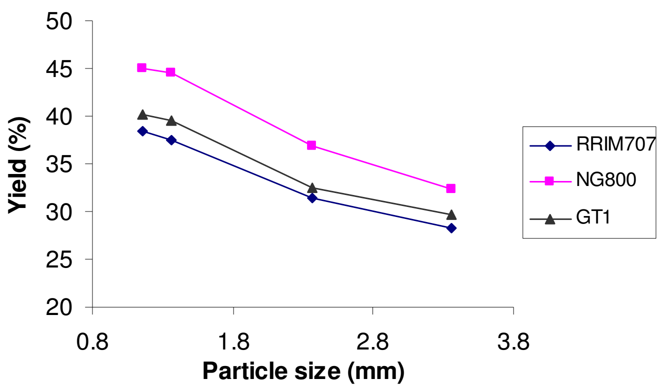

Figure 1. Effect of particle size on yield of RSO from different rubber clones.

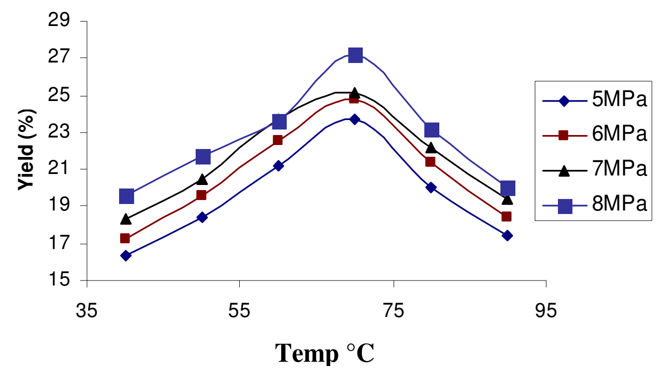

Figure 2. Effect of temperature on yield of RSO at different pressures.

seeds from different rubber clones. In each of the experiment, it is observed that the yield decreased with increase in the particle size.

The highest oil yield for the seeds from the different rubber clones was obtained at the smallest particle size of 1.16 mm while the lowest oil yield was obtained at the highest particle size of 3.36 mm. Among the clones, the highest yield was in the order of NG800 (45.03%) > G.T.1 (40.21%) > RRIM707 (38.42%) using the particle size of 1.16 mm. The trend was similar for the other particle sizes. By decreasing the particle size from 3.36 to 1.16 mm, oil yield was increased from 32.31 to 45.03% for NG800. It does show that less oil is extracted from the larger particles compared to the smaller sized particles. Similar results were obtained by (Goodrum and Kilgo, 1987) while extracting oil from peanut. They found that total oil recovery was increased from 36 to 82% when the particle size range was decreased from (3.35 – 4.75 to 0.86 – 1.19 mm). This phenomenon could be attributed to the fact that smaller particles have larger amount of surface area as well as an increased number of ruptured cells resulting in a high oil concentration at the particle surface. Little diffusion into the particles surface takes place; therefore, the amount of oil available for extraction is proportional to the surface area. (Sayyar et al., 2009) while investigating the extraction of oil from Jatropha seed posited also that larger particles present smaller contact surface areas and are more resistant to solvent entrance and oil diffusion. Therefore, less amount of oil will be transferred from inside the larger particles to the surrounding solution compared to the smaller one.

The oil yield obtained from the seeds of the different rubber clones compared favourably with oil yield reported for some local plant oils (Dawodu, 2009) and commercial vegetable oils such as cottonseed (19.5%), soybean (19%), groundnut (49%) and palm oil (48.6%). Therefore, the rubber seeds from the different clones studied are rich in oil but the ones from the rubber clone NG800 were found to yield more oil than those from the other rubber clones. It is important to note that the locally developed local rubber clone, NG800, apart from producing the highest yield of latex of 2,600 kg/ha/year also produces rubber seeds with high oil content.

Subsequent experiments on mechanical pressing were carried out with oil from the seeds of the rubber clone NG800.

Effect of temperature on oil yield

The effect of temperature on yield is presented in Figure 2. Temperature was found to affect the yield of rubber seed oil which is found to be in agreement with earlier report on temperature effect on oil yield from oilseeds (Koo, 1942).

It is observed that oil yield increased initially with increasing temperature and then subsequently decreased with further increase in temperature. The optimum oil yield was obtained at 70℃. The positive effect of temperature as observed for oil recovery for RSO has also been reported for cottonseed (Hickox, 1953). The reason for the increase in yield is that increase in temperature is believed to facilitate the rupturing of oil cell walls, creating a void which serves as migratory space for the contents of the oil bearing cells (Adeeko et al., 1990). Temperature also lowers the viscosity of the oil and coagulates protein, thus facilitating the release of the oil out of the cells into the inter-kernel void (Ajibola et al., 1993; Nwithiga et al., 2007; Ward, 1976). However, at higher temperature of extraction, there is substantial loss of moisture leading to a hardening of samples (Alonge et al., 2003) and oil degradation (Nwithiga et al., 2007). It was observed that at 90℃ the colour of the oil turned dark brown and the resultant cake was charred. This may account for the decrease in oil yield from 80 to 90℃.

Effect of pressure on oil yield

The effect of pressure on the yield of rubber seed oil is illustrated in Figure 3.

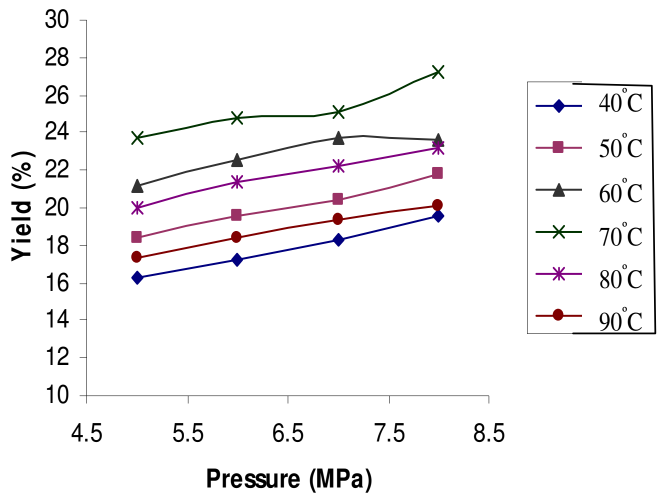

Figure 3. Effect of pressure on yield of RSO.

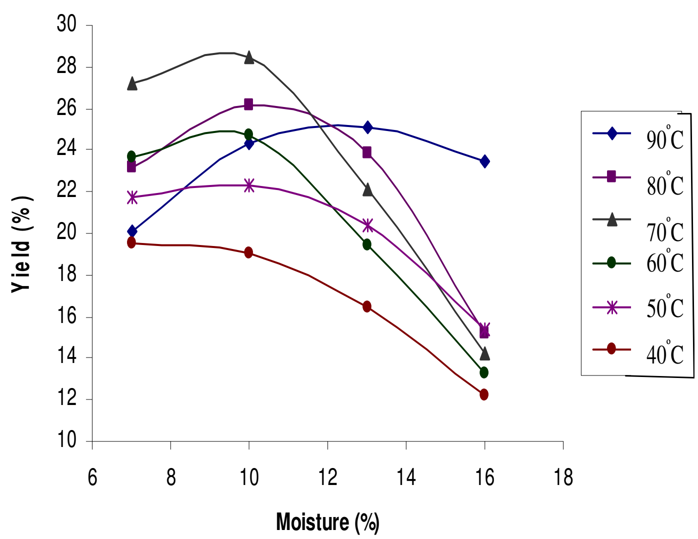

Figure 4. Variation of oil yield with moisture content.

There was consistent increase in oil yield when the applied pressure was increased from 5MPa to 8MPa. However, the oil recoveries reflect the temperature dependence discussed in the previous section: at all applied pressures, oil recoveries increased with increasing pressure and initially as temperature increased from 400 to 700ºC but decreased subsequently as temperature increased from 800 to 900ºC even when applied pressure increased. This may be attributed to the interaction of temperature and pressure which at higher levels tend to be counteractive: increasing the temperature decreases the viscosity of the oil thereby increasing its flowability through the compressed medium whereas an increase in pressure increases the viscosity and reduces the flowability (Bargale et al., 1999). Arising from these results, it can be seen that higher oil recovery is obtained at a pressure of 8MPa applied at a temperature of 700°C

Effect of moisture content of rubber seed on yield

Effect of moisture content of rubber seed on oil yield at different temperatures under condition of constant pressure of 8MPa is graphically illustrated in Figure 4. It is observed that oil yield rose at low moisture content of 7% to reach a maximum value at moisture contents of between 10 to 13% for all temperatures except at 40 and 90°C. At a temperature of 40°C oil yield decreased with increase in moisture content whereas at 50°C there was a marginal increase in yield up till 10% moisture content and thereafter decreased as the moisture content is increased. At 60, 70 and 80°C the optimum yield was essentially at 10% moisture content and followed by rapid decrease in yield at higher moisture content. The trend at 90°C is slightly different as optimum yield is at a moisture content of 13%. The results show that maximum yield of 28.46% was recorded at a moisture content of 10% at a pressing temperature of 70°C while the lowest yield of 12.22% was observed at moisture content of 16% and temperature of 40°C. This is an indication that within the limits of experimental conditions, the highest yield of rubber seed oil was obtained at moisture content of 10%, temperature of 70°C and pressure of 8 MPa.

The effect of moisture content on oil yield from seeds such as cottonseed, groundnut, neem and canola has been studied by some investigators (Hickox, 1953; Alonge et al., 2003; Soetaredjo et al., 2008; Vivek et al., 1988; Bargale et al., 1999) and the above observed range of moisture content for rubber seed oil extraction compare favourably with the reported moisture content of between 5 and 13% as optimum range for maximum oil yield from oilseeds. Moisture in oilseeds during extraction serves as heat transfer medium and helps in the coagulation of protein which aids oil yield. As the temperature increases, substantial amount of the moisture is lost leading to the hardening of the seed particles. Increase in temperature also promotes binding between the oil and the protein within the seed structures, making the oil more attached to the seeds and cannot easily flow out of the seedbed (Soetaredjo et al., 2008). This may account for the reduction in oil yield at higher temperature of extraction.

Physico-chemical properties of the extracted rubber seed oil

The physico-chemical properties of rubber seed oil extracted at the experimental conditions where maximum yield was obtained: temperature 70°C, pressure of 8 MPa and moisture content of 10% are as presented in Table 1 with the properties of other vegetable oils.

Table 1. Physico-chemical properties of rubber seed oil compared to other vegetable oils.

Parameter	RSO	Soybean oil[a]	Sunflower oil[a]
Specific gravity {25°C}	0.943	0.919 - 0.925	0.918 - 0.923
Iodine value {gI_2/100 g}	142.45	124 - 139	110 - 144
Peroxide value {mEq/kg}	16	10	10
Free fatty acid (%)	37.96	-	-
Saponification value {mgKOH/g}	226.02	189 - 195	188 - 194
Colour	Dark brown	-	-

[a]Goli et al., 2008

The specific gravity of 0.943 reported in this study is comparable with other vegetable oils such as soybean and sunflower reported in literatures (Goli et al., 2008). The iodine value (I.V) of 142.45 is indicative of high contents of unsaturated fatty acids in the oil and is comparable to soybean oil and sunflower oil as shown in Table 1. The I.V. is useful in predicting the drying property of oils and the value for RSO suggests that it has semi-drying property, a useful characteristic required in surface coating formulation. Unsaturation in vegetable oil is a desirable property in vulcanized oil synthesis. Thus, the high I.V. recorded for RSO is a strong indication that it would be suitable for vulcanized oil synthesis. The peroxide value of 16 is high compared to most vegetable oils (Dawodu, 2009; Rafiquzzaman et al., 2006). Peroxide value is used as an indicator of the level of deterioration of vegetable oils. Fresh oils have lower peroxide value and higher values indicate high level of rancidity (Dawodu, 2009). Peroxide value (PV) depends on number of factors (Oluba et al., 2008) such as exposure to air, the method of extraction and the type of fatty acids in the oil. The observed high PV for RSO may be attributed to the heating during extraction as heat favours the oxidation of fatty acids most especially polyunsaturated fatty acids. The free fatty acid (FFA) of 37.96% shows that RSO is highly acidic. It indicates that the oil may not be suitable for edible purpose except for technical purposes. Even in some technical uses, for example in biodiesel production (Ramadhas et al., 2005) there may be need for some level of purification to reduce the high acidic content. The saponification value (SV) of 226.02 mgKOH/g obtained for RSO agrees with values for most vegetable oils ranging from 188 - 253 mgKOH/g (Oluba et al., 2008; Atasie and Akinhanmi, 2009). This indicates that RSO has potential application in the production of soap and shampoos. The observed dark brown colour of the oil is most probably due to the extraction process and could be removed by bleaching (3). However, the colour of the oil is not an important factor in end use applications except in some cases where bright colour is a prime consideration such as in pigmented coatings.

Conclusion

From this study, the following conclusions can be drawn:

(1) Rubber seeds irrespective of the rubber clone consist of relatively high quantities of oil. The oil content in the seeds is comparable to that in most oilseeds. Solvent extraction is a more effective process for the oil recovery than the mechanical hydraulic process. Within the experimental conditions, the smaller the size of the milled seeds, the higher the oil recovery.

(2)Process conditions such as temperature, pressure and moisture markedly affect oil recovery from the seeds. Oil yield was found to increase initially with increase in temperature from 40°C and subsequently decreased as temperature was increased to 90°C. The optimum yield was obtained at 70°C. The study also shows a linear relationship between applied pressure and oil yield at a given temperature. Moisture content of 10% is found to be adequate for maximum oil yield.

(3) Rubber seed oil in view of its high iodine and saponification values could be considered as important technical (industrial) oil that could be used in surface coating formulation, soap, biodiesel and vulcanized vegetable oil (VVO) production.

REFERENCES

Abdullah BM, Salimon J (2009). Pysicochemical characteristics of Malaysian rubber (*Hevea Brasiliensis*) seed oil. Eur. J. Sci. Res. 31: 437-445.

Achinewhu SC, Akpapunam MA (1985). Physical and chemical characteristics of refined vegetable oils from rubber seed oil and bread-fruit. Qual. Plant Foods Hum. Nutr. 35: 103-107.

Adeeko KA, Ajibola OO (1990). Processing factors affecting yield and quality of mechanically expressed groundnut oil. J. Agric. Eng. Res. 45: 31-43.

Aigbodion AI, Okieimen FE, Ikhuoria EU, Bakare OI, Obazee EO (2005). Rubber seed oil modified with maleic Anhydride and fumaric acid and alkyd resins as binders in water reducible coatings. J. Appl. Polym. Sci. 89: 3256-3259.

Aigbodion AI, Pillai CKS (2000). Preparation, analysis and applications of rubber seed oil and its derivatives in surface coatings. Prog. Org. Coating, 38: 1187-1192.

Ajibola OO, Owolarafe OK, Fasina OO, Adeeko KA (1993). Expression of oil from sesame seeds. Can. Agric. Eng. 35: 83-88.

Alonge AF, Olaniyan AM, Oje K, Agbaje CO (2003). Effects of dilution water temperature and pressing time on oil yield from groundnut oil expression. J. Food. Sci. Technol. 40: 652 -655.
Atasie VN, Akinhanmi TF (2009). Extraction, compositional studies and physicochemical characteristics of palm kernel oil. Pak. J. Nutr. 8(6): 800-803.
Bargale PC, Ford RJ, Sosulski FW, Wulfsohn D, Irudayaraj J (1999). Mechanical oil extraction from extruded soybean samples. J. Am. Oil. Chem. Soc. 76(2): 223-229.
Dawodu FA (2009). Physico – chemical studies on oil extraction processes from some Nigerian grown plant seeds. EJAFChe 8(2): 102-110.
Firestone D (1998). Official methods and Recommended practices of the American Oil Chemists Society, 5th Ed. AOCS Chapaign Illinois.
Gas assisted mechanical expression of oilseeds, http://doc.utwente.nl/58041/1/thesis-willems.pdf assessed 13/01/2010.
George KT, Reghu CP, Nehru CR (2000). By products and ancillary source. In: Natural Rubber Agro management and crop processing (Ed: P.J George and C. Kuruvilla Jacob) Rubber Research Institute of India , kottayam pp. 509-520.
Goli SAH, Rahimmalek M, Tabatabaei BES (2008). Physicochemical characteristics and fatty acid profile of yarrow seed oil. Int. J. Agric. Boil. 10(3): 355- 357.
Goodrum JW, Kilgo MB (1987). Peanut oil extraction using compressed carbon dioxide. Eng. In. Agric. 6: 265-271.
Hickox GH (1953). Some factors affecting the hydraulic extraction of cottonseed oil. J. Am. Oil. Chem. Soc.30: 481-486.
Hosen SBM, Chin HF, Hor YL (1981). Fruit and Seed Development in *Hevea* in Malaysia J. Rubb. Res. Inst. Malaysia 32(1): 101-110.
Ikhuoria EU, Aigbodion AI, Okieimen FE (2004). Enhancing the quality of alkyd resins using methyl esters of rubber seed oil. Trop. J. Pharm. Res. 3(1): 311-317.
Ikwuagwu OE, Ononogbu IC, Njoku OU (2000). Production of biodiesel using rubber seed oil, Ind. Crops. Prod. 12(1): 57-62.
Iyayi AF, Akpaka PO, Ukpeoyibo U (2008). Rubber seed processing for value-added latex production in Nigeria. Afr. J. Agri. Res. 3(7): 505-509.
Iyayi AF, Akpaka PO, Ukpeoyibo U, Balogun FE, Momodu IO (2007) Rubber seed oil: An oil with great potentials. Chemtech J. 3: 507-516.
Jacob CK, Srinivas P, Prem EE, Manju MJ, Mushrif SK, Idicula SP (2007). Rubber seed oil for partial substitution of mineral oil used as carrier for copper fungicide in the management of abnormal leaf fall disease of rubber J. Rubb. Res. 10(1): 54-61.
Koo EC (1942). Expression of vegetable oils. Ind. Eng. Chem. 34(3): 342-345.
Njoku OU, Ononogbu IC (1995). Preliminary studies on the preparation of lubricating grease from bleached rubber seed oil. Ind. J. NR. Res. 8(20): 140-141.
Nwankwo BA, Aigbekaen EO, Sagay GA (1985). Estimates of Rubber (*Hevea Brasiliensis*) Seed production in Nigeria. In: Industrial Utilization of Natural Rubber, Seed Latex and Wood. Proceedings of Natural Conference (Ed: (Ephraim E. Enabor) Rubb. Res. Institute of Nigeria pp. 78-87.
Nwithiga G, Moriasi L (2007). Study of yield characteristics during mechanical oil extraction of preheated and ground soybeans. J. App. Sci. Res. 3(10): 1146-1152.
Nwokolo E, Kitts DD, Kanhai J (1988). Serum and liver lipids of rats fed rubber seed oil. Plant Foods. Hum. Nutri. 38: 145-153.
Oluba OM, Ogunlowo YR, Ojieh GC, Adebisi KE (2008). Physicochemical properties and fatty acid composition of melon seed oil. J. Bio. Sci. 8(4): 814-817.
Omokhafe KO, Nasiru I (2005). Genetic improvementof Hevea brasiliensis in Nigeria, Proceeddings International Natural Rubber Conference, India, 6-8 Nov.
Perera EDIH, Dunn PD (1990) Rubber seed oil for diesel Engines in Sri-lanka, J. Rubb. Inst. Sri-lanka 70: 11-25.
Rafiquzzaman M, Hossain MA, Hasan MM (2006). Studies on the characteristics and glyceride composition of safflower seed oil. Bangladesh J. Sci. Ind. Res. 41(3-4): 235-238.
Ramadhas AS, Jayaraj S, Muraleedharan C (2005). Biodiesel production from high FFA rubber seed oil. Fuel 84(4): 335-340.
Ramadhas AS, Jayaraj S, Muraleedharan C (2005). Characterization and the effect of using rubber seed oil as fuel in the compression ignition engines. Renewable Energy 30(5): 795-803.
Reethamma J, Rosamma A, Premalatha CK, Kuriakose B (2005). Use of rubber seed oil soap in latex foam from natural rubber/styrene butadiene rubber blend. J. Nat. Rubb. Res. 18(1): 7-13.
UNIDO (1987). Rubber seed processing for the production of vegetable oil and animal feed project (1989) report No. us/Glo/81/103 (http://unido.org/data/ida/017854.cfm).
Sayyar S, Abidin ZZ, Yunus R, Muhammed A (2009). Extraction of oil from Jatropha seeds – optimization and kinetics. Am. J. App. Sci. 6(7): 1390-1395.
Soetaredjo FE, Budijanto GM, Prasetyo RI, Indraswati N (2008). Effects of Pre-treatment condition on the yield and quality of neem oil obtained by mechanical pressing. ARPN. J. Eng. App. Sci. 3(5): 45-49.
Vivek SV, Sosulski FW (1988). Mechanics of oil expression from canola. J. Am. Oil. Chem. Soc. 65(7): 119-1176.
Ward JA (1976). Processing high oil content seeds in continuous screw presses. J. Am. Oil. Chem. Soc. 53(6): 261-264.