Futo Journal Series (FUTOJNLS)
e-ISSN : 2476-8456 p-ISSN : 2467-8325
Volume-5, Issue-1, pp- 22 - 34
www.futojnls.org

Research Paper July 2019

Comparative Analysis of Physicochemical Properties of Ackee Apple (*Blighiasapida)* Seed Oil and other Seed Oils for Bioresin Production

*Orhevba, B.A, Yusuf, O. H and Shuaib, S.

Department of Agricultural and Bioresources Engineering, School of Infrastructure, Process Engineering and Technology, Federal University of Technology, Minna, Nigeria
*Corresponding Author's Email: bosede.orhevba@futminna.edu.ng; borhevba@yahoo.com

Abstract
Oil was solvent extracted from seeds of ackee apple using n-hexane. The moisture content of the seeds and extraction temperature were varied (7.5, 9.5 and 11.5% and 40, 50 and 60^{0}C respectively.) The oil was characterized for yield, relative density, free fatty acid value, acid value, iodine value, and saponification value. The values obtained were: oil yield 23.41%, relative density 0.81 g/cm^3, free fatty acid value 0.561 mg NaOH/g oil, acid value 1.112 mg KOH/g oil, iodine value 66.2 mg iodine/100 g oil and saponification value 589.1 mg KOH/ g oil. Assessments and comparison of the physicochemical properties of the oil with oils (rosigold mango kernel oil, palm oil, hemp seed oil and soya bean oil) that have been used for bioresin production; revealed that the oil yield was fairly adequate. The free fatty acid and acid values of the *ackee* apple seed oil were low compared to the aforementioned oils. Despite its comparatively low oil yield, the oil has advantages over palm oil and soya bean oil as it is a waste material that is readily available and sustainable; thus, its use in bioresin production will not compete for its use as an edible oil. Furthermore, the values obtained for iodine value and saponification value shows that ackee apple seed oil is suitable for bioresin production.

Keywords: Ackee apple, bioresin, oil yield, physicochemical properties

1. Introduction

Resin is a natural or synthetic compound that occurs in a highly viscous state and hardens with treatment. It is usually soluble in alcohol, but not in water. Resin can be classified in a number of different ways depending on the chemical composition and potential uses. It also has many applications, which ranges from art to polymer production, also, many people come in contact with products that contain it on a daily basis (Fiebach & Grimm, 2000).

Ackee apple also known as *achee* (*Blighiasapida*) is a fruit which belongs to the *sapindaceae* (soapberry) family. It is native to tropical West Africa; Cameroon, Gabon, Benin, Burkina Faso, Ivory Coast, Gambia, Ghana, Mali, Togo and Nigeria (Hai, 2014). In Yoruba language, it is known as *isin*. The scientific name, *Blighia sapida,* was in honour of Captain William Bligh who took the fruit from Jamaica to the royal botanical gardens in Kew, England in 1793 and introduced it to science. The common name is derived from the West African term *Akanakyefufo* (Metcalf, 1999).

Ackee, an evergreen tree grows about 10 m tall and has short trunk and a dense crown. The leaves are paripinnately compound,15-30 cm long, with 6-10 elliptical to obovate-oblong leathery leaflets (Vinken & Bruyn, 1995). Each leaflet is 8-12 cm long and 5-8 cm wide. The inflorescences are fragrant, up to 20 cm long, with unisexual flowers that bloom during warm months, each flower as five greenish-white petals (Riffle, 1998). The fruit which is shaped like a pear, turns from green to a bright-red to yellow-orange when it ripens. The fruit usually contains large, shiny black seeds. The fruit typically weighs 100-200 g (Vinken & Bruyn, 1995). Figure 1 shows the ripe fruit and seeds of ackee apple.

Fig. 1: Samples of Ackee fruit and seeds

According to Duke (1985), the fruit is used to treat colds, fever, edema and epilepsy in South America. Many parts of the plant are used in folkloric medication in several tropical countries, such uses include: treatment of nausea and vomiting, whitlow, head lice, dental decay, eye problems, wounds, burns, massage for fractured limbs and internal hemorrhage (www.healthbenefitstimes.com). Ackee is also a good source of nutrients, vitamins and minerals, consuming 100 g of ackee offers 15.2 g of total Fat, 30 mg of vitamin C, 240 mg of sodium, 1 mg of zinc, 0.7 mg of iron, 2.7 g of total dietary Fibre, 1.1 mg of vitamin B3 and 2.9 g of Protein (www.healthbenefitstimes.com)

The term 'bio-derived adhesive' includes natural materials, non-mineral or non-petroleum based organic and agro wastes capable of reproducing the property of synthetic resins. The following constituents give rise to resin property: lignins, carbohydrates, unsaturated oils, liquefied wood and wood welding by self-adhesion. According to Ray (2002), these bioresins may be superimposed with natural or synthetic fibres creating natural fibre composites or biocomposites. Bioresins have replaced new synthetic adhesives for forest products industry in the UK (Ray, 2002).

Polymers derived from renewable resources are an alternate to fossil-based materials (Raquez, Deleglise & Lacrampe, 2010). According to Il'ina and Varlamov (2004), concern for the protection of the environment is encouraging people to initiate measures to seek and find environment friendly bio-composites.

Any component of a liquid that will usually set into a hard lacquer or enamel-like finish is normally referred to as resin (Fiebach & Grimm, 2000). An example is nail polish. Some synthetic resins (like epoxy resin) are also called resins. Some resins when soft are known as 'oleoresins', and when containing benzoic acid or cinnamon acid they are called balsams (Fiebach & Grimm, 2000). Oleoresins are naturally occurring compounds comprising of mixtures of oil and resin, which can be extracted from various plants.

Composite material consists of two or more distinct material phases combined into one engineering material. This is with a view to optimize the properties of the materials while at the same time mitigating the effects of some of the less desirable characteristics (Astron, 1997).

The polymer matrix is one of the two major constituents of composite material commonly called resin (Strong, 1999). Traditional fibre reinforced polymer (FRP) composites manufacturers use thermosetting resins as the polymer matrix (binder) to hold the structural fibre firmly in place. The most common thermosetting resins widely used today for wide range of engineering activities are the polyester, vinyl ester and epoxy resins respectively (Strong, 1999).

1.1. Statement of Problem

Despite the huge potential and vast engineering applications of composite materials in the areas of air, land and sea transportation among others, synthetic resins (petrochemical resins) have serious limitations in terms of sustainability, renewability, biodegradability and health hazards among others (Sadiq, Bello & Tokan, 2016). According to Sadiq (2008), the bulk of the resins used in Nigeria are imported materials. Thus, the need to investigate materials that not only have similar characteristics as the existing synthetic resins but are also renewable, affordable, available and degradable.

2. Materials and Methods

2.1. Materials

Samples of fresh and mature seeds of ackee apple were obtained from farms around Ijabe, Odo-otin Local Government Area of Osun State, Nigeria. The following apparatuses were used in the study: soxhlet apparatus, pipette, 500 ml beaker, 500 ml measuring cylinder, 1000 ml separating funnel, digital weighing balance (model no: AR2140, serial no. 1228060578), crucible, drying oven (model no: PBSH85F, serial no: 941234), thermometer, measuring spoon, titrating apparatus, density bottle, heating mantle (model no: ER5, serial no: 07208070) and desiccator (model no: 42027).

2.2. Methods

The seeds were screened to remove bad ones, washed, oven dried at a temperature of 110 ^{o}C for 4 hrs, pulverized with pestle and mortar and sieved using 2 mm sieve size. The seeds were then put in an air-tight container to prevent it from absorbing moisture and stored until further analysis. The experimental design of the study is presented in Table 1.

Table 1: Experimental Design

Run	Block	A	B	Responses: Oil Yield g oil/100g	AV (mg NaOH/g oil)	FFA (mg NaOH/g oil)	IV (mg iodine/100g oil)	SV (mg KOH/ g oil)	RD (g/cm^3)
1	1	50	9.5						
2	1	60	9.5						
3	1	40	9.5						
4	1	40	7.5						
5	1	50	11.5						
6	1	40	11.5						
7	1	60	7.5						
8	1	60	11.5						
9	1	50	7.5						

Where:
A: Extraction temperature ^{0}C
B: Moisture content %
Responses
Oil yield
AV: Acid value
FFA: Free fatty acid
IV: Iodine value
SV: Saponification value
RD: Relative density

2.2.1 Determination of Moisture content

The moisture content was determined using the method described by Kyari (2008). *Ackee* seeds were dried in an oven at a temperature of 110℃ for 8 hrs to 11.5% moisture content for easy milling. The seeds were milled into 2mm sieve size particles using a milling machine.

The initial moisture content of the milled sample was calculated using Equation 1.

$$MC = \frac{w_1 - w_2}{w_1} \times 100 \qquad (1)$$

where:
Mc = moisture content (%), W_1 =wet weight of sample or the initial weight of sample (g) and W_2 = dry weight of sample or the final weight of sample (g).

2.2.2 Moisture Content Variation

Two samples of the ackee apple seed powder were conditioned by adding calculated amounts of water, in order to achieve the desired moisture content. After the addition of water, the samples were refrigerated in sealed bags at a temperature of 5^{o}C for 4 days. This was done to achieve uniformity of water adsorption by the seeds. The amount of water added to vary moisture content was calculated from Equation 2;

$$Q = \frac{W_i \quad (M_f - M_i)}{100 - M_i} \qquad (2)$$

where:
Q = amount of water to be added in g,
W_i = initial weight of sample in g,
M_i = initial moisture content of seeds in %
M_f = final moisture content in %.

2.2.3 Oil extraction

Soxhlet extraction process was used for the oil extraction. 20 g of the seed sample was placed inside a thimble made from thick filter paper; and placed in the main chamber of a soxhlet extractor. The soxhlet extractor was placed into a flask containing the extraction solvent and equipped with a condenser. 250 ml of n-hexane was used for the extraction which lasted for about six hours at 40 – 60 ^{0}C. The solvent vapour travelled up the distillation arm and flooded into the chamber housing the thimble of solid, the condenser ensured that any solvent vapour cooled and dripped back down into the chamber housing the solid materials.

The chamber containing the solid material slowly filled with the warm solvent. Some of the desired compound dissolved in the warm solvent. When the soxhlet chamber was almost full, the chamber automatically emptied by a siphon side arm, with the solvent running back down to the distillation flask. During each cycle, a portion of the sample dissolved in the solvent. After many cycles, the desired compound became concentrated in the distillation flask. And after the extraction process was completed, the solvent was evaporated, yielding the extracted oil.

2.2.4 Determination of Percentage Yield of Oil Extracted

The percentage oil yield (Y_p) was determined using International Standard Organization (ISO -3657) method described by Kyari (2008). The extracted oil was weighed and the percentage yield was calculated on dry matter bases using percentage oil yield formula (Equation 3). This procedure was repeated twice to obtain the average result.

$$Y_p = \frac{w_o}{w_s} \times 100 \qquad (3)$$

where;
Y_p= percentage oil yield,
W_o = weight of oil, g
Ws = weight of sample on dry matter basis, g

2.2.5 Characterization of Oil

2.2.5.1 Determination of Relative Density of Extracted Oil

The relative density of the oil was determined in line with ISO method as described by Ejilah (2010). A relative density bottle was washed, rinsed with acetone and dried at 45^{o}C in oven. After the bottle was cooled to room temperature in a desiccator, it was weighed empty using electronic weighing balance. The bottle was filled to a mark with distilled water and weighed again on the same electronic weighing balance. The water was poured out, bottle rinsed with acetone and dried in oven and then filled to the same mark with the *ackee* seed oil extracted. The specific gravity of the oil was calculated using relative density formula (Equation 4). The procedure was repeated twice to obtain the average result.

$$\rho = \frac{w_3 - w_2}{w_1} \quad (4)$$

where:

ρ = Relative density of oil
W_3 = weight of bottle and pure oil sample, g
W_2 = weight of empty bottle, g
W_1 = weight of equal volume of water = weight of bottle and distilled water - weight of empty bottle.

2.2.5.2 Determination of Free Fatty Acid

The free fatty acid value of the oil was determined using the Association of Official Analytical Chemists (AOAC, 1998)'s method as described by Kyari (2008).1g of the oil was placed in 250 cm^3 conical flask and warmed. 25ml of methanol was added while stirring thoroughly; 2 drops of Phenolphthalein indicator and a drop of 0.14 M NaOH solution were also added. The contents were titrated with 0.14M NaOH solution until a light pink colour which persisted for one minute appeared. The volume of the end point was recorded. At the end of the titrations, the free fatty acid (FFA) was calculated from FFA formula (Equation 5). The procedure was repeated twice.

$$FFA = \frac{Tv \times M \times 28.2}{w_o} \quad (5)$$

where:

Tv = Titre volume,
W_o = Weight of oil, g
M = morality of the base (NaOH) used.

2.2.5.3 Determination of acid value

The acid value of the oil was determined in line with Association of Official Analytical Chemists (AOAC, 1998) method described by Kyari (2008). The free fatty acid value of the oil was multiplied by a constant (2) to determine the acid value of the oil (Equation 6)

$$AV = \%\ FFA \times 2 \quad (6)$$

where:

AV = Acid value of the oil

FFA = free fatty acid of the oil.

2.2.5.4 Determination of Iodine Value

The iodine value was determined by titration using ISO method as reported by Kyari (2008). 21g of the oil and 30 cm^3 Hanus solution were placed in a 250 cm^3 conical flask and stoppered. The contents were thoroughly mixed by shaking and later placed in a drawer for thirty minutes (for complete reaction), it was then titrated with Sodium triosulphate ($Na_2S_2O_3$) until the solution became light yellow. 2 cm^3 of 1% starch indicator was added and the titration continued until the yellow colour almost disappeared. The iodine value was calculated from Equation 7. The procedure was repeated twice.

$$IV = \frac{(B-S)\times N\times 12.69}{W} \tag{7}$$

where:

IV = Iodine value of oil
B = bank titre (without oil) = volume (ml) of $Na_2S_2O_3$ used
S = sample titre (with oil) = volume of $Na_2S_2O_3$ used
N= normality of Sodium triosulphate = 0.1
W= weight of oil = 1g.

2.2.5.5 Determination of Saponification Value

The saponification value of the oil was determined by titration using ISO 3657 method described by Kyari (2008). 2 g of the oil was placed in a 250 cm^3 conical flask and 25 cm^3 of 0.5 M ethanol potassium hydroxide solution was added. A reflux condenser was attached and the flask contents were refluxed for 30 minutes on a water bath while swirling until it started to boil gently. The warm contents in the flask were titrated with 0.5M hydrochloric acid while phenolphthalein served as the indicator. The saponification value of the oil was calculated using Equation 8. The procedure was repeated twice to obtain the average value.

$$SV = \frac{(B-S)\times 28.5}{W} \tag{8}$$

where:

SV = Saponification value of oil
B = titre volume (ml) of blank sample (without oil)
S = titre volume (ml) of sample (with oil)
W = weight of oil = 2 g

3 Results and Discussion

3.1. Results

The results of the study carried out on the oil extraction and assessment of physicochemical properties of *ackee* apple (*Blighiasapida*) seed oil are presented in Tables 2-3.

Table 2: Percentage Oil Yield of Ackee Apple Seeds at Various Moisture Contents

Samples	Moisture Content %	Temperature ^{O}C	Oil Yield %
1	7.5	40	10.33
2	7.5	50	11.98
3	7.5	60	10.52
4	9.5	40	14.98
5	9.5	50	15.43
6	9.5	60	16.18
7	11.5	40	20.61
8	11.5	50	21.50
9	11.5	60	23.41

Table 3: Physiochemical Properties of Ackee Apple Seed Oil

S/No	Parameters	Average Values
1	Percentage yield of oil (g oil/100g dry matter)	23.41
2	Relative density (g/cm^3)	0.81
3	Acid value (mg NaOH/g oil)	1.112
4	Iodine value (mg iodine/100g oil)	66.2
5	Saponification value (mg KOH/ g oil)	589.1
6	Free fatty acid (mg NaOH/g oil)	0.556

3.2 Discussion

The highest oil yield (23.41%, Table 2) was achieved when the moisture content was 11.5% at 60^{o}C. This value (23.41%) is high when compared with those reported for mango kernel oil (19.6) and soya oil (21.4) but lower when compared with palm oil (30.2%) and hemp seed oil (32.4%) (Nursyazana, 2014, Nathan, 2013). The initial value of yield obtained from oil extraction helps to determine whether to proceed with further extraction or change to other fruits or seeds with possibly better yields. Considering the fact that the source of the oil is a waste material discarded by consumers and poisonous, the low yield value may be tolerated since the seeds are abundantly available for use with virtually no cost. Statistical analysis (Table 4) revealed that the temperature and moisture content had significant effect on the yield.

Table 4: ANOVA of Moisture Content and Temperature on Oil Yield

Variables	Oil yield
Moisture content	
7.5	10.95^{c}±1.08
9.5	15.53^{b}±0.68
11.5	21.84^{a}±1.26
Sig.	**
Temperature	
40	15.61^{c}±4.90
50	16.01^{b}±3.79
60	16.70^{a}±5.60
Sig.	**
Interaction	
M*T	**

Means on the same column with different superscript for each variable are significantly different (P≤0.05). Values are mean ±standard deviation
** significant at 5% level

Statistical analysis showed that the interaction between the moisture content had significant effect on the yield as shown in Table 5.

Table 5: Interaction between Moisture Content and Temperature for oil yield

Moisture Content (%)	T (^{o}C)		
	40	50	60
7.5	10.35^{f}	11.98^{e}	10.52^{f}
9.5	14.98^{d}	15.43^{d}	16.18^{c}
11.5	21.51^{b}	20.61^{b}	23.41^{a}

Mean with different superscripts are significantly different.

As presented on Table 2, Ackee apple seed at 11.5% moisture content and temperature of 60^{0}C gave the highest yield of 23.41%. Orhevba , Adejumo and Ubochi (2016) reported oil yields of 41.52% and 50.33% for cashew nut oil extracted at 55^{o}C and 65^{o}C respectively. They concluded that oil yield increases with increase in extraction temperature. Sivala, Bhole & Mukherjee (1991) reported that moisture content in excess of 9% for canola seed adversely affected the oil yield while 10% and 11% moisture contents gave the maximum oil recovery for unseived rice bran and sieved rice bran respectively.

3.2.1 Physiochemical Properties of Ackee apple seed oil

The physiochemical properties obtained for ackee Apple Seed Oil were compared with the physiochemical properties of (Rosigold mango kernel oil, palm oil, soya bean oil and hemp seed oil) as presented in Table 6. Ackee apple seed oil like other renewable oils has numerous physical and chemical properties inherent in it. However, the physiochemical properties that will give an insight into the suitability of the oil for bioresin production are presented in Table 6.

Table 6: Comparison of Physiochemical Properties of Rosigold Mango Kernel Oil, Soya Bean Oil, Hemp Seed Oil and Palm Oil with Ackee Apple Seed oil.

Parameter	Ackee apple oil	Rosigold Mango kerel oil	Soya bean oil	Hemp seed oil	Palm oil

Oil yield %	23.54	19.6	21.4	32.3	30.2
Relative density	0.81	0.874	0.908	0.893	0.931
Acid value (mg NaOH/g)	1.112	6.18	2.13	2.15	2.86
Free fatty acid (mg NaOH/g)	0.556	3.09	2.08	1.79	1.06
Iodine value (mg iodine/100g oil)	66.2	60.7	135.7	163.5	53.8
Saponification value (mg/ KOH/g oil)	589.1	143.6	185.4	190.2	203

The relative density of ackee apple seed oil obtained in this study is 0.81 g/cm^3. Although, the value is low when compared with the relative densities of rosigold mango kernel seed oil (0.874 g/cm^3), palm oil (0.931g/m^3), hemp seed oil (0.893g/m^3) and soya bean oil (0.908g/m^3) as reported by Nursyazana (2014) and Nathan (2013) on oils that have been used for bioresin production, the ackee apple seed oil value of 0.81 g/cm^3 implies that the oil is less dense than water due to the absence of heavy element or hydroxyl groups in it. According to Kakani and Amit (2004), the value of relative density of any oil gives an idea about its dense nature when compared with that of distilled water. According to Sadiq, Ejilah and Aroke (2017), resins generally should be light in weight so as to contribute to the overall light weight of the composite product and this has to start from the raw material (oil) itself.

The acid value of oil gives an idea about the quality of the oil and its tendency to spoil and shelf life and thus its quality (Ejilah, 2010). The acid value of (1.112mg NaOH/g oil) obtained for ackee apple in this study is lower than the values of 6.18 mg KOH/g; 2.86 mg KOH/g; 2.15 mg KOH/g and 2.08 mg KOH/g oil reported for rosigold mango kernel seed oil, palm oil, hemp seed oil and soya bean oil respectively; reported by Nursyazana (2014) and Nathan (2013). The low acid value of *ackee* apple seed oil indicates that it has low free fatty acids and carboxylic acid group in it. This implies that the oil is more unsaturated when compared with those above. This low acid value of the oil makes its suitable for bioresin production. According to Asuquo, Anusiem and Etim (2012), acid value measures the degree of saturation of oil and high acid value indicates high saturation level of free fatty acid and carboxylic acid group present in the oil. According to Ekpa and Ekpe (1995), the acid value is a measure of total acidity of the lipid, involving contributions from all the constituent fatty acids that make up the glyceride molecule. The lower the acids value of the oil, the fewer the free fatty acids it contains which makes it less exposed to the phenomenon of rancidification (Ekpa & Ekpe, 1995).

In this study, the free fatty acid value of 0.556 mg NaOH/g is lower than those reported for Rosigold mango kernel seed oil (3.09 mg KOH/g oil), Palm oil (1.43 mg KOH/g oil), Hemp seed oil (1.075 mg KOH/g oil) and Soya bean oil (1.04 mg KOH/g oil) by Nursyazana (2014) and Nathan (2013). Free fatty acid like the acid value of oil limits the degree of unsaturation of oil and thus undesirable elements in bioresin production (Amos-Tautua & Onigbinde, 2013). The low free fatty acid value thus obtained for the oil makes the oil useful for the production of bioresin.

The iodine value obtained for apple seed oil is 66.2 mg iodine/100g oil. The value is slightly higher than that reported for rosigold mango kernel oil (60.7 mg iodine/100g oil) and palm oil (53.8 mg iodine/100g oil) but much lower than that reported for hemp seed oil (163.5 mg iodine/100g oil) and soya bean oil (135.7 mg iodine/100g oil) by Nursyazana (2014) and Nathan (2013). According to Wool (2005), high iodine value of oil simply implies high degree of unsaturation and thus more C=C bond present in the oil. A successful epoxidation reaction will convert the high proportion of the C=C bond into an epoxide oil which serves as raw material for bioresin production (Nathan, 2013). From the foregoing, it then means that the ackee apple seed oil is better than mango kernel oil and palm oil for bioresin production than the other two oils (hemp seed oil and soya bean oil). Also, the minimum bench mark of iodine value of oil for bioresin production is 50mg iodine/100g oil.

Saponification value of oil is necessary in evaluating the molecular weight of fatty acids in the triacylglycerols in the oil. Thus, low saponification value of oil indicates a very high content of low molecular weight triacylglycerols. However, oil with high saponification value is better for bioresin production than the one with low value (Nursyazana, 2014). The saponification value of the oil obtained in this study 589.1 mg KOH/g oil is higher than the values reported by Nursyazana (2014) and Nathan (2013) on rosigold mango kernel seed oil (143.6 mg KOH/g oil), palm oil (203.9 mg KOH/g oil), Hemp seed oil (190.2 mg KOH/g oil),) and soya bean oil (185.4 mg KOH/g oil) respectively. High saponification value of oil indicates high Lauric acid content of that oil which determines its suitability for making soap, Alkyl resin, wetting agents and detergents among others.

4. Conclusions

The ackee apple seed oil was extracted with an average yield of 23.41%. Assessments and comparison of the physicochemical properties results with those of four other oils (rosigold mango kernel oil, palm oil, hemp seed oil and soya bean oil) that have been used for bioresin production; revealed that the oil yield is fairly adequate. The free fatty acid and acid values of the *ackee* apple seed oil are low compared to the aforementioned oils. These parameters of the oil (acid value and free fatty acid value) compare favourably with the other oils. Despite its comparatively low oil yield (compared with hemp oil and palm oil), the oil has advantages over palm oil and soya bean oil because it is a waste and also a poisonous material that is readily available, affordable and sustainable; thus, its use does not compete for use as edible oil. The saponification value is high as compared with the other oils that are been utilized for production of bioresin, Moreover, considering the minimum iodine value bench mark of 50 mg iodine/100 g oil for oil suitable for bioresin production, Ackee apple seed oil is thus suitable for bioresin production.

The use of ackee apple oil for bioresin production will not only give room for alternative resin that is renewable and sustainable, but will also help to ameliorate some of the challenges associated with total dependence on petrochemical resins thereby hindering the adverse effects of synthetic resins on health, environment and economy.

References

Amos-Tautua, B.M.W. & Onigbinde, A.O. (2013). Physicochemical properties and fatty acid profiles of crude oil extracts from three vegetable seeds. *Pakistan Journal of Nutrition*, 12(7), 647 – 650.

Association of Official Analytical Chemists, (AOAC) (1988). Official methods of analysis. analytical chemist. 3rd Ed. Washington. D.C.

Astron, B.T. (1997). Manufacturing of polymer composites, London: Chapman and Hall.

Asuquo, J. E.; Anusiem, A. C. I. & Etim, E. E. (2012). Extraction and Characterization of Rubber Seed Oil. *International Journal of Modern Chemistry*, 1(3). IJMChem.aspx ISSN: Florida, USA: 109- 115.

Ejilah, I.R. (2010). Performance, emission and wear characteristics of single-cylinder gasoline engine running on seed oil-blended lubricants. Unpublished PhD Thesis, Mechanical Engineering Programme, Abubakar Tafawa Balewa University, Bauchi, Nigeria

Ekpa, O.D. & Ekpe, U.J. (1995). The effects of coconut oil concentration and air exposure to the total acidity of palm oil. *Global Journal of Pure and Applied Sciences* 11, 51-58.

Fiebach, K & Grimm, D. (2000) Resins, Natural. *Ullmann's encyclopedia of Industrial chemistry.* Weinheim: Wiley-VCH.ISBN 978-3-527-30673-2

Hai, H. D. (2014). Vietnamese fruits from soapberry family. https://www.edibleplantsinvietnam.com/vietnamese-fruits-from-family-apindaceae.html. Accessed on 24th July, 2018.

Il'ina, A & Varlamov, V. (2004). Hydrolysis of chitosan in lactic acid. *Applied Biochemistry and Microbiology.* 40(3), 300–303.

Kakani, S. L. & Amit, K. (2004). Material science, new age international publisher, New Delhi, India 267-270.

Kyari, M.Z. (2008). Extraction and characterization of seed oils. *International Agrophysics*. 22, 139- 142.

Metcalf, A. (1999). *The World is so Many Words.* ISBN 0-395-95920-9.

Nathan, W. M. (2013). Development of hemp oil based bioresins for biocomposites. A Dissertation submitted for the award of Doctor of philosophy. Centre of excellence in engineered fibre composites. Faculty of Engineering and Surveying University of Queensland, Australia.

Nursyazana, B.T. (2014). Production of bioresin from Palm oil. Unpublished thesis submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Chemical Engineering Faculty of Chemical and Natural Resources Engineering. Malaysia Pahang

Orhevba B. A., Adejumo B. A & Ubochi V. O. (2016). Effect of extraction temperature on the yield of cashew nut, *Nigerian Journal of Technological Research* 11, 2.

Raquez J.M, Deleglise M & Lacrampe, M.F. (2010). *Progress in Polymer Science.* 35, 487 - 509.

Ray, D. (2002). Impact fatigue behaviour of vinylester resin matrix composites reinforced with alkali treated jute fibres, *Composites Part A: Applied Science and Manufacturing.* 33, 233–241.

Riffle, R. (1998). *The tropical look*. Timber press. ISBN 0-88192-422-9

Sadiq, S. A (2008). Exploring the suitability of coconut fibre as reinforcement in hand-layup fibre reinforced plastic composite: via compression test. Journal of Engineering and Technology (JET). 3 (1), 100-105.

Sadiq, S.A. Bello, A. A & Tokan, A. (2016). Shift towards using renewable oil for resin production for fibre reinforced composite materials in Nigeria. Proceeding of the 29th

AGM & International Conference of the Nigerian Institution for Mechanical Engineers (NIMechE). Uyo in Akwa Ibom state, Nigeria

Sadiq, A. S, Ejilah, I. R. & Aroke, U. O. (2017). Extraction and assessment of physicochemical properties of rosigold mango (*MangiferaIndica*) seed kernel oil for bioresin production. Arid Zone Journal of Engineering, Technology and Environment. 13(5), 643-654.

Sivala, K., Bhole, N. G. & Mukherjee, R. K. (1991). Effect of moisture on rice bran oil expression. *Journal of Agricultural Engineering Research, 50*, 81–91.

Strong, A.B. (1999). Fundamentals of composites manufacturing: materials, method and Applications. SME Publishing Ltd. Dearbarn, MI U.S.A

Vinken P & Bruyn, G. W. (1995). Intoxications of the nervous system Amsterdam, Netherlands: Elsevier science b. v. ISBN 0-444-81284-9

Wool, R.P (2005). Polymers and composite resins from plant oils biobased polymers and composites information bulletin. UK.