Assessment ofMahogany (*khaya senegalensis*) Oil as a Biodieseland Solution to theImpact of Fossil Fuel in the Environment

ABSTRACT

African Mahogany (Khaya senegalensis) is an important tree in Africa. A deciduous tree, reaching up to 35m in height on fertile soils. It has a diameter of up to 1.5 m with 8-16 m bole. The bark is dark grey or pink with red latex. The plant is commonly found in all the Northern States and around South Western States of Nigeria in the rain forest zone. The plant begins to produce fruit after 15 – 25 years throughout the dry season. The fruit is woody capsule, 4-10 cm long and dehisces at maturity. The seeds have a very low moisture content which is good for oil extraction hence its selection. For the purpose of this study, Mahogany seed, distillation apparatus, jaw crusher, water distiller, chiller, soxhlet extractor, oven, digital weighing balance, n-hexane, are the materials used for the extraction.According to Soxhlet procedure, oil and fat from solid material are extracted by repeated washing (percolation) with an organic solvent, usually hexane or petroleum ether. 325 g of mahogany seed was used in 25-x 80-mm thimble.The Sample has an oil yield of 63.58%, with a cake of 206.62g after extraction and a moisture content of 9% as a result of volatile substance due to high vapor pressures.Further studies on the extraction of oil from mahogany seed is recommended with method other than soxhlet extraction method using n-hexane as extracting solvent as the best method of extraction for end users.

Keywords: Mahogany, Soxhlet, Oil, Organic solvent, Thimble, n-hexane.

INTRODUCTION

Due to increasing demand, cost of fossil fuel and environmental degradation, alternative sourceof diesel have to be found toreplace the fossil diesel.Oil from African *Mahogany* (Khaya senegalensis)as a non-edible oil and a good source of biodiesel comparative to Jatrophacurcus which was tried in a crude form by Rudolph Diesel thus the name diesel (Dignity, *et.al.,* 2019). Oils from these plants are highly viscous, about 17 times higher than fossil fuel, therefore biodiesel can be produced by the trans-esterification of vegetable oils, especially non-edible oils to avoid competition andscarcity with food (Fadhluulah,*et. al.*, 2015).

The plant Mahogany (*Khaya senegalensis*) is an important multipurpose tree in its natural range in Africa and Madagascar (Roger, 2004). A deciduous tree, 15-20m tall, reaching up to 35m on fertile soils with a diameter of up to 1.5m and a clean bole of 8 – 16m. The bark is dark grey with a dark pink slash and red latex. It has a compound leaf of up to 20cm long, with 3-7 pairs of usually opposite leaflets, each leaflet is 7-12cm long, 3-5cm wide, underside grey.The flowers are small, about 5 mm, with white petals; unisexual, but with well-developed vestiges of the opposite sex, making it difficult to distinguish between male and female flowers. Flowers are borne on up to 20cm long, much branched inflorescences. All species become big trees, 20 – 35m tall with a trunk over 1 m in diameter, often buttressed at the base. The plant strives well in riverine forest and scattered in high rainfall Savannah woodland with 700 – 1750mm rain/year and a dry season of 4 – 7months (Dorthe and Sylvie, 2003). The plant is commonly found in Northern Nigeria and around Lagos, Ogun, Edo, Osun and Oyo states in the rain forest zone, while in the middle belt it is found around Niger, Benue, Adamawa and Taraba states (Michael, 2004). The plant begins to produce seeds when they are 15 – 25 years and in most places,fruiting is regular and the fruits remain on the tree for most of the dry season. The plant is rated as one of the best for timber due to the hard and moderately hard wood with a density of 0.6 – 0.8 g/cm. The plant is valued for its medicinal purposes, especially the bark, which is used to treat a number of diseases. The leaves have low forage value and are used at the end of the dry season(Dorthe and Sylvie, 2003). In West Africa, particularly Nigeria, the seed oil is used for cosmetics, due to its high oil content of 67%, comprising 21% palmitic acid, 10% stearic acid, 65% oleic acid and 4% unidentified acid (Dorthe and Sylvie, 2003).

During the 20th century, the use of non-edible oil seeds products declined substantially due to availability of relatively and cheap oil derived from fossil reserves. Hence, looking into alternative oil source from various seeds remains a subject of active investigation (Rana, *et al*., 2015). Mahogany*(Khaya senegalensis)* seed is valued among the best in production of non-fossil oil used for various applications. Although, such oils are not expected to replace petrochemicals in their entirety, however, the processing of the seeds for the extraction of oil is mostly done conventionally and has great effect on the quality, efficiency and oil yield of the seeds. As such the need to optimize the post-harvest production process which has not received significant engineering research like investigating the physical and mechanical properties of the seed that constitute an important and essential engineering data in the mechanization of its production, handling, processing and storage (Wibawa, *et. al.*, 2017).

The aim of this study was to determine the available quantity of oil per unit quantity of mahogany seeds and to justify its use as biodiesel. The study generated information and data that is useful in choosing the best potential method for extraction of oil from Mahogany seeds.

MATERIALS AND METHODS

The materialsused in this research includes shelled Mahogany seeds, thermometer,measuring cylinder,electronic sensitive weighing balance (Explorer pro EP241C), 100ml beaker, 250ml conical flask,Cotton wood,Foil paper, Masking tape,Cork,Funnel (glass),Water bath (Beijing Zhogxinging Weiye instrument co. (DZ 5L)), set of 50ml measuring cylinder,Spatula,Complete Soxhlet extractor (Witeg NS 60/46), N-Hexane (extraction solvent),heating mantle (international equipment DAS42000) used for the heating, Simple distillation (Ignos *RVO* 400) used for efficient and gentle removal of solvents from samples distillation unit, Mortar and pistil (Retsch KG BB1/A) used to crash and reduce the sizes or change the sample form.

Chemicals Used

The different chemicals used during the process of extraction of the oil were as follows, where most of the reagents are of analytical grade: normal hexane (99%), distilled water and mahogany seed.

Preparation of Mahogany Seed

The Mahogany seeds were collected from Michika a community in Adamawa state in the North Eastern part of Nigeria. The seeds were selected and separated from wastes and other debris manually.

Reduction and Sieving process

The selected seeds were placed in an oven at a temperature of 105^{0}C for a period of 12 hours to dry or remove excessmoisture;the mahogany seed were fed into a jaw crusher to crush the seedsto a particle size of less than 5mm and higher than 0.2 mm. This increases the surface area of theseed and aid in good extraction (Perez, *et. al.,* 2018).

Oil Extraction Using Soxhlet Apparatus

In the solvent extraction process, Soxhlet extraction using normal hexane as solvent was used. The extraction equipment was setup as follows:

A round bottom flask was placed in a heating mantle with a Soxhlet extractor fixed on top of the round bottom flask. A condenser was also placed on top of the Soxhlet extractor. The extractor has sight glass (double glass tube) the inner tube purge into the round bottom flask when the equipment is completely set, while the other indicates the level of the solvent in the extractor.Hexane (solvent) was introduced into the round bottom flask which was placed inside the heating mantle. The minimum amount of solvent required was determined by filling the Soxhlet extractor to the point where it purges. The crushed seed was placed in the thimble, which was put inside the extractor and fixed on top of the round bottom flask. The condenser was placed on top of the extractor. The mantle containing the solvent (220v) was heated and vaporized. The vapor passes through one tube of the extractor into the chamber where the crushed seeds were placed. Some of the rising vapors were condensed back into the extractor by the condenser to ensure maximization of the solvent. The hot solvent was contacted with the crushed seed inside the thimble which extract the oil from the crushed seed. This continues until the mixture of oil and solvent reached the purge point of the extractor. At this point, the mixture was purged into the round bottom flask. The process is then repeated continuously. When the colour of the solvent in the sight glass was almost the same as its original colour, it was assumed the majority of the oil has been extracted and the process was stopped by turning off the heating mantle.After theextraction process, the round bottom flask containing the mixture of mahogany seed oil and solvent was separated from the solvent by simple distillation method (Abdulhamid, *et. al.*, 2013)and Mursiti, *et al* (2019).

Extraction with volatile solvents

The principle of extraction with volatile solvents is simple. Fresh seeds were charged into specially constructed extractors and extracted systematically at a specified temperature. The solvent penetrates the seed material and dissolves it. As we used hexane to extract oil from Mahoganyseeds in this study. Some reports site a solvent residue of 6 - 20% still present in the finished extraction, but this was normally the case when benzene was the standard solvent used. With hexane as the solvent material, the solvent residue goes down to about 10 ppm (parts per million) and this is extremely low concentration of solvent in the resultant product.

Experimental procedures of solvent extraction using hexane

Oil Extraction using Soxhlet Method is the most commonly used semi-continuous process for the extraction of lipids from foods. According to Soxhlet procedure, oil and fat from solid material are extracted by repeated washing (percolation) with an organic solvent, usually hexane or petroleum ether. The n-hexane was used for the purpose of this work, using a modified Soxhlet extraction method with an average of 325g of mahogany seed in 25x 80mm thimble. Grounded Mahogany seed samples were placed in a porous cellulose thimble. The thimble was then placed in an extraction chamber which is being suspended above a flask containing the solvent and below a condenser. Heat was being applied to the flask and the solvent evaporates and moves to the condenser where it is converted into liquid that trickles into the extraction chamber containing the sample. The extraction chamber was made in such a way that when the solvent surrounding the sample exceeds a certain level it overflows and trickles back down into the boiling flask. The flask containing solvent and lipid was removed at the end of the extraction process. The solvent in the flask was separated via distillation and the mass of the lipid remaining was measured. The percentage of the lipid in the initial sample was then calculated. The process of solvent extraction is shown in Figure 1.

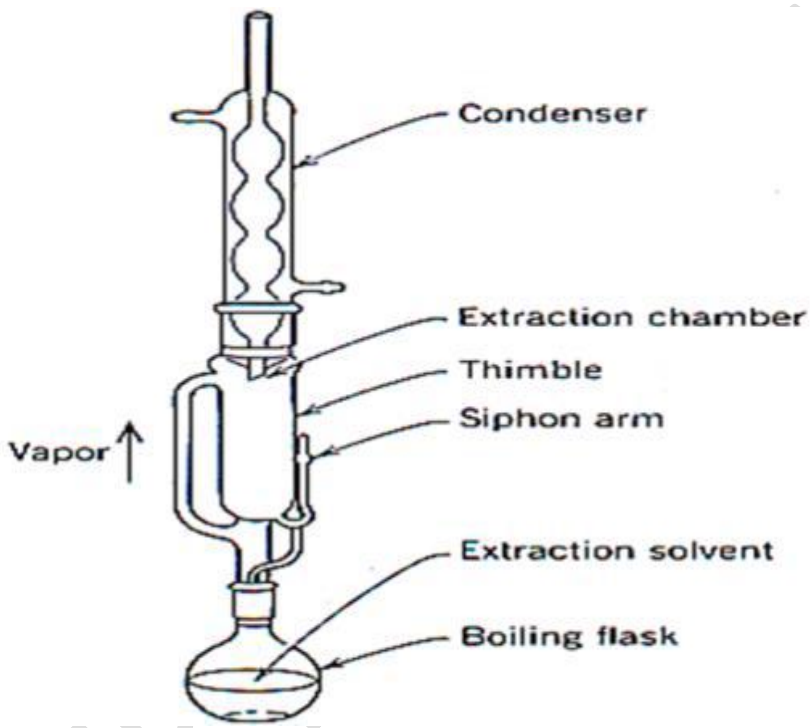

Fig 1:Showing Soxhlet extraction apparatus.

Determination of Percentage of Oil Extracted

The percentage of oil yielded was calculated using the following relations

Initial mass of sample before extraction= 325g

Final mass of sample (oil cake) after extraction=206.62g

Volume of oil after extraction= 90ml

% Yield of oil = $\frac{w1}{w2} \times 100$

Where w1= mass of the cake after extraction

w2= mass of the seed before extraction

% Yield of oil = $\frac{206.62}{325} \times 100 = 63.58$

RESULTS AND DISCUSSIONS

Effect of Moisture Content on the Yield of Mahogany Seed oil

The results obtained were used to determine the effect of the differences in moisture content on oil yield as presented in the table below.

Table 1: Physical Properties of Mahogany Oil Extracted

S/no	Property	Value
1	Initial Weight of Mahogany seeds (g)	325
2	Density (mg/l)	0.885
3	Color	Golden yellow
4	Oil volume (ml)	90
5	Yield (%)	63.58

Table 2:The Effect of Variation in Moisture Content and Yield of Mahogany Oil.

Initial Quantity of seeds	Volume of oil (ml)	% Volume of oil	Quantity of cake (g)	% Quantity of cake	Moisture content (g)	%Moisture content	Color
325	90	27.69	206.62	63.58	30	9.23	Golden yellow
300	80	26.67	188.4	62.80	31.6	10.53	Light yellow
250	65	26.0	157.2	62.88	27.8	11.12	Light yellow
310	85	27.42	198.12	63.91	26.88	8.67	Light yellow

In the results of extraction analysis of the physical properties (Table 1) and the effect of variation in moisture content and yield of Mahogany oil (Table 2). The initial weight of the seed during the first trial was 325g with a density of 0.885mg/l with golden yellow colour. The volume of oil extracted was 90ml which represents 27.69% of the initial seed. According to Ibrahim et al (2019)using the mechanical pounding method of extraction other than soxhlet as employed in this research, oil yield of 73.56% whichis higher than 90 mills (27.69%) as obtained in this research. The wide gap in yield could be attributed to the method employed in extraction. However, this result agrees with Mursiti(2019) who opined that 1400 (28%) mills of oil from 5000g of mahogany seed were obtained using the press method of extraction while the maceration method of extraction yielded 43%. The quantity of the residue (cake) was 206.62g representing 63.58% which is higher than 31.4 and 20.2% found in Azadirachta indica and Carapaprocera despite a low ash content of 5.3 and 8.3 respectively (Djenontin,*et al.*, 2012). This result shows that kernels with higher moisture content produce more oil than those with lower moisture contentoil. There 90 mils of oil 30g of moisture (9.23%) higher than 65 mils of oil at 27.8g of oil(11.12%) this result contradictsOrhevba (2013)where the following of oil was obtained at different moisture content levels22.37% oil yield gave(6.3% moisture content) 24.86% oil yield at a moisture content of 8.1%, 21.21% oil yield with moisture content of 13.2% and 16.6% moisture content yielded an oil of 15,6% the discrepancy could be attributed to method of extraction and differences in environmental factors of where the oil was extracted. However, the pattern of moisture content was consistent with Singh (2019) who reported that oil extracted from seed having 8.4% moisture content on wet basis was considered to be of good quality with a maximum extraction of 91.66% were obtained at 5.8% moisture contentThegolden yellow colour is secondary factor.This is confirmed by the second and third trials respectively where extraction yielded less quantity oil where 300g of seed was used to produce an oil of 80g representing 26.67% with a cake of 188.4g (62.80%) with the highest moisture content of 31.6g (10.53%) but light yellow colour.The third trial used 250g of seed where only 65g (26.0%) of oil was generated as the least quantity with a cake of 157.2g (62.88%) and a moisture content of 27.8g (11.12%) with light yellow color.The final trial with 310g of seeds yielded 85g of oil representing 27.42% with a cake of 198.12g (63.91%) with a moisture content of 26.88g (8.67%) and yellow colour.

There was no consistent pattern with the volume of moisture and quantity of seed. However, the highest moisture content of 31.6g (10.53%) was from 300g of seed and the least of 26.88g of moisture (8.67%) was from 310g.The value of volatile substances ranged from 0.0 to 0.80 with an oil 0.61g which is negligible and can be attributed to heating temp, period of experiment and environmental factors. This result agrees with Idah and Ezeh (2017) that extractable oil is influenced by moisture content of the seed similarly, Perez*et al* (2018) observed that in Sunflower oil was extracted using the batch system at 50^0C using hexane and three moisture content levels 5.65%, 12.40% and 18.92% in a dry season. The increasing moisture content caused an increase in yield and total amount of minor compounds. Also using the screw press method oil yield is affected by moisture content of 0%,1.2% and 20% and particle size of 0.81 min, 2.90 and 8.60 min. The average value of the four trials was 296.25g of seeds which yielded 80g of oil (26.95%) with a residue or cake of 187.59g (63.24%) and moisture content of 29.0g (9.89%).

CONCLUSION

It can be concluded that oil from mahogany can be extracted using hexane as a solvent with a golden colour as a reflection of the quality of the oil. The volume of extractable oil decreases with high moisture content in mahogany. In other plants like Sunflower and Pumpkin the highest yield of oil is obtained with increasing moisture content.Based on the number of trials as indicated in the second trial with 300g of seed yielding 80g of oil (27%) with 188g ofresidue (cake) (63%) and a moisture content of 29g (10%). The volatile substance was negligible.

RECOMMENDATION

Further studies on the extraction of oil from mahogany seed are needed with method other than Soxhlet extraction method using n-hexane as extracting solvent as the best method of extraction for end users. However, it is recommended that moisture content should be maintained to the barest minimum in order to achieve maximum yield of oil.

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