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Production of biodiesel via NaOH catalyzed transesterification of mahogany seed oil

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ABSTRACT

This work focuses on the extraction and refining of mahogany oil from Khaya senegalensis (also known as African mahogany or dry-zone mahogany) seeds, and subsequent production of biodiesel from the refined mahogany oil. The refined mahogany oil was converted into biodiesel via NaOH catalyzed transesterification reaction. The basic properties of the synthesized mahogany biodiesel are in conformity with the ASTM D6751-06 standard for biodiesel fuel (B100). Utilization of the African mahogany seed oil for the production of biodiesel will add value to the African mahogany plant (which is mostly used for timber and fuelwood purposes) thanks to the high inedible oil content of mahogany seeds.

Keywords: Mahogany oil, solvent extraction, biodiesel, ethanol, *Khaya senegalensis*.

INTRODUCTION

Biodiesel is an environmentally benign renewable fuel can be used in any diesel engine without the need for modification. Hence, it is a good alternative to petrodiesel. Biodiesel is a mixture of esters with long-chain fatty acids made from various biological resources ranging from vegetable oils to animal fats. More than 95% of biodiesel production is based on edible oils. However, there is a competition between human consumption of edible oils and production of biodiesel from edible oils. It is because of this reason that many researchers focus their attention on the production of biodiesel from non-edible oils [1-5].

Non-edible oils are not fit for human consumption because they contain toxic compounds. The cost of cultivation of biodiesel from non-edible oils is usually lower than that of biodiesel from edible oils because nonedible oil bearing crops, such as jatropha, can often be grown in lands that are not suitable for food and cash crops [5, 6]. Non-edible oil bearing crops often do not require intensive care. About 60–80% of the total production cost of biodiesel is that of raw materials. Therefore, the search for cheaper raw materials for biodiesel production is a topic of considerable research interest [3, 5, 6].

Khaya senegalensis (also known as African mahogany or dry-zone mahogany) is a dry zone mahogany plant which is widely found in sub-Saharan Africa. It is valuable for timber, fuelwood and medicinal purposes [7]. Proper growth of African mahogany requires mean annual temperature of 24.5 – 31.5 ^{0}C and mean annual rainfall of 400 – 1750mm. African mahogany is tolerant to a wide range of soil conditions ranging from neutral to highly acidic and

from well drained coarse sandy loam to poorly drained clay. In northern Nigeria, African mahogany is often planted by the road sides to provide shade. Furthermore, African mahogany is exported to the United States, where it substitutes expensive American mahogany for America's wood industry [7]. The fruit of Khaya Senegalensis is spherical woody capsule (4-6cm in diameter) as shown in Figure 1. Usually, each capsule contains at least six seeds. Mahogany seeds have about 53 % by weight oil [8, 9]. However, it is used in traditional medicine of several African communities [10]. The fatty acid constituents of mahogany oil are: stearic acid (10.41%), palmitic acid (21.39%), oleic acid (64.62%) and unidentifiable acid (3.58%) [9]. Mahogany oil does not contain essential fatty acids; hence, it does not have nutritional value. Mahogany seed oil is inedible [9]. This paper describes our preliminary study of biodiesel production from mahogany seed oil. To the best of our knowledge this is the first attempt to produce biodiesel from mahogany seed oil.

Mahogany fruit **Ruptured mahogany fruit** **Seeds of mahogany fruit**

Figure 1: Mahogany fruits and seeds

MATERIALS AND METHODS

Mahogany fruit were collected from Zaria town, Kaduna state, Nigeria. Mahogany capsules were broken in order to collect the seeds. The seeds were dried under the sun for about 7 hours. Thereafter, the seeds were roasted to remove the husk. The seeds were then grinded to powdered form with the aid of pestle and mortar. The powdered seeds were then mixed with hot water and boiled for four hours with stirring. The oil layer was carefully skimmed from the top of the boiling mixture. Crude mahogany oil was degummed with phosphoric acid, and then neutralized with 0.8 M sodium hydroxide solution. The neutralized oil was washed with deionised water. The oil was then dried. Activated charcoal was then used to bleach the oil.

For the transesterification reaction, 15 cm^3 of refined dry-zone mahogany oil was stirred at 60 ^{0}C. A solution of 0.1648 g of sodium hydroxide pellets in 42 cm^3 of methanol in a 250 cm^3 was then carefully added to the heated refined dry-zone mahogany oil. The reaction mixture was stirred at 60±2^{0}C for 30 minutes. The reaction mixture was cooled to room temperature. The formed mahogany biodiesel was then separated from glycerine. The biodiesel was washed with deionised water and dried. Standard literature procedures were employed to determine the physical properties of the mahogany oil and mahogany biodiesel [1].

RESULTS AND DISCUSSION

The basic physicochemical properties of mahogany oil and mahogany oil mahogany oil biodiesel are presented in Tables 1 and 2, respectively. As apparent in Table 1, refining of crude mahogany oil leads to the reduction of specific gravity, moisture content, viscosity, and acid value. The reduction of these properties can be attributed to the removal of phospholipids via degumming with phosphoric acid followed by neutralization with sodium hydroxide solution, and adsorption of other impurities by activated charcoal. The 53 % yield of Mahogany oil is comparable to that of the widely used non-edible biodiesel feedstock (jatropha curcas seed oil) [6, 8]. The oil content of the jatropha curcas seed ranges from 30% to 50% by weight [6].

Table 1: Properties of crude and refined dry zone mahogany oil

Property	Crude	Refined
Density at 15^0C, kg/m^3	937	888
Moisture content , % by weight	0.25	0.07
Kinematic viscosity at 40^0C, mm^2/s	56.0	37.0
Acid value, mg KOH/g	5.99	2.53

Table 2 compares some basic properties of the synthesized mahogany biodiesel with those of jatropha biodiesel and the ASTM D6751-06 standard for biodiesel fuel (B100) [4]. The major important property of biodiesels is viscosity which is the measure of biodiesel's ability to flow. In fact the direct use of vegetable oils in diesel engines is limited by its high viscosity which prevents good fuel atomization which results in the thickening of lubricating oil. As apparent in Table 2, the kinematic viscosities of jatropha biodiesel and that of mahogany biodiesel are very close, and fall within the range specified the ASTM D6751-06 standard [4]. The other basic properties (density, acid value, cloud and pour points) of the mahogany biodiesel are also in conformity with the ASTM D6751-06 standard, even though the values of some of the properties of the mahogany biodiesel particularly cloud and pour points, deviate from that of jatropha biodiesel. The difference in some of the properties of mahogany and jatropha biodiesels can be attributed to different composition of the two biodiesels [11].

Table 2: Properties of the synthesized mahogany biodiesel with comparison to jatropha biodiesel and ASTM D6751biodiesel standard

Property	Mahogany biodiesel	[a]Jatropha biodiesel	ASTM D6751-06 standard
Density at 15^0C, kg/m^3	863	862	860 – 900
Kinematic viscosity at 40^0C, mm^2/s	4.83	4.80	1.90 - 6.00
Acid value, mg KOH/g	0.49	0.40	0.80 max
Cloud point, ^{O}C	10	6	-3 – 12
Pour point, ^{O}C	6	2	-15 – 10

[a]*Adapted from ref. 6*

CONCLUSION

Mahogany oil has been extracted from African mahogany seeds and refined. The refined mahogany oil was converted into biodiesel via NaOH catalyzed transesterification reaction. The basic properties of the synthesized mahogany biodiesel are in conformity with ASTM D6751-06 standard for biodiesel fuel (B100). Utilization of the African mahogany seed oil for the production of biodiesel will add value to the African mahogany plant (which is mostly used for timber and fuel wood purposes) thanks to the high inedible oil content of mahogany seeds. More research work is needed in order to optimize biodiesel production from mahogany seed oil.

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