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Short communication

Swietenia mahagoni seed oil: A new source for biodiesel production

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ABSTRACT

Swietenia mahagoni seed oil contains common unsaturated fatty acids such as oleic (25.5%), linoleic (32.6%), linolenic (12.2%) and saturated fatty acids, namely, palmitic (13.0%) and stearic (14.1%) as major fatty acids with 58.1% oil content. In the present study, the oil with 1.39% free fatty acids was converted into biodiesel employing conventional acid-catalyzed esterification followed by base-catalyzed transesterification reaction. The resultant biodiesel was evaluated for physico-chemical properties namely iodine value (104.6), free fatty acids (0.05%), phosphorous content (0 ppm), flash point (165.0 °C), cloud point (7 °C), pour point (9 °C), viscosity at 40 °C (4.13 cSt), oxidative stability at 110 °C (3.7 h), density (0.880 g/cm^3 at 15 °C), and trace metals (Group I metals, 0.5 ppm). The physico-chemical properties were found to be within the range of ASTM and almost falling in the range of EN biodiesel specifications.

1. Introduction

Biodiesel is a renewable, ecofriendly, alternative, non-toxic diesel fuel and is being produced from sources such as vegetable oils, animal fats or used cooking oils. The advantages of this biofuel over the conventional diesel are high cetane number, low smoke and particulates, low carbon dioxide and hydro carbon emissions (Encinar et al., 2007) and it can be used in existing diesel engines without major modifications to the engines. Biodiesel comprises of mono alkyl esters of long chain fatty acids and is produced through transesterification of oils and fats with methanol or ethanol in the presence of different acidic or alkaline catalysts (Ma and Hanna, 1999; Foidl et al., 1996; De and Bhattacharyya, 1999; Fernandes and Ferreira, 2001; Zullaikah et al., 2005). The physico-chemical properties of the various individual fatty esters depend on the structural features of the fatty acid and alcohol moieties that comprise a fatty ester. Structural features that influence the physical fuel properties of a fatty ester molecule include chain length, degree of unsaturation and branching of the chain. Important fuel properties of biodiesel that are influenced by the fatty acid profile and other structural features of the various fatty esters include ignition quality, heat of combustion, cold flow, oxidative stability, exhaust emissions, viscosity, and lubricity (Cvengros et al., 2006). The choice of feedstock for biodiesel production largely depends on geography; rapeseed oil dominating the EU production, soybean oil dominating the USA and Latin American production, and palm oil mostly being used in Asia. There is an increasing interest to search for suitable alternative oils for the production of biodiesel (Sukumar et al., 2005; Usta, 2005) as the usage of edible oils are being discouraged globally. Several non-edible oils such as jatropha and karanja are being exploited for biodiesel preparation (Rashed et al., 2016). However, still new sources are being searched to find out higher oil content-based tree-borne oil seeds which will make biodiesel production economically feasible.

Swietenia mahagoni (Linn) Jacq belongs to plant family *Meliaceae*, locally known as mahagoni, is a large, deciduous and economically important timber tree native to the West Indies, mainly cultivated at the tropical countries such as India, Bangladesh, Malaysia, Southern China, and also in America (Mulholland et al., 2000; Anon, 1989). The tree having seeds chestnut brown in colour, 4–5 cm long (Schmidt and Joker, 2000) and are potentially rich in fat (57.9%) as reported in previous study (Ali et al., 2011). Swietenia mahagoni seed oil consists of linoleic, oleic, stearic, linolenic and palmitic fatty acids (Ali et al., 2011). The oil was not exploited much to develop value-added products. There exist some studies on the analysis and usage of Swietenia mahagoni oil, crude extracts, phenolic compounds for antioxidant, antimicrobial applications (Ali et al., 2011; Mostafa et al., 2011; Subhadip et al., 2011). As this is a tree borne seed-based oil, there will be a good scope for utilizing this oil as a potential feedstock for biodiesel production. However, earlier no studies were conducted on the preparation and evaluation of *S. mahagoni* oil-based biodiesel. Therefore, present study aimed at the preparation and evaluation of biodiesel from *S. mahagoni* seed oil.

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2. Materials and methods

2.1. Materials

The seeds of *S. mahagoni* were supplied by the Andhra Pradesh Forest Department. The authentication of the specimen was done at Andhra Pradesh Forest Department, Hyderabad, India. All reagents and solvents used were purchased from M/s. Sd Fine Chemical Co., Ltd. (Mumbai, India).

2.2. Extraction of Swietenia mahagoni seed oil

The ripe seeds were collected and the damaged seeds were discarded. The seeds were cleaned and dried in an oven at 100 °C for 1 h. The dried kernels of the seed were powdered (750 g) and extracted thoroughly using n-hexane at 60–80 °C temperature (3000 ml) in a Soxhlet extractor for 8 h. After 8 h, the solvent was removed in vacuum at 40 °C by using rotary evaporator and further dried under the reduced pressure to recover the oil (439/750 = 0.585 (58.5% yield)).

2.3. Physico-chemical characteristics of Swietenia mahagoni oil and biodiesel

American Oil Chemists' Society (AOCS) methods were used to determine the free fatty acid (FFA) content, unsap matter, iodine value, saponification value (Firestone, 2003a,b,c,d). International Union of Pure and Applied Chemistry (IUPAC) method was used to determine the phosphorous content (Paquot and Hautfenne, 1987). The viscosity, flash point, cloud point, pour point were determined according to the American Society for Testing and Materials (ASTM) methods (ASTM, 2010a,b,c,d). The remaining physico-chemical characteristics, namely, methyl ester content, oxidation stability and the presence of Group I metals namely Na, K, (EN, 2011a,b,c,; Method 14103, 14112, 14538, respectively) were determined using EN methods.

2.4. Typical procedure for acid catalyzed esterification

Swietenia mahagoni seed oil (280 g) was taken in excess of methanol (methanol-to-oil ratio 15:1) and 1% concentrated H_2SO_4 was then added. The reaction was carried out for 1 h at 65 °C under refluxing and magnetic stirring. The FFA was measured as per AOCS procedure (Firestone, 2003a).The product mixture was transferred to a separating funnel and washed with distilled water to neutralize the organic layer. The organic layer was dried under reduced pressure to remove moisture traces.

2.5. Typical procedure for base-catalyzed methanolysis of oil

Biodiesel was prepared by adopting the procedure reported earlier (Nakpong and Wootthikanokkhan, 2010). The FFA free oil (280 g, 0.327 mol) which was prepared using acid-catalyzed esterification (procedure given in Section 2.4) from crude oil was taken and to this sodium hydroxide-methanol solution [4.07 g (0.102 mol) NaOH in 62.8 g (1.962 mol) methanol] was added. The oil and alkaline methanol solution was mechanically stirred for 1 h at 60 °C. After 1 h, the reaction mixture was taken in a separating funnel to separate the glycerol layer (24.2 g). The top layer which consists of partially esterified product was taken separately and mixed again with sodium hydroxide-methanol solution [1.358 g (0.034 mol) NaOH in 20.9 g (0.654 mol) methanol] and transesterification reaction was carried out to convert the unreacted partial acylglycerols to biodiesel under same temperature and other reaction conditions as described above. After this reaction, the reaction product was again poured in to a separating funnel and allowed it to settle for about 30 min to separate the remaining glycerol as layer (2.5 g). The layered glycerol was removed and the final product was given several water washings to remove traces of alkali, soap and glycerol and at the end the product was dried under high vacuum to obtain biodiesel (275.0 g).

Table 1
Physico-chemical properties of *Swietenia mahagoni* oil.

Characteristic	*S. mahagoni*
Free fatty acids (wt%)	1.39
Unsaponifiable matter (wt%)	0.87
Phosphorous content (ppm)	175.0
Specific gravity at 30 °C	0.9213
Iodine value (g/100 g)	106.0
Viscosity at 40 °C (cSt)	35.6
Density (g/cm^3)	0.9173
Saponification value	192.9

Table 2
Fatty acid composition (wt%) of biodiesel prepared from *Swietenia mahagoni* oil.

Fatty acid	*S. mahagoni*
16:0	13.0
16:1	0.4
18:0	14.1
18:1	25.5
18:2	32.6
18:3	12.2
20:0	1.2
20:1	0.1
22:0	0.2
24:0	0.9

2.6. Fatty acid composition

The fatty acid composition of biodiesel was analyzed by an Agilent 6890 Gas chromatograph (GC) equipped with an Flame ionization detector (FID) detector, split/split less injector, and a non-bonded cyano silicone column (DB-225, 30 m × 0.25 mm × 0.2 μm). The oven temperature was maintained at 160 °C for 2 min and this was increased from 160 to 180 °C at 6 °C/min with a holding time of 2 min and finally raised to 230 °C at 4 °C/min with a holding time of 15 min at 230 °C. The injector and detector were at 250 °C. Chemstation software was used for the data analysis.

3. Results and discussion

Initially the physico-chemical properties of kernel oil of *S. mahagoni* seeds extracted by Soxhlet method were determined using standard methods (Table 1). The yield of the oil obtained from seeds was 58.1%. After careful examination of physico-chemical characteristics of oil it was found that the FFA content was slightly high (i.e 1.39%) which indicates that a two-step strategy should be followed for the preparation of biodiesel from *S. mahagoni* oil. As part of this strategy, initially acid catalyzed esterification reaction was carried out to bring down the FFA present in the oil from 1.39% to 0.05%. In this step, the FFA present in oil was converted to fatty acid methyl esters (FAME) using methanol-sulfuric acid. Subsequently, in the second step the FFA free oil was converted to FAME using a base-catalyzed transesterification reaction where sodium hydroxide-methanol solution was used as methylating agent. In this biodiesel the FFA content was found to be 0.05% which is within the range of ASTM and EN specifications (0.25%). The fatty acid composition of the biodiesel was determined using GC analysis. The GC analysis revealed that linoleic (32.6%), oleic (25.5%) and stearic (14.1%) and palmitic (13%) are the major unsaturated and saturated fatty acids present in the *S. mahagoni* oil (Table 2). The methyl ester content was determined using GC