



Short communication

Characterization and production of *Ceiba pentandra* biodiesel and its blendsA.S. Silitonga^{a,b,*}, H.C. Ong^{a,*}, T.M.I. Mahlia^{c,d}, H.H. Masjuki^a, W.T. Chong^a^a Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia^b Department of Mechanical Engineering, Medan State Polytechnic, 20155 Medan, Indonesia^c Department of Mechanical Engineering, Universiti Tenaga Nasional, 43000 Kajang, Selangor, Malaysia^d Department of Mechanical Engineering, Syiah Kuala University, 23111 Banda Aceh, Indonesia

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ABSTRACT

This paper investigates the opportunity of biodiesel characterization and production from *Ceiba pentandra* seed oil. The biodiesel production was conducted by two step acid–base transesterification. The process was carried out using acid catalyst (H_2SO_4) and alkaline catalyst (NaOH). It has been found that the properties of *C. pentandra* methyl ester fell within the recommended biodiesel standards (ASTM D6751 and EN 14214). Beside, this study also suggests biodiesel–diesel blending to improve the properties of biodiesel such as viscosity, density, flash point, calorific value and oxidation stability. Finally, it can be concluded that this feedstock can be considered as a possible source for biodiesel production.

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1. Introduction

Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from a renewable lipid feedstock such as vegetable oil, animal fat and alcohols [1,2]. Biodiesel is considered as an alternative and clean fuel to replace petro-diesel [3]. There are several studies regard non-edible as promising feedstocks for biodiesel production. Singh and Singh [4] had reported that non-edible vegetable oils have lower price than edible vegetable oil. Besides, the uses of non-edible oil do not compete with food crop. Therefore, some of non-edible methyl ester (biodiesel) have been investigated and reported such as *Jatropha curcas* L. [5], *Calophyllum inophyllum* L. [6], *Datura stramonium* L. [7] and *Sterculia foetida* L. [8]. It is show that exploration of non-edible oil is one of solutions for energy demand and reduce the dependency on the edible oils.

Ceiba pentandra L. Gaertn or locally known as kekabu and kapok belongs to the Malvaceae family [9]. It was native to Southeast Asia and cultivated in Southeast Asia, India, Sri Lanka and tropical America [10,11]. It was grown naturally in humid and sub humid tropical region. *C. pentandra* is generally drought-resistant tree and pods from these trees are leathery, ellipsoid and pendulous capsule [12]. *C. pentandra* seeds occupy about 25–28% (w/w) of each fruit [13]. The oil seed yield was producing on average 1280 kg/ha. *C. pentandra* seeds were low feeding value due to its higher fiber content. Moreover, the possibility of kapok fiber as bioethanol feedstock has been investigated by Tye et al. [14]. They found that kapok fiber contains 34–64% of cellulose and high potential to produce cellulosic ethanol. Traditionally, kapok fibers are utilized as stuffing material for beds and pillows [9]. *C. pentandra* contain a pair of unique cyclopropene fatty acids (malvalic acid) which are more reactive than the double bond carbon (polyunsaturated) in the reaction with radical formation by atmospheric oxygen. Thus, this hydrocarbon chain reduce oxidation stability in vegetable oil [15]. Moreover, poor oxidation stability was also caused by higher polyunsaturated fatty acid in vegetable oil [16]. Bindhu et al. [17] reported that cyclopropene fatty acids (malvalic acids) lead to increase viscosity and caused oxidation more rapid than palmitic acid. Therefore, the aim of this paper is to study the biodiesel production from *C. pentandra* oil using homogeneous catalyst. Besides, the physicochemical properties of *C. pentandra* methyl ester were determined and compared to petro-diesel and other biodiesel.

Abbreviations: ASTM, American Society for Testing and Materials; EN, European Standard; CaCl_2 , calcium chloride; CE, cyclopropene ester; H_2SO_4 , sulphuric acid; H_3PO_4 , phosphoric acid; NaOH , sodium hydroxide pellet; Na_2SO_4 , sodium sulfate.

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Table 1

List of equipment used for properties test.

Property	Equipment	Standard method	Accuracy
Kinematic viscosity	NVB classic (Normalab, France)	ASTM D445	±0.01 mm ² /s
Density	DM40 LiquiPhysics™ density meter (Mettler Toledo, Switzerland)	ASTM D127	±0.1 kg/m ³
Flash point	NPM 440 Pensky-martens flash point tester (Normalab, France)	ASTM D93	±0.1 °C
Cloud and pour point	NTE 450 Cloud and pour point tester (Normalab, France)	ASTM D2500	±0.1 °C
Calorific value	6100EF Semi auto bomb calorimeter (Perr, USA)	ASTM D240	±0.001 MJ/kg
Acid number and Iodine value	Automation titration rondo 20 (Mettler Toledo, Switzerland)	ASTMD664 and EN 14111	Acid number ± 0.001 mg KOH/g, Iodine value ± 0.1 I ₂ mg/g and deviation 0.001%
Canradsons carbon residue (100 sample)	NMC 440 micro-Carbene conradson residue tester (Normalab, France)	ASTM D4530	±0.01%
Copper strip corrosion (3 h at 50 °C)	Seta copper corrosion bath 11300-0 (Stanhope-Seta, UK)	ASTM D130	–
Sulfate ash content	Professional laboratory furnace Model L40/11 (Nabertherm, Germany)	ASTM D874	±0.001%
Sulfur content (S 15 grade and S500 grade)	Multi EA 5000 (Analytical jena, Germany)	ASTM D6667	±0.00 ppm
Oxidation stability, 110 °C	873 Rancimat (Metrohm, Switzerland)	EN 14112	±0.01 h
Methanol content	Agilent 7890 gas chromatograph (Agilent, USA)	EN 14110	±0.008% or 0.0008 min
FAME content		EN 14103	
Cetane number	92000-3 Ignition quality tester (IQT™) (Stanhope-Seta, UK)	ASTM D6890	±0.1
Water content	837 KF coulometer (Metrohm, Switzerland)	EN ISO 12937	±0.001%
Carbon			
Hydrogen	CE 440 CHN Elemental Analyzer (EIA, USA)	ASTM D5291	±0.00 %wt.
Oxygen			

2. Materials and methods

2.1. Materials

Crude *C. pentandra* oil, *J. curcas* and palm biodiesel were purchased from Cilacap, West Java, Indonesia. All reagents used are methanol, H₂SO₄, H₃PO₄, NaOH, CaCl₂ anhydrous, Na₂SO₄ anhydrous and Whatman filter paper size 150 mm (filter fioroni, France) were purchased from Metta Karuna Enterprise (Kuala Lumpur, Malaysia).

2.2. Esterification–transesterification process

In this process, 1 l of crude *C. pentandra* oil with 8:1 molar ratio of methanol to oil and 1% (v/v) of H₂SO₄ were added to the pre-heated oils at 60 °C for 2 h at 1200 rpm stirring speed. After completion reaction, the products were poured into a separating funnel to separate the excess alcohol, H₂SO₄ and impurities presented in the upper layer. The lower layer was separated and settling down for 4 h. Then, the esterified oil entered into a rotary evaporator at 65 °C under vacuum conditions for 1 h to remove extra methanol and water. After that, the esterified oil was reacted with 8:1 molar ratio of methanol and 1% (w/w) of NaOH and maintained at 50 °C for 1 h at 1200 rpm stirring speed. Upon completion of the reaction period, the biodiesel was deposited in a separating funnel for 6 h to separate glycerol from biodiesel. The lower layer which contained impurities, excess methanol and glycerol was drawn off. The *C. pentandra* methyl ester produced was entered into a rotary evaporator to remove remain methanol. Then, the methyl ester was washed with distilled water for several times to remove the entrained impurities glycerol. In this process, 50% (v/v) of distilled water at 50 °C was sprayed over the surface of the esters and stirred gently. The lower layer was discarded and upper layer was entered into a flask. The methyl ester was dried using CaCl₂ anhydrous for 1 day then Na₂SO₄ for 3 h and filtered by a paper filter. Finally, the methyl ester further purified using rotary evaporator at 65 °C for 1 h to remove the water from completely biodiesel.

Table 2The physical properties and fatty acid composition of crude *Ceiba pentandra* oil.

Properties	Crude <i>Ceiba pentandra</i> oil
Density at 15 °C (kg/m ³)	905.2
Kinematic viscosity at 40 °C (mm ² /s)	34.45
Acid value (mg KOH/g)	16.80
Flash point (°C)	170.5
Fatty acid composition	Percentage (wt.%)
C12:0 (Lauric acid)	0.1
C14:0 (Myristic acid)	0.1
C16:0 (Palmitic acid)	19.2
C16:1 (Palmitoleic acid)	0.3
C18:0 (Stearic acid)	2.6
C18:1 (Oleic acid)	17.4
C18:2 (Linoleic acid)	39.7
C18:3 (Linolenic acid)	1.5
C20:0 (Arachidic acid)	0.6
18:CE ^a (Malvalic acid)	18.5

^a CE: cyclopropene ester.

2.3. Biodiesel–diesel blending

The preparation of biodiesel–diesel blends was done at 26 °C by beaker glass on a volume basis at agitation of 2000 rpm for 30 min to ensure homogeneity of the mixture. In this study, biodiesel was blended with diesel at four different ratios which are 10%, 20%, 30% and 50% to examine properties of biodiesel–diesel blending.

2.4. Characterization fuel properties

The physical and chemical properties of the crude oils, biodiesel and blends produced in this study were tested according to ASTM 6751 and EN 14214 standard [3,18,19]. Table 1 shows a summary of the equipment and method used to analyze the properties. Each property test was repeated for three times and the mean value was calculated for each sample.

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