Turnitin Originality Report

IJIC by Suryadi Ismadji

From Hippo (Hippo-03)

Processed on 21-Aug-2018 08:37 WIB
ID: 991684041
Word Count: 5128

Similarity Index	Similarity by Source	
12%	Internet Sources:	6%
	Publications:	12%
	Student Papers:	5%

sources:

1 1% match (Internet from 14-Mar-2016)
https://www.springerprofessional.de/biocomposites-of-polyamide-4-10-and-surface-modified-microfibril/7014084?fulltextView=true

2 1% match (Internet from 18-Nov-2016)
http://ir.lib.hiroshima-u.ac.jp/files/public/3/37620/20150618115411753332/k6594_3.pdf

3 1% match (Internet from 29-Nov-2011)
http://pubs.acs.org/doi/abs/10.1021/je200239p

4 1% match (publications)
Soetaredjo, F.E.. "KOH/bentonite catalysts for transesterification of palm oil to biodiesel", Applied Clay Science, 201108

5 1% match (publications)
Santosh Ashok Kadapure, Kiran A, Anant J, Dayanand N, Rahul P, Poonam K. "Optimization of conversion of Pongamia pinnata oil with high FFA to biodiesel using novel deep eutectic solvent", Journal of Environmental Chemical Engineering, 2017

6 1% match (student papers from 25-Nov-2013)
Submitted to University of KwaZulu-Natal on 2013-11-25

7 1% match (publications)
Kok Tat Tan, Keat Teong Lee, Abdul Rahman Mohamed. "Production of FAME by palm oil transesterification via supercritical methanol technology", Biomass and Bioenergy, 2009

8 1% match (Internet from 18-Jun-2017)
http://www.europarl.europa.eu/RegData/etudes/STUD/2015/513991/IPOL_STU(2015)513991_EN.pdf

9 < 1% match (publications)
"Green Fuels Technology", Springer Nature, 2016

10 < 1% match (Internet from 20-Apr-2010)
http://aem.asm.org/cgi/content/full/72/7/4604

11 < 1% match (publications)
Ang, Gaik Tin, San Nee Ooi, Kok Tat Tan, Keat Teong Lee, and Abdul Rahman Mohamed. "Optimization and kinetic studies of sea mango (Cerbera odollam) oil for biodiesel production via supercritical reaction", Energy Conversion and Management, 2015.

12 < 1% match (student papers from 27-Jun-2013)
Submitted to University Tun Hussein Onn Malaysia on 2013-06-27

13 < 1% match (Internet from 03-Nov-2009)
http://www.foodmaster.com/directories/229/2007/230774/fm08pola_online3.pdf

14 < 1% match (publications)
Kansedo, Jibrail, and Keat Teong Lee. "Process optimization and kinetic study for biodiesel production from non-edible sea mango (Cerbera odollam) oil using response surface methodology", Chemical Engineering Journal, 2013.

15 < 1% match (student papers from 01-Jul-2011)
Submitted to Higher Education Commission Pakistan on 2011-07-01

16 < 1% match (Internet from 27-Jan-2017)
http://cdn.intechopen.com/pdfs-wm/52608.pdf

17 < 1% match (Internet from 25-Mar-2016)
http://www.innspub.net/wp-content/uploads/2014/07/IJB-V5No2-p47-55.pdf

18 < 1% match (publications)
Chandra, T.C.. "Adsorption of basic dye onto activated carbon prepared from durian shell: Studies of adsorption equilibrium and kinetics", Chemical Engineering Journal, 20070301

19 < 1% match (publications)
Zuo, Wenqiang Liu, Jiaping Tian, Qian Xu. "Norm method to define and evaluate robustness of self-compacting concrete due to component quantity ", Construction and Building Materials, Feb 10 2018 Issue

20 < 1% match (publications)
Yuhui Wei. "An integrated simultaneous distillation-extraction apparatus for the extraction of essential oils from herb materials and its application in Flos Magnoliae", Biomedical Chromatography, 2009

21 < 1% match (student papers from 12-Jul-2018)

Submitted to St Padarn's Institute on 2018-07-12

22 < 1% match (publications)
Somkiat Ngamprasertsith, Ruengwit Sawangkeaw. "Chapter 12 Transesterification in Supercritical Conditions", InTech, 2011

23 < 1% match (publications)
Istadi, I., Didi D. Anggoro, Luqman Buchori, Dyah A. Rahmawati, and Dinnia Intaningrum. "Active Acid Catalyst of Sulphated Zinc Oxide for Transesterification of Soybean Oil with Methanol to Biodiesel", Procedia Environmental Sciences, 2015.

paper text:

https://doi.org/10.1007/s40090-018-0138-3 RESEARCH Production of biodiesel from sea mango (Cerbera odollam) seed using in situ subcritical methanol–water under a non-catalytic process Jenni Lie1 · Maria Bangun Rizkiana1 · Felycia Edi Soetaredjo1 · Yi-Hsu Ju2 · Suryadi Ismadji1 Received: 23 March 2017 / Accepted: 17 February

212018 / Published online: 26 February 2018 © The Author(s) 2018. This article is an open access publication

Abstract A catalyst-free and environmentally friendly process was employed for the production of biodiesel from sea mango seed oil. This oil is non-edible and contains several fatty acids such as palmitic acid (C16), trans-9-elaidic acid (C18:1t), oleic acid (C18:1), linoleic acid (C18:2), and linolelaidic acid (C18:2n6t). The in situ extraction and transesterification of the oil were carried at the subcritical methanol–water condition.

2The effect of reaction temperature and time on the yield of biodiesel was studied. The

maximum yield of biodiesel was 98.58% and achieved at 200 °C, 40 bar and reaction time of 6 h. The ratio among sea mango seed, methanol, and water was 2:10:1. Keywords Sea mango seed · Biodiesel · Subcritical methanol–water Introduction A large number of studies on biodiesel production have been conducted due to its potential to reduce the dependence of fossil-based liquid fuel [1] and to lessen the CO2 emission from the transportation sector [2]. Aside from reducing the net CO2 emission, biodiesel is also known for its biodegra- dability [3], non-toxicity [4], and low emission profile of SOx [5] and other pollutants, such as COx, hydrocarbon, NOx [6], and low particulate matter [7]. Biodiesel is a renew- able biofuel. Thus, it is environmentally friendly [8]. Rashid et al. [9] defined biodiesel as mono-alkyl esters

8derived from vegetable oils/animal fats by a chemical process called the transesterification process

[9]. However, vegetable oils/ani- mal fats may contain high free fatty acid (FFA) and water [10] that may cause the formation of soap during the reac- tion [11]. *

4Felycia Edi Soetaredjo felyciae@yahoo.com * Suryadi Ismadji

suryadiismadji@yahoo.com 1

3Department of Chemical Engineering, Widya Mandala Surabaya Catholic University, Kalijudan 37, Surabaya 60114, Indonesia 2 Department of Chemical Engineering, National Taiwan University of Science and Technology, 43 Keelung Road, Sec 4, Taipei 10607, Taiwan

Due to the lack of non-consumable resources of vegetable oils and animal fats as raw materials for biodiesel produc- tion, in the early studies of biodiesel production high-quality food-grade oils were used as the starting materials. In the USA, biodiesel is produced in industrial scale using soybean oil as the raw material, while palm oil is used to produce biodiesel in Malaysia [12]. However, the use of edible feed- stock creates several economic and environmental issues, the competition between crop land used for food production and biodiesel can become intense especially in develop- ing and less develop countries with food shorage problems [12–14]. Non-edible and non-conventional feedstocks have been selected to substitute edible feedstocks for biodiesel production, and in this study we utilized

11sea mango (Cerbera odollam), which is

known as a poisonous fruit as the raw material for biodiesel preparation. Sea mango is a tree of the Apocynaceae family. The seed of this poisonous fibrous-kernelled fruit contains a signifi- cant amount of oil [15]. The presence of non-edible oil in sea mango makes it a potential candidate for use as non-edible feedstock for biodiesel production [15]. Kansedo

9et al. [16] studied the production of biodiesel from

sea mango seed using sulfated zirconia catalyst. They found that the yield of FAME from sea mango seed could reach up to 83% via an ex situ method. Unfortunately, the use of the conventional method of biodiesel production has some drawbacks, such as the high price of the catalyst, the high cost of the pre- treatment process, and slow reaction time [17]. Vol.:(011233456789) Water is environmentally friendly and the cheapest sol- vent for many kinds of processes [18]; however at ambi- ent condition, water is not a suitable solvent or reactant for organic compounds due to its high polarity, and it also can- not be used as extracting agent for non-polar compounds. Studies have found out that by increasing its temperature and pressure, water can be utilized as an extracting agent. Water in the liquid state condition at temperature above the atmospheric boiling point and below the critical temperature (374 °C) is called as subcritical water (SubCW) [19], and at this condition water can be used as extracting and reaction media for many kinds of reaction systems with or without the presence of catalyst [20]. In the present, there is no study on the utilization of in situ subcritical methanol–water

16**for the production of biodiesel from** sea mango seed **oil** without **the**

presence of a catalyst. One of the main drawbacks of using catalyst, especially homogeneous catalyst, is the difficulty in the purification step, which often requires a complicated procedure and at the end will affect the cost of production itself [21]. In this study, we utilized the non-catalytic process for the produc- tion of biodiesel from sea mango seed. This study aimed to find the best condition for the man- ufacture of biodiesel from sea mango seed with the non- catalytic process using subcritical water and methanol. The

2**effects of temperature and reaction time on** the **yield** of biodiesel **were studied**

at constant pressure (40 bar) and a constant mass ratio among methanol, water, and sea mango seed (10:1:2). Materials and methods Materials Sea mango seeds were collected from several streets in Surabaya, East Java, Indonesia. The sea mango seeds

18**were repeatedly washed** using tap **water to remove dirt and other impurities and** subsequently **dried at** 100 °C **for 24 h. The**

dry sea mango seed was pulverized in Junke and Kunkel hammer mill. The chemicals used in this study such as n-hexane (90%) and anhydrous methanol (99.9%) were pur- chased from Merck, Germany. Ultrapure N2 gas (99.9%) was obtained from Aneka Gas Pty. LTD. The reference standard mix of (Supelco) fatty acid methyl esters (FAMEs) consists of C14–C22 fatty acids and was purchased from Sigma- Aldrich Co. USA. All the chemicals were used without any further purification. Analysis of sea mango seed oil mass fraction The oil mass fraction in the sea mango seed was deter- mined by Soxhlet extraction method. Forty-five grams of dried powder of sea mango seeds was placed in a porous bag made of durable filter paper.

20**n-Hexane was** used **as** the **extracting solvent.**

250 ml

20**of n-hexane was placed in a round bottom flask,**

and then the flask was attached to the Soxhlet extractor. Subsequently, the flask was heated until the n-hexane evaporated and the vapors condensed in the condenser. The liquid n-hexane then trickled back into the extraction chamber containing the sea mango seed powder, and the oil was extracted from the seed powder. When the level of liquid in the extraction chamber rose to the top of the siphon tube, n-hexane in the extraction chamber flowed back into the flask. This process was repeated many times

15**until a drop of solvent from the siphon tube did not leave** a **residue when evaporated. The liquid** from **the**

Soxhlet extractor was evaporated using IKA RV10 B rotary evaporator to remove n-hexane, and the mass of oil obtained was weighed using Mettler Toledo analytical balance.

7**Yield % = Total weight of** oil × 100%. **Total weight of the sample**

(1) The chemical characteristics of sea mango seed oil used in this study are given in Table 1. In situ subcritical methanol transesterification In situ subcritical water methanol

14**transesterification of sea mango** seed **oil was carried out in a**

laboratory-scale high-pressure batch reactor (150 cm3, temperature limit: 100–300 °C, pressure range: 0–80 bar). The stainless steel reactor was equipped with an external heater, a pressure gauge, and a thermos controller to maintain the system at the desired temperature. The ratio of methanol, sea mango seed powder, and distilled water was 10:2:1, this ratio was based on the stoichiometry of transesterification reaction between triglycerides and methanol. The reactor was closed with its cap using M8 screws, and it was heated Table 1 Crude sea mango seed oil characteristics Parameters Sea mango oil Methods

13**Fatty acid composition (%) C16:0 (palmitic acid) C18:0 (stearic acid) C18:1 (oleic acid) C18:2 (linoleic acid)**

Water content (%) Free fatty acid (%) Acid value (mg KOH g−1) Density (kg m−3) Viscosity at 40 °C (mm2 s−1) 31.52 3.64 47.85 16.99 0.94 6.53 12.84 921.85 28.97 GC Karl-Fisher MPOB P2.5 Standard titration ASTM ASTM 6 4 was programmed at 120 °C for 3 min,

10**and then** heated **to 300 °C** with **a** heating **rate of 20 °C min−1 and kept at 300 °C for** 2 **min. The**

amount of the sample injected into 2 8 the column was 1 μl with 1:100 split ratio. Other physical 5 and chemical properties of the biodiesel were determined by the ASTM D6751 method. 9 1 3 Results and discussion Oil content of sea mango seed 7 To determine the oil content of the sea mango seeds, the Fig. 1 Diagram of subcritical reactor—N2 gas cylinder (1); relief

11**extraction of oil from sea mango** seeds **was**

conducted using valve (2); magnetic bar (3); release valve (4); reactor (5); pressure the Soxhlet extraction procedure. The extraction experi- gauge (6); RPM controller (7); thermocouple (8); heating element (9) ments were conducted three times, and the results are given in Table 2. High oil content in the sea mango seed (average at a rate of 20 °C min−1 to the desired temperatures (140, 48.72 wt. %) indicates that this unedible seed is a suitable precursor for biodiesel production. 160, and 180 °C). The temperatures were kept constant for specific times (4, 5, and 6 h). To keep the temperature and Effect of reaction temperature on FAME yields pressure constant, it was controlled by a PID-type con- troller with an uncertainty of ± 1 °C and pressure gauge The yield of biodiesel obtained from the transesterification to monitor the pressure at 40 bar. The schematic diagram of sea mango oil using subcritical water–methanol at various of the subcritical reactor is given in Fig. 1. N2 gas was temperatures and reaction time is summarized in Table 3. injected into the reactor to maintain the pressure of the From this table, it can be seen that the maximum yield of system and to ensure that water and methanol existed in biodiesel was 98.58%. The highest yield of the biodiesel the liquid form. During the reaction, the system was kept was obtained

2**at a temperature of** 200 **°C and reaction time**

under constant stirring at 400 rpm using a magnetic stir- of 6 h. At 200 °C, the increase in the reaction time gave rer. After the reaction was complete, the reactor was sud- no significant effect on the yield of biodiesel. In the in situ denly cooled to room temperature and the vent valve was production of biodiesel, temperature played a significant opened to release nitrogen gas. The liquid was separated role in the yield of biodiesel as indicated in Table 3. At from the mixture using Whatman filter paper no. 41. The temperature 140

16**°C and reaction time of 4 h, the** yield **of**

biodiesel was extracted from the filtrate using n-hexane biodiesel was 14.08% and increased almost two times when in a separatory funnel, and then glycerol (bottom phase) the temperature was increased to 160 °C. At subcritical con- was separated from the organic phase. The organic phase dition, the increase in temperature decreased the polarity was evaporated using IKA RV 10 B rotary evaporator to of methanol, leading to increase in the miscibility of sea remove n-hexane. The yield of biodiesel (FAMEs) was mango oil in methanol. With the increase of the miscibility weighed and analyzed using gas chromatography. of oil in methanol, the amount of oil extracted from the solid

7**Yield % = Total weight of methyl esters** × 100%. interior **of**

mango seed also increases. The oil and methanol

7**Total weight of oil in the sample**

become one homogeneous phase [22]. The transesterifica- (2) tion reaction of sea mango oil with methanol is reversible Analysis of FAME in biodiesel and endothermic; therefore, with the increase of temperature The content of fatty acid methyl ester in biodiesel was ana- lyzed using Shimadzu gas chromatograph 2014. Gas chro- Table 2 Oil content in the sea mango seed matography was equipped with FID and 30 m × 0.25 mm Run Weight of sea Weight of oil (g) Yield (% w/w) DB-WAX capillary column; the film thickness was mango seed (g) 0.25 μm. The analysis was conducted using helium as car- 1 45.0005 21.6088 48.02 rier gas at a linear velocity of 34 cm s−1 and the injector 2 44.9997 21.8357 48.52 temperature was kept constant at 250 °C, while the FID 3 45.0003 22.3241 49.61 temperature was kept at 300 °C. The column temperature

Average 48.72 Table 3 The yield of biodiesel from sea mango seed Temperature (°C) Pressure (bar) Reaction time (h) 4 5 6 140 40 14.08% ± 1.55 19.04% ± 0.78 25.24% ± 1.02 160 40 28.27% ± 0.98 32.62% ± 1.19 48.36% ± 0.01 180 40 88.88% ± 1.25 90.12% ± 0.43 90.20% ± 1.71 200 40 98.12% ± 1.18 98.41% ± 0.96 98.58% ± 0.21 and miscibility of oil in methanol (become one phase), the rate of transesterification reaction to form fatty acid methyl ester also increases. The esterification reaction also occurred simultaneously in this process due to the 6.4%

11**free fatty acid** contained **in sea mango** seed **oil**

as shown in Table 1. The high content of free fatty acid in the feedstock was not a problem for biodiesel production using the subcritical water methanol process, because no alkaline catalyst was used in this process that may cause a saponification reaction and give a low yield of biodiesel. Effect of water on FAME yields The addition of water into the subcritical system also plays an important role. When water was added to the system, the biodiesel yield rose to 98.58%. This value is ~ 26% higher compared to biodiesel yield from water-free process under similar conditions (200 °C, 40 bar for 6 h). Silva et al. [23] investigated the effect of water addition on biodiesel produc- tion from Jatropha curcas L. oil under supercritical ethanol. In the water-free system, the maximum fatty acid ethyl ester obtained was about 80%, and when 10% water was intro- duced to the process the yield became 87%. It was reported that the presence of water would stimulate the parallel reac- tions of transesterification and decrease the decomposition degree of fatty acid [23–25]. At subcritical condition, the dielectric constant of water is lower than at standard pres- sure and ambient temperature. Therefore, the water is eas- ily dissociated into H3O+ and OH−. With the presence of excess H3O+, the system becomes acidic. The presence of H3O+ (hydroxonium) in the system represents the nature of the proton in aqueous solution, and this proton subsequently acts as a catalyst for the transesterification process at the temperature below

22**the critical point of the mixture** [26] and reduce **the**

reaction time to achieve the same biodiesel yield. Effect of reaction time on FAME yields In general, the reaction time gives a positive effect on the yield of biodiesel as seen in Table 3. The longer the reac- tion time, the higher is the yield of biodiesel. As mentioned before, the transesterification reaction to produce biodiesel is an endothermic and reversible process; it requires energy to shift the reaction toward the biodiesel product

22**(fatty acid** methyl **ester).** With **the** increase **of reaction time, the**

energy added to the system also increases and more energy is avail- able to shift the reaction toward the formation of fatty acid methyl ester. Since the reaction was maintained at subcriti- cal condition under nitrogen environment without the pres- ence of any catalyst, the oxidation or secondary reaction of the biodiesel product did not occur. Therefore, the yield increased with the increase of reaction time. FAME content in biodiesel It has been reported that sea mango seed mainly contains oleic acid (48.1%), followed by palmitic acid (30.3%), lin- oleic acid (17.8%), and stearic acid (3.8%) [27]. GC analysis showed that sea mango seed oil contains several fatty acids such as palmitic acid (C16), trans-9-elaidic acid (C18:1t), oleic acid (C18:1), linoleic acid (C18:2), and linolelaidic acid (C18:2n6t). During the transesterification reaction with methanol, these fatty acids were converted to their esters [C16 (methyl palmitate), C18:1t

6**(trans-9-elaidic methyl ester), C18:** 1c **(cis-9-oleic methyl ester), C18:**

2 (methyl linoleate), C18:2n6t (methyl ester)]. The

23**fatty acid methyl ester (FAME)** compositions **in** the **biodiesel**

obtained from sea mango seed oil are given in Table 4. Fuel properties of biodiesel The physical and chemical characteristics of the

17**biodiesel such as** density, **kinematic viscosity, flash point, cetane number,**

and acid number were determined according to the ASTM standard. The density was determined by ASTM D1298, and the kinematic viscosity was determined using ASTM D445-10. ASTM D93 was employed for the determi- nation of

17**the flash point of the biodiesel.** The cetane number **was determined**

by ASTM D613, which is a standard method for the determination of the cetane number of diesel fuel oil. The values of chemical and physical characteristics of the biodiesel are given in Table 5. In a combustion chamber, the density of the biodiesel plays an essential role since it determines the mass of the biodiesel injected into the chamber [28]. The standard den- sity of biodiesel at 15 °C is in the range of 860–900 kg m−3. The density of the biodiesel obtained in this study is in the Table 4

14**Fatty acid methyl** ester content **in biodiesel from** sea mango **seed oil**

Sample Parameters Composition, % T (°C) P (bar) t (h) C16 C18:1t C18:1c C18:2 C18:2n6t 1 140 2 160 3 180 4 200 5 140 6 160 7 180 8 200 9 140 10 160 11 180 12 200 40 4 40 4 40 4 40 4 40 5 40 5 40 5 40 5 40 6 40 6 40 6 40 6 31.80 ± 1.04 4.66 ± 0.18 53.35 ± 2.31 3.99 ± 1.42 6.20 ± 0.45 48.75 ± 2.56 9.06 ± 1.07 24.12 ± 2.98 11.67 ± 0.39 6.38 ± 1.22 36.07 ± 1.82 5.41 ± 0.53 50.95 ± 1.75 6.17 ± 0.01 1.39 ± 0.03 32.64 ± 3.91 6.31 ± 1.42 48.51 ± 2.43 9.81 ± 1.11 2.73 ± 0.05 45.24 ± 2.78 8.33 ± 1.90 32.97 ± 0.59 9.87 ± 1.72 3.59 ± 2.43 49.26 ± 1.13 0.66 ± 0.09 41.39 ± 2.73 7.94 ± 0.90 0.76 ± 0.01 38.41 ± 2.09 3.90 ± 1.07 48.92 ± 1.19 4.04 ± 0.02 4.73 ± 0.87 43.39 ± 1.27 5.17 ± 0.81 43.10 ± 1.19 3.11 ± 0.18 5.23 ± 0.07 38.90 ± 2.31 3.69 ± 0.09 20.48 ± 2.26 14.22 ± 1.76 22.72 ± 1.36 34.72 ± 1.53 1.71 ± 0.02 54.40 ± 2.31 8.46 ± 0.58 0.70 ± 0.08 23.62 ± 0.94 1.76 ± 0.05 43.29 ± 1.09 2.57 ± 0.03 28.76 ± 0.77 30.91 ± 1.42 2.85 ± 0.54 58.01 ± 2.41 4.76 ± 1.62 3.47 ± 0.90 Fatty acid methyl esters: C16 (methyl palmitate), C18:1t

6**(trans-9-elaidic methyl ester), C18:** 1c **(cis-9-oleic methyl ester), C18:**

2 (methyl linoleate), C18:2n6t (linolelaidic acid methyl ester) Table 5 Fuel properties of biodiesel from sea mango seed oil Sample (T/t)a D @ 15 °C (kg m−3) KV @ 40 °C (mm2 s−1) FP (°C) CN AN (mg KOH g−1) 140/4 885.1 2.89 133 55.1 0.3761 140/5 883.4 2.91 132 55.6 0.3302 140/6 881.7 2.93 133 55.4 0.3549 160/4 882.9 2.96 129 53.8 0.3618 160/5 887.5 2.94 125 52.9 0.3446 160/6 885.4 2.92 127 53.4 0.4014 180/4 882.9 2.99 124 53.2 0.3785 180/5 881.6 2.94 125 54.6 0.4151 180/6 884.2 2.97 122 53.4 0.3493 200/4 886.4 2.91 119 54.7 0.3526 200/5 887.3 2.95 120 53.9 0.3857 200/6 885.9 3.01 119 53.7 0.4067 ASTM D6751 Na 1.9–6.0 93 °C min 47 min 0.5 max D, density; KV, kinematic viscosity; FP, flash point; CN, cetane number; AN, acid number aT/t: temperature (°C)/reaction time (h) range of 881.6–887.5 kg m−3. These values are in the range of the standard density of biodiesel. The kinematic viscosity strongly influences the volatilization and atomization of the biodiesel upon injection in the combustion chamber. This physical property also influences the engine life. The higher viscosity enhances the fuel spray penetration, resulting in the improvement of air–fuel mixing. However,

5**fuel with high viscosity tends to form** a **deposit in the engine** and reduce **the**

combustion efficiency [20, 28, 29]. Nevertheless,

5**fuel with low viscosity** may **not provide sufficient lubrication in the combustion system**

[28]. The ASTM kinematic viscosity standard for biodiesel is 1.9–6.0 cSt (mm2 s−1), and the kin- ematic

23**viscosity of the** sea mango **biodiesel is** in **the range of**

2.89–3.01 cSt. Flash point is one of the essential characteristics of biodiesel. This physical property relates to the ignition of biodiesel. The moderate value of a flash point is required for the safety of handling and storage. Since the flash point of the biodiesel produced in this study is above the mini- mum value of the ASTM standard, this biodiesel

4**is safe for handling and storage for** a **period of time.**

Cetane number is an index that

8**measures the combustion quality of diesel fuel during compression ignition**

[28]. This index strongly influences the performance of the engine during fuel com- bustion and exhaust emission. The low value of cetane number causes difficulties in the startup of the engine and, during combustion, produces noise in the engine and smokes of

4**exhaust gas. The cetane** number **of biodiesel produced in this**

study is higher than the minimum value of the ASTM standard D6751. The compositions of

9**fatty acids in the** feedstock or **raw material**

also have significant effect on the cetane number of the biodiesel product.

9**If the** oil **contains a high** percentage **of** saturated **fatty acid,**

the value of cetane number of the resulting biodiesel is high. On the contrary, a low value of cetane number will be obtained if the oil contains a significant amount of unsatu- rated fatty acids [20, 30]. One of the crucial properties of biodiesel is the

12**acid number. The acid number indicates the quantity of free fatty** acids **and mineral acids present in the biodiesel.** High **acid number**

causes corrosion problem in the engine and fuel injectors [28]. The degradation of biodiesel during storage will increase the acid number; therefore, this property can be used as a measure of biodiesel degradation. The acid number of biodiesel obtained in this experiment is in the range of 330–415 mg kg−1. The values are still in the inad- missible range, since the maximum acid number allowed in the ASTM D6751 is 500 mg kg−1. Conclusion In this study, the biodiesel was produced from non-edible seed oil using the subcritical methanol-water process. The sea mango seed, which contains highly toxic compounds, was used as the source of the non-edible oil. The in situ extraction and transesterification of the oil were carried out without the presence of acid or base catalyst. This process drastically reduces the production cost, since it does not require extraction and separation of the catalyst. However, the main disadvantage of this process is that the transes- terification reaction must be conducted at high temperature and pressure.

2**The maximum** FAME **yield of** 98.58% **was obtained at** 200 **°C,**

at a pressure of 40 bar and reaction time of 6 h. Acknowledgements The financial support from NTUST through the Joint Research Collaboration Program is highly acknowledged. The first and second authors also acknowledge the partial support of the Directorate of Higher Education (DIKTI) through the Student Creativ- ity Research Program. Authors contribution JL and MBR conducted the experiments, FES performed statistical analysis, YHJ drafted the manuscript, and SI per- formed the experiment design and corrected the manuscript.

19**Compliance with ethical standards Conflict of interest The authors declare that they have no conflict of interest.**

Open Access This

References 1. Kouzu M, Hidaka J (2011) Transesterification of vegetable oil into biodiesel catalyzed by CaO: a review. Fuel 93:1–12 2. Olivares-Carrillo P, Quesada-Medina J (2011) Synthesis of bio- diesel from soybean oil using supercritical methanol in a one- step catalyst-free process in batch reactor. J Supercrit Fluids 58:378–384 3. Mariano AP, Tomasella RC, de Oliveira LM, Contiero J, de Ange- lis DF (2008) Biodegradability of diesel and biodiesel blends. Afr J Biotechnol 7:1323–1328 4. Innocent DS, Sylvester PO, Yahaya MF, Nwadike I, Okoro LN (2013) Comparative analysis of biodiesel and petroleum diesel. IJERN 1:1–8 5. Szybist JP, Song J, Alam M, Boehman AL (2007) Biodiesel com- bustion, emissions and emission control. Fuel Process Technol 88:679–691 6. Idusuyi NP, Ajide OO, Abu R (2012) Biodiesel as an alternative energy resource in Southwest Nigeria. IJST 2:323–327 7. Moser BR (2012) Preparation of fatty acid methyl esters from hazelnut, high-oleic peanut and walnut oils and evaluation as bio- diesel. Fuel 92:231–238 8. Kaur M, Ali A (2011) Lithium ion impregnated calcium oxide as nanocatalyst for the biodiesel production from karanja and jat- ropha oils. Renew Energy 36:2866–2871 9. Rashid U, Rehman HA, Hussain I, Ibrahim M, Haider MS (2011) Muskmelon (Cucumis melo) seed oil: a potential non-food oil source for biodiesel production. Energy 36:5632–5639 10. Gashaw A, Teshita A (2014) Production of biodiesel from waste cooking oil and factors affecting its formation: a review. IJRSE 3:92–98 11. Alptekin E, Canakci M (2011) Production of biodiesel from waste cooking oil and factors affecting its formation: a review. Fuel 90:2630–2638 12. Fan X, Burton R (2009) Recent development of biodiesel feed- stocks and the applications of glycerol: a review. Open Fuels Energy Sci J 2:100–109 13. Karatay SE, Dönmez G (2011) Microbial oil production from thermophile cyanobacteria for biodiesel production. Appl Energy 88:3632–3635 14. Kumar A, Sharma S (2010) Non-edible oilseeds as biodiesel feed- stock for meeting energy demands in India. Renew Sustain Energy Rev 15:1791–1800 15. Gaillard Y, Krishnamoorthy A, Bevalot F (2004) Cerbera odollam: a 'suicide tree' and cause of death in the state of Kerala, India. J Ethnopharmacol 95:123–126 16. Kansedo J, Lee KT, Bhatia S (2009) Cerbera odollam (sea mango) oil as a promising nonedible feedstock for biodiesel production. Fuel 88:1148–1150 17. White K, Lorenz N, Potts T, Penney WR, Babcock R, Hardison A, Canuel EA, Hestekin JA (2011) Production of biodiesel fuel from tall oil fatty acids via high temperature methanol reaction. Fuel 90:3193–3199 18. Li CJ, Chen L (2006) Organic chemistry in water. Chem Soc Rev 35:68–82 19. Liang X, Fan Q (2013) Application of sub-critical water extraction reaction medium on noncatalytic ester production from used fry- in pharmaceutical industry. MSCE 1:1–6 ing oil with supercritical ethanol. Energy Fuels 28:3122–3128 20. Gunawan F, Kurniawan A, Gunawan I, Ju YH, Ayucitra A, Soe- 26. Pitzer KS (1982) Self-ionization of water at high-temperature taredjo FE, Ismadji S (2014) Synthesis of biodiesel from vegetable and the thermodynamic properties of the ions. J Phys Chem oils wastewater sludge by in situ subcritical methanol transesteri- 86:4704–4708 fication: process evaluation and optimization. Biomass Bioenergy 27. Sarin A (2012) Biodiesel: production and properties. RSC Pub- 69:28–38 lishing, Cambridge, p 170 21. Bernal JM, Lozano P, Garcia-Verdugo E, Burguete MI, Sánchez- 28.

Margaretha YY, Prasetyo HS, Ayucitra A, Ismadji S (2012) Cal- Gómez G, López-López G, Vaultier MPM, Luis SV (2012) Super- cium oxide from Pomacea sp. shell as a catalyst for biodiesel critical synthesis of biodiesel. Molecules 17:8696–8719 production. Int J Energy Environ Eng 3:33 22. Glišić SB, Skala DU (2010) Phase transition at subcritical and 29. Xue J, Grift TE, Hansen AC (2011) Effect of biodiesel on supercritical conditions of triglycerides methanolysis. J Supercrit engine performances and emissions. Renew Sustain Energy Rev Fluids 54:71–80 15:1098–1116 23. Silva C, Colonelli TAS, Silva EA, Cabral VF, Oliveira JV, Car- 30. Yoshiyuki K (2000) Effects of fuel cetane number and aromatics dozo-Filho (2014) Continuous catalyst-free production of ester on combustion process and emissions of a direct injection diesel from Jatropha curcas L. oil under supercritical ethanol. Braz J engine. JSAE Rev 21:469–475 Chem Eng 31(3):727–735 24. Vieitez I, Silva C, Borges GR, Corazza FC, Oliveira JV, Grom- Publisher's Note Springer Nature remains neutral with regard to pone MA, Jachmanián I (2008) Continuous production of soybean jurisdictional claims in published maps and institutional affiliations. biodiesel in supercritical ethanol–water mixtures. Energy Fuels 22:2805–2809 25. Abdala ACA, Colonelli TAS, Trentini CP, Oliveira JV, Cardozo- Filho L, Silva EA, Silva C (2014) Effect of additives in the International Journal of Industrial Chemistry (2018) 9:53–59 54 International Journal of Industrial Chemistry (2018) 9:53–59 International Journal of Industrial Chemistry (2018) 9:53–59 55 56 International Journal of Industrial Chemistry (2018) 9:53–59 International Journal of Industrial Chemistry (2018) 9:53–59 57 58 International Journal of Industrial Chemistry (2018) 9:53–59 International Journal of Industrial Chemistry (2018) 9:53–59 59 13 13 13 13 13 13