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BIOLOGICAL CHARACTERISTICS OF POON TREES *Calophyllum inophyllum* L. AND ITS EXTRACTED OIL USED AS STARTING MATERIAL FOR BIODIESEL PRODUCTION

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ABSTRACT

This study was aimed to investigate the chemical and biological characteristics of Poon trees Calophyllum inophyllum L. and its extracted oil as starting material for synthesizing biodiesel. Density, seed yield and biomass of Poon trees were investigated in the field for biological characteristics while fatty acid composition and oil quality were determined as chemical characteristics. Seed yield of a ten-year Poon tree was 74.8 kg/tree/ year. Poon tree density and biomass were 625 trees/ha and 0.16 ton/tree, respectively; oil yield was 13.4 L/tree/season or 17,187 L/ha/year. Fatty acid composition of poon oil was found to include 2.35%, 7.62%, 12.4% and 3.44% of stearic, oleic, linoleic and palmitic acids, respectively. Acid value; saponification value; iodine value and oil density were 10.5, 184, 88.8 and 0.94 Kg/L, respectively. Biodiesel produced from the extracted Poon oil contained 91% of fatty acid methyl esters.

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1 INTRODUCTION

Fossil fuels has been over-exploited in the last decades and caused the depletion of this type of energy. Biofuel produced from biomass, is a type of renewable energy and has been widely used in transportation. It is expected to reduce greenhouse gases emission (Rainer *et al.*, 2007). Onga *et al.* (2011) and Atabani and da Silva César (2014) showed that *C. inophyllum* L. oil based biodiesel could become an alternative fuel in the future. Poon tree *Calophyllum inophyllum* L. is distributing in Eastern Africa, Southern parts of India, Malaysia and Australia. In Vietnam, Poon trees are growing well in different ecological zones from the North to the South and on saline soils as well as acid sulfate soils (Hop, 2002). A one-year poon tree produces 4 Kg of seeds but for years after it can produce 30-50 Kg of seeds which are harvested in November to December as main season and April to May before rainy season (Loi, 2006). There were few publications related to biodiesel production from Poon seed oil in the Mekong delta. Vuong (2009) reported that poon seeds have outside cover 2-4 cm and seed weight of 100-200 seeds/Kg. Neutral acid (92%), glycolipid acid (6.4%) and phospholipid acid (1.6%) were the three main acids in poon seed oil (Minh, 2009). Dat *et al.* (2012) reported the optimal synthesized conditions of biodiesel from *C. inophyllum* L. e.g. catalyst (KOH) concentration 1% (in volume), methanol to oil ratio 6:1, reaction temperature at 60°C in 120

minutes resulted in 92.1% biodiesel yield. These primitive studies of Poon tree in the Mekong delta however did not show biological characteristics of Poon tree e.g. height, trunk diameter, biomass, fruit yields. Hence, it is necessary to carry out this study. The aim of this study is to investigate biological characteristics of Poon trees *Calophyllum inophyllum* L. and its extracted oil used as primary material for biodiesel production.

2 MATERIALS AND METHODS

Growth, biomass, number of seeds as well as biological characteristics of Poon trees in the fields of Can Tho city and Dong Thap province were investigated. Height (h), diameter of trunk at breast height 1.3 m (DBH), canopy of six Poon trees was measured to determine biomass according to the following equation:

Biomass = [(π/4) × r (ton/m^3) × DBH^2(m) × h(m) × Treeform × BEF]

In which 0.5 and 1.5 were used for Treeform deciduous leaf BEF, respectively.

Carbon and CO_2 of the Poon tree were calculated as:

$$C = \frac{biomass}{2};\ CO_2 = \frac{Cx44}{12}$$

Five 10-year-Poon trees were selected for determination of biological characteristics. Each Poon tree was measured canopy dimension to determine the density. All fruits of the tree were collected to determine the number of fruits per tree. Later, 20 random fruits of each tree were selected and weighed after removing the outside cover and flesh in order to determine the seed mass. The seeds were dried under sunlight for 3 days and chopped into small pieces. These pieces were compressed by a compressing system for Poon oil extraction. Extracted oil was subjected to transesterification process using methanol to produce biodiesel. The reaction conditions as follows: 3370 mL Poon oil + 228 mL methanol + 254 mL CH_3ONa 0.004 M. Hence, the methanol/oil ratio was 14.7/1. The reaction was conducted at 60°C for 2 hours. Extracted Poon oil and the synthesized biodiesel (B100) were determined for chemical characteristics (conducted by the Quality Assurance and Testing Center 3 in Ho Chi Minh city).

3 RESULTS AND DISCUSSION

3.1 Biological characteristics of poon trees

A 10-year poon tree had a height of 12.4 m, DBH 60.6 cm and biomass 6.16 ton. The carbon and equivalent CO_2 storage in a Poon tree were estimated as 0.08 ton and 0.29 ton, respectively (Table 1): The height of the Poon trees in the Mekong delta is lower than average height of the Poon trees in Viet Nam and in the world which were found 20-25 m high (Hop, 2002; Atabani and da Silva César, 2014).

Table 1: Biological parameters of a 10-year poon tree

Parameters	Tree						Average
	1	2	3	4	5	6	
Height (m)	12.0	14.0	12.0	11.0	13.0	12.4	12.4
DBH (cm)	59.0	74.0	59.0	42.0	69.0	60.6	60.6
Biomass (ton)	0.14	0.25	0.14	0.06	0.20	0.14	0.16
C (ton)	0.07	0.13	0.07	0.03	0.10	0.07	0.08
CO_2 (ton)	0.26	0.48	0.26	0.11	0.37	0.26	0.29

Table 2: Fruits and seeds parameters of a 10-year Poon tree in a season

Parameters	Tree					Average
	1	2	3	4	5	
Number of fruits (fruits/tree)	16,000	18,000	13,200	10,800	16,800	14,960
Mass of 20 fruits (Kg)	0.11	0.14	0.11	0.13	0.11	0.12
Fruit yield (Kg/tree)	88.0	126	72.6	70.2	92.4	89.8
Mass of 20 seeds (Kg)	0.05	0.05	0.05	0.05	0.05	0.05
Seed yield (Kg/tree)	40	45	33	27	42	37.4
Oil extraction yield (L/tree)	5.36	6.03	4.42	3.62	5.63	5.01
Theoretical oil yield (L/tree) (Total lipid: 34.6%)	14.7	16.6	12.1	9.93	15.4	13.8

The canopy dimension of each selected Poon tree was approximately 2 m × 2 m, hence the density of Poon trees was 625 trees/ha. Seed yield of a Poon tree was found 37.4 Kg/tree/season; and the tree

could be harvested in 2 seasons annually. Hence, the seed yield could be 74.8 Kg/tree/year. This seed yield of the Poon trees in the Mekong delta is higher compared to other parts of Viet Nam (30-50 Kg/tree/year; Loi, 2006). The theoretical oil yield was found 13.8 L/tree (Table 2). In the Mekong delta, with the above density, the theoretical oil yield could be estimated as 17.190 L/ha/year or 6.26 ton/ha/year which is higher than 4 ton/ha/year as reported by Atabani and da Silva César (2014).

3.2 Fatty acid composition of extracted Poon oil

Table 3: Fatty acid composition of Poon seed oil

Fatty acids	(%)
Stearic (C18:0)	2.35
Oleic (C18:1)	7.62
Linoleic (C18:2)	12.4
Palmitic (C16:0)	3.44
Total	25.8

Table 3 shows that the total fatty acids (stearic, oleic, linoleic and palmitic) was 25.8%. Linoleic acid had the highest proportion (12.4%) while stearic acid had the lowest one compared to those of other fatty acids. The contents of fatty acids in order from low to high respectively were stearic, palmitic, oleic and linoleic. This order was in accordance with the study of Atabani and da Silva César (2014) which were 6.1-20.0%, 12.1-18.5%, 13.7-38.3% and 36.2-46.1% respectively for stearic, palmitic, oleic and linoleic. Other fatty acid contents *e.g.* myristic (C14:0), linolenic (C18:3), arachidic (C20:0), behinic (C22:0) were found to be less than 2.1% or non-detected (Atabani and da Silva César, 2014). It has been reported that biodiesel containing high amount of unsaturated fatty acids has good flow properties compared to that with high content of saturated fatty acids (Atabani and da Silva César, 2014).

3.3 Acid, saponification and iodine values of Poon seed oils

The acid, saponification and iodine values of the extracted Poon seed oil were 10.5, 184 and 88.8, respectively and agreed with the saponification (191-202) and iodine values (82-98) reported in the study of Venkanna *et al.* (2009) except for the acid value which indicated a doubled value (4.76).

Table 4: Chemical characteristics of Poon seed and other popular oils

Parameters	Unit	Poon oil	Diesel(*)	Soya bean oil(*)	Coco-nut oil(*)	Sesame oil(*)
Density at 15°C	Kg/L	0.941	0.82 - 0.86	0.92	0.915	0.914
Cloud point	°C	+6	(-)	-4	20-28	9
Kinetic viscosity at 40°C	mm^2/s	49.22	2 - 4.5	58 - 63	30 - 37	85
Flash point	°C	(+)	(-)	330	110	258
Cetane number	-	(+)	46	36 - 38	40 - 42	39 - 41
Sulfated ash (S)	mg/Kg	35	500	-	-	-
Residue carbon in ash (Wt)	%	2.05	(-)	0.54	0.11	0.5
Water content (V/Wt)	%	0.8	(-)	-	-	-
Calorific value	MJ/Kg	38.1	(-)	37.3	37.1	39.3
	Kcal/Kg	9105		8925	8875	9410

***Note**: (+): Not tested, -: Not data, (-): Not in standard. (*) (Bong et al., 2010)*

Poon seed oil had similar characteristics compared to other oils (Table 4). The density was found 0.941 Kg/L which was similar to 0.91 Kg/L as reported in the study of Venkanna *et al.* (2009). However, the Poon seed oil, like other vegetable oils, cannot be used directly as diesel for the engines. It must be converted into biodiesel B100 via a transesterification reaction with methanol using a base as a catalyst. In this study, the synthesized B100 from Poon seed oil had the fatty acid methyl ester of 91% and almost meets the QCVN 1:2009/BKHCN (National technical regulation on gasoline, diesel fuel oils and biodiesel).

The study then examined the quality of the B5 diesel-biodiesel blend which was formed by blending 5 mL of the formed biodiesel B100 with 95 mL fossil diesel. The results are presented in Table 6.

Table 5: Biodiesel B5 synthesized from Poon seed oil and its standards

Parameters	Standard for B5 biodiesel	B5 biodiesel synthesized from poon oil
1. Sulfated ash, mg/kg, less than - 0.05S	500	2095
2. Cetane number, higher than	46	49
3. Distillation temperature at 9 % volume, °C, less than	360	352
4. Density at 15°C, Kg/m^3	820-860	849.1
5. Kinetic viscosity at 40°C, mm^2/s	2-4.5	3.270
6. Fatty acid methyl ester (FAME), % V	4-5	(+)
7. Oxidation stability, mg/100 mL, less than	25	(+)
8. Water content, mg/Kg, less than	200	240
Parameters not in standard		
9. Calorific value, MJ/Kg or Kcal/Kg		45.17 or 10790
10. Cloud point, °C		-3

***Note**: (+): Not tested. Standard QCVN 1:2009/BKHCN (National technical regulation on gasoline, diesel fuel oils and biofuels)*

As shown in (Table 5), the quality of diesel B5 almost meets the standard and therefore could be considered for use for internal-combustion engines.

4 CONCLUSION

The density of Poon trees in the Mekong delta was 625 tree/ha. A 10-year poon tree had biomass of 0.16 ton/tree, seed yield of 37.4 Kg/tree/season, oil yield of 13.8 L/ha/season or 17,187 L/ha/year for 2 seasons. The fatty acid composition of Poon seed oil was stearic acid (2.35%); oleic acid (7.62%); linoleic acid (12.4%) and palmitic acid (3.44%). Acid, saponification and iodine values were 10.5, 184, 88.8, respectively. Biodiesel B100 synthesized from Poon seed oil had 91% of fatty acid methyl esters. The B5 biodiesel blend from Poon seed oil almost meets the standard and can be considered for use for internal-combustion engines**.**

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