Characterization and Performance of Biofuel from Passion Fruit Processing Residues

Nakorn Tippayawong and Phichet Chumjai

Abstract—**Passion fruit seeds are a byproduct from juice production. Oils were extracted from the passion fruit seeds, and transesterified to produce biodiesel with KOH as a catalyst. The obtained biofuel was characterized for its fuel properties in accordance with the Thai and international standards. Constant speed tests were also carried out to evaluate performance of the biofuel against petro-diesel in a small, unmodified, compression ignition engine. Analysis showed that the quality of biodiesel obtained was within the limits set by the Thai and American biodiesel specifications. Engine test results revealed that performance based on engine torque and power between petro-diesel and biodiesel was comparable. The biofuel appeared to have higher efficiency and lower CO emission than petro-diesel.**

Index Terms— **biodiesel, engine testing, transesterification, vegetable oil, renewable energy**

I. Introduction

Energy provides services to meet many basic human needs, productive uses, and modern society needs. Access to energy and poverty are closely linked. According to the IEA World Energy Outlook, a major fraction of world population is still living with no access to electricity and clean energy, predominantly in sub-Saharan Africa and South Asia. Modern energy sources such as electricity and petroleum fuels can be expensive for poor rural people. They may be difficult to achieve regular supplies to remote and isolated rural communities. Apart from meeting household needs, there is growing demand for rural services such as water supply, sanitation, health care and education, as well as for productive uses such as agriculture and small industries. Future demand for energy services in developing countries is projected to increase rapidly, mainly due to economic and population growth.

Increased access to energy in developing countries is a challenging and contentious issue. There are a number of technological options available to provide the energy required; electricity grid extensions, small scale hydropower systems, solar energy systems, small scale wind energy systems, improved biomass utilization, and hybrid systems. The choice will be specific to each location and dependent on various technical and socio-economic factors.

Mae Hong Son is one of the smallest provinces in Thailand. It is remotely situated in the northern region, surrounded by mountain ranges. It is difficult to provide energy services from centralized sources. Electricity grid extension to Mae Hong Son is not practical and cost effective. Small decentralized energy systems are widely used in the areas, usually with engine-generator sets. Adoption of hydropower, solar and wind energy systems is still relatively very small. Liquid biofuels are generally scarce and expensive.

Utilization of renewable biomass is one of various ways to respond to the challenges of the energy crises. Biomass is traditionally used in rural areas, and is considered to be promising energy sources for substitution of petroleum based fuels in many applications. In most rural industries such as processing of agricultural products, diesel engines are most widely used for mechanical shaft works, and electricity generation. Seed oils and their derivatives may be used in these diesel engines [1]. It has been demonstrated that vegetable oils can be successfully considered as substitutes for diesel fuels. However, vegetable oils have high viscosity that leads to poor combustion [2]. Transesterification is a method of reducing vegetable oil viscosity by converting them to esters. Vegetable oils contain triglycerides which when reacted with excess alcohol in the presence of catalyst, esters and glycerol are formed. The resulting esters have been called biodiesel [3, 4].

Passion fruit (shown in Fig. 1) is cultivated commercially in many parts of the country including Mae Hogn Son. A native to Brazil, it is a popular tropical fruit throughout the world. The soft, orange pulp of this fruit is full of tiny albuminous seeds (up to 25% of the fresh pulp by weight), and all of these are edible. The passion fruit is usually used for juice production in Asia, and works best as a flavoring additive in many delicacies. In the juice industry, the passion fruit generates large amount of seeds as agricultural byproducts during juice extraction. These seeds, having high oil content, are generally discarded after being crushed. In recent years, many studies have aimed to investigate possible use of fibre from the byproducts [5, 6], but very few works was on vegetable oil extracted from passion fruit seeds [7, 8]. Liquid fuel in terms of biodiesel is an attractive option that can be derived from vegetable oils [9, 10].

The objective of this work is to demonstrate energy potential of passion fruit processing residues, especially seed oil that may be used as improved form of energy in rural areas.

Manuscript received June 5, 2012; revised July 2, 2012. This work was supported by the Graduate School, Chiang Mai University, and the Commission of Vocational Education, Ministry of Education, Thailand.

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Fig. 1. Passion fruit.

Fig. 2. Engine test bed.

TABLE I
PROPERTIES OF FRUIT SEED OIL AND ITS BIODIESEL

Properties	Seed oil		Standards*
	Raw	Biodiesel	
Density @ 25 °C (kg/m^3)	904	865	860 > x > 900
Viscosity @ 40 °C (cSt)	29.2	3.9	3.5 > x > 5.0
Flash point (°C)	332	186	> 120
Pour point (°C)	-16	-8	< 10
Acid value (mg KOH/g)	0.39	0.22	< 0.50
Specific gravity	0.910	0.875	< 0.88
Heating value (cal/g)	7633	7600	-
Ash (%)	0.03	0.02	max 0.02
Biodiesel yield (%)	-	93.6	-
Ester content (%)	-	96.6	> 96.5

* referred to Thai, ASTM and EN standards where applicable

II. EXPERIMENTAL METHODS

A. Sample Preparation

In this work, utilization of passion fruit processing residues to generate fuels and energy was carried out and demonstrated. The seeds of passion fruit were collected after juice extraction from the Farmers Association of Mae Hong Son, Thailand. The seeds were cleaned and finely grounded to 0.5 mm in size for analyses. Moisture content was estimated by drying the seed samples at 120°C for 12 h until its weight was constant. The seed powder was fed to screw press. The seed meal was subsequently extracted with petroleum ether. Sample of the oil obtained was sent for analysis for its composition and free fatty acid (FFA) content.

B. Transesterification Process

The passion fruit seed oils were transesterified by heating them with a large excess of anhydrous methanol and a catalyst. In this work, alkali catalyzed transesterification method was adopted. KOH was dissolved in methanol by vigorous stirring in a beaker. The oil was transferred into the reactor, then, the catalyst/alcohol mixture was mixed into the oil. The final mixture was heated and stirred vigorously at 65°C in ambient pressure. In this work, methanol to oil molar ratio, catalyst concentration, and reaction time were varied between 3:1 to 9:1, 1.0 to 2.0% w/w, and 5 to 120 min, respectively. A successful transesterification reaction produced two separate liquid phases: ester and crude glycerin. Phase separation was observed within 30 min, but left to complete settling for 24 h. Crude glycerin, the heavier liquid, was collected at the bottom after settling. Water was then added to the methyl ester and stirred for 10 min. Air was also carefully introduced into the aqueous layer while simultaneously stirring very gently. This process was continued until the ester layer became clear. The glycerin was allowed to settle again. The aqueous solution was eventually drained. Washing the ester was performed with water for several times. Subsequently, moisture removal process was carried out by heating the biodiesel product to 105°C in an open container until there was no more steam from the fuel. An advantage of heating was that it drives off any traces of remaining alcohol within the product. The bio-fuels from passion fruit seed oil were characterized for fuel properties.

C. Engine Tests

The biodiesel obtained was used in a small engine. A 4-stroke, single cylinder air-cooled, Yanmar engine model TFR75LM with a compression ratio of 23:1 was used. It has a displacement of 0.437 L, able to produce continuously a rated maximum power output of 5.5 kW at 2200 rpm. The engine is fixed stationary and the output shaft is connected to a dynamometer. The engine setup is shown in Fig. 2. The ordinary diesel was used in the tests as a base fuel for comparison. Part load engine performance was considered at speeds between 1000 – 1800 rpm. Initially, the engine was fueled with neat diesel at full throttle opening to give 1800 rpm and no load. The dynamometer load was increased gradually as the engine speed decreased at an interval of 200 rpm down to 1000 rpm. Torque, fuel consumption and gas emission data were recorded. When the engine was tested with biodiesel, the same testing procedures were carried out.

III. Results and Discussion

Starting with fresh passion fruits, their seeds and fiber were found to account for around 10% w/w. About 47% of which was the juice, and 43% was the peels, respectively. The dry seeds were accounted for approximately 6% w/w dry basis, with average oil content of 20% w/w. Details on its composition and biodiesel yields can be found in our previous reported work [8].

A summary of physical and chemical properties of passion fruit seed oil and its biodiesel are listed in Table 1 with those values from diesel fuel standard. It was clear that transesterification can improve fuel properties of the seed oil. Biodiesel obtained was comparable to diesel fuel standard.

It may be adequate to state that the engine running on biodiesel performed smoothly with no abnormal vibration or startup problems. The results reported here were derived from the engine that was unaltered and designed to run on commercial diesel fuel.

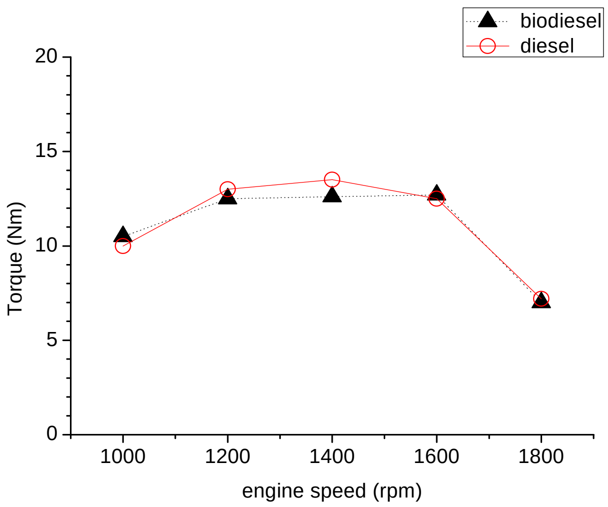

Fig. 3. Engine torque.

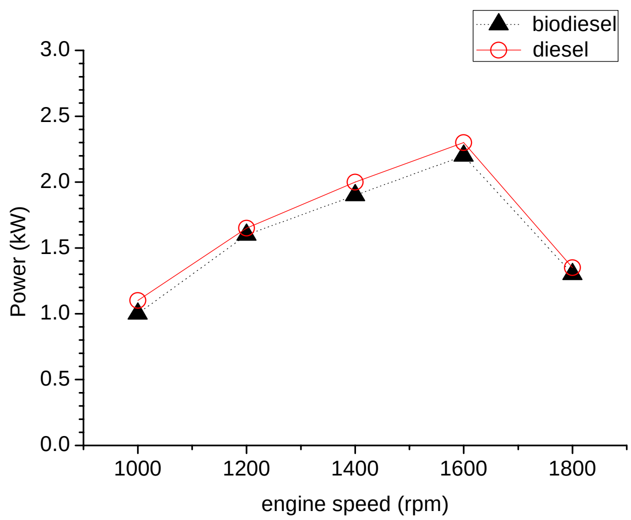

Fig. 4. Engine brake power.

Figs. 3 and 4 show the engine torque and brake power output as a function of engine speed for both diesel and biodiesel fuels. Similar patterns between the two fuels were obtained. Biodiesel appeared to result in slightly higher power output relative to diesel fuel. The brake specific fuel consumption (bsfc) is shown in Fig. 5. It was observed that the reference diesel fuel exhibited lager fuel consumption

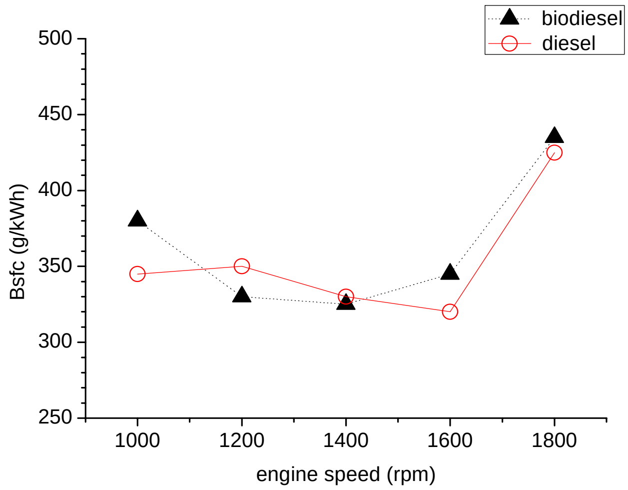

Fig. 5. Brake specific fuel consumption.

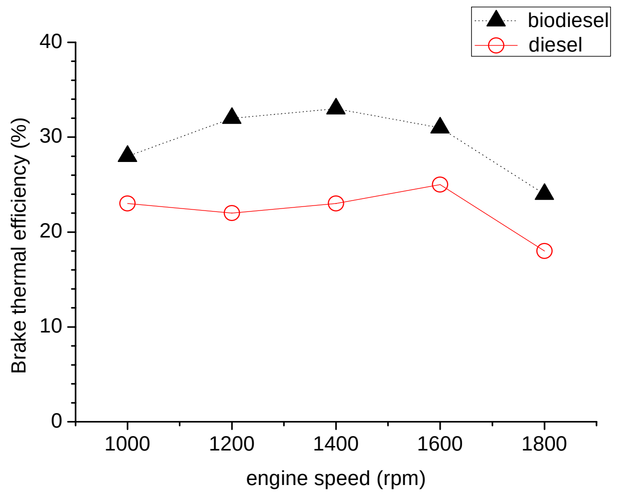

Fig. 6. Brake thermal efficiency.

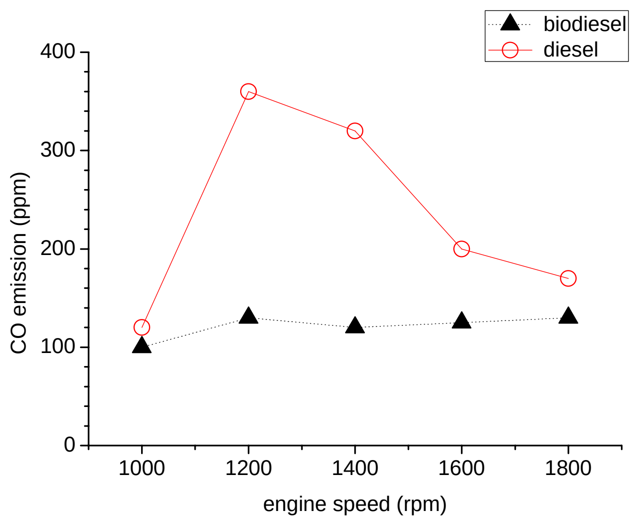

Fig. 7. CO emission.

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

per unit energy output, compared to biodiesel. The effect of lower heating value of biodiesel was more than offset by operating at higher fuel to air ratio. It should be noted that difference in heating value was less than 5%. Fig. 6 shows the brake thermal efficiency. With regards to emissions, biodiesel appeared to be superior to diesel as far as CO was concerned (Fig. 7). This observation may be partially due to the presence of oxygen in the biofuel. It was possible to derive biodiesel from passion fruit seed oil with relatively straight forward technology appropriate for rural use. Biodiesel obtained was found to meet Thai and international standards. It was shown to have satisfactory performance in engine tests and compare well with conventional diesel fuels.

IV. Conclusion

Potential use of passion fruit processing residues as bioenergy sources was considered in this work. The fruit seeds can be pressed to generate oil for biodiesel production. These biomass fuels were utilized successfully in a small engine to generate mechanical and electrical power. Comparable performance between diesel and biodiesel was obtained in constant engine speed tests. Renewable energy from these residues can help to improve energy efficiency, environmental sustainability, and quality of life in rural Thailand.

Acknowledgment

We would like to thank Kru Urai and Farmers Association of Mae Hong Son, Thailand for providing passion fruit seeds.

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