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Research Study on Biofuels at Chiang Mai University

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Abstract: This paper presents the results of research studies on biofuels in the terms of bioethanol and biodiesel at Chiang Mai University, Thailand. For bioethanol, the studies are concerned with the selection of ethanol producing microbes and the methods of the microbe cultivation to produceget high yields of ethanol. For biodiesel, various methods have been carried out to achieve high energy efficiency in biodiesel or emulsified oil products to replace diesel in diesel burners and low speed diesel engines. Fewer emissions were observed when the biodiesel and the emulsified oil were utilized. Moreover, bio-oil and bio-char from freshwater algae have been considered. The production process was carried out under a slow pyrolysis. Finally, life cycle impact assessment of the biofuel production has also been undertaken.

Keywords: biofuels, bioethanol, biodiesel, emulsified oil, bio algae-oil.

1. Introduction

Biomass is the largest source for renewable energy in Thailand which is about 4,000 ktoe at present or over three quarters of total renewable energy utilization [1]. It will be the main source of renewable energy for the country until the year 2022 with the amount increasing up to about 8,700 ktoe.

Biofuel in Thailand is promoted in the form of ethanol and biodiesel. For the 15 year Alternative Energy Plan starting in 2008, the amount of biofuel will be expected to be up to 3,986 ktoe by 2022, or about one-third of total renewable energy utilization. Ethanol and biodiesel are promoted as alternatives for conventional gasoline and diesel oil, respectively due to high oil price and their green house gas emissions. Thus gasohol and biodiesel consumption have increased rapidly in the past few years.

Research studies on biofuels at Chiang Mai University have been undertaken at the Faculty of Agro-Industry, Energy Research Development Institute Nakornping (EDRI) and Department of Mechanical Engineering, Faculty of Engineering.

2. Bio-ethanol

Ethanol can be produced from fermentable sugars (such as fructose, glucose, and sucrose) of agricultural products and waste. The initial overall sugar concentration of fermentable sugars, in the absence of the inhibitory compounds and/or conditions, must not be less than 130 g/L for biofuel production to be economically viable. There are many studies on the selection of ethanol producing microbes and the method of the microbe cultivation.

Saccharomycs cerevisiae has been used to convert fermentable sugars obtained from agricultural raw materials into ethanol. Jaiwanglok et al (2008) [2] reported that *S. cerevisiae* TISTR 5020 and TISTR 5606 obtained from Thailand Institute of Science and Technology Research (TISTR) could produce 43.4±4.0 and 41.8±1.2 g/L ethanol, respectively.

Kanchanwong et al (2008) [3] investigated the optimal cultivation time for microbial propagation based on 15 microbial strains (*Candida utilis*, *S. cerevisiae*, *Zymomonas mobilis*, *Escherichia coli*, and *Klebsiella* sp.) obtained from Thailand Institute of Science and Technology Research (TISTR). Phrathong et al (2008) [4], and Poodtatep et al (2008) [5] also reported the optimal cultivation time was 48 h in static conditions when compared with cultivation of 24 and 72 h. *S. cerevisiae* TISTR 5606 and TISTR 5020 were able to produce the highest levels of ethanol concentration. Phrathong et al (2008) [4] also utilized *S. cerevisiae* TISTR 5020 with six months old dried longan as a carbon source at an initial overall sugar concentration of 74.4±5.2 g/L. The highest ethanol concentration was 45.0±6.1 g/L with an ethanol yield ($Y_{P/S}$) of 0.50 g ethanol/g overall sugar.

Leksawasdi (2009)[6] developed an ethanol producing microbe for converting sugars into ethanol. It was used to produce ethanol from dried longan extract and 209±14 L ethanol/ 1,000 kg of dried longan flesh was obtained.

Some studies found that the addition of nitrogen could give positive effects on growth and ethanol production. The results were reported by Kumthip et al. (2009)[7], Buakham *et al*. (2009)[8], and Tadkaew et al. (2009)[9] who took 6 year old dried longan sample as carbon source with/without addition of extrageneous nitrogen and carbon source was molasses.

Aeration is another important factor that can assist the cells propagation in both inocula preparation and cultivation stages, this is especially true in case of batch or fed-batch fermentation in a static condition. Saikaew et al. (2010) [10] presented kinetics growth and ethanol production of *S. cerevisiae* TISTR 5606 in a static condition without aeration at 1,500 ml with high ethanol concentration. Palakul et al. (2006) [11] and Chaweekulayakun et al (2010) [12] developed empirical fed-batch strategies to enhance the level of ethanol production in 5 L cultivation with aeration.

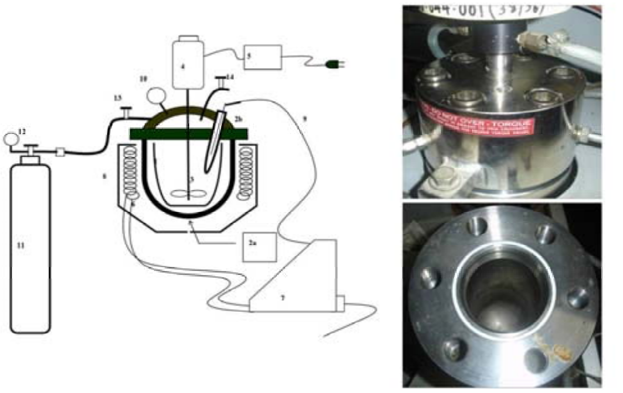
In order to minimize the costs involved with ethanol production the effect of inoculum size (Chaweekulayakun et al, 2010) [12], type of nitrogen source, type of carbon sources (either in the form of Dried Longan Extract (DLE) or Digested Dried Longan Flesh Hydrolysate (DDLFH); Tangsunthornkun et al., 2010) [13]) as well as strategy development for cultivation of a microbial strain in 5 and 100 L fermenters, have been investigated. Mathematical model development and simulation techniques based on Euler's method were employed by Saikaew et al. (2010) [10] to elucidate the growth and ethanol production kinetics of *S. cerevisiae* TISTR 5606 for further development of a continuous fermenter and an optimal feeding profile in a fed-batch system. The developed model showed a good agreement with the fermentation kinetics of cultivation media containing pure sugars (glucose alone, fructose alone, and sucrose alone at 40 g/L), mixtures of all three sugars with 1:1:1 ratio at 20/20/20, 30/30/30, 40/40/40, and 60/60/60 g/L, as well as dried longan extract at 60, 120, and 180 g/L.

3. Bio-Diesel

The Energy Reserch Development Institute (EDRI), Chiang Mai University has developed a prototype that could produce biodiesel from used-cooking oil under transesterification. The unit shown in Fig. 1 gives a yield of 150 L/batch and has been made commercially available. A prototype unit having a capacity of over 1,000 L/batch was also constructed.

Biodiesel from transesterification of vegetable oil could also be generated by supercritical technique. Permsuwan et al [14] performed some experimental tests on biodiesel production from palm oil and ethanol under pressurized carbon dioxide and methanol. The experimental setup is shown in Fig. 2. The pressure was high and the energy efficiency for the oil production was rather low.

Figure 1. A demonstration of biodiesel unit from used vegetable oil developed by ERDI.



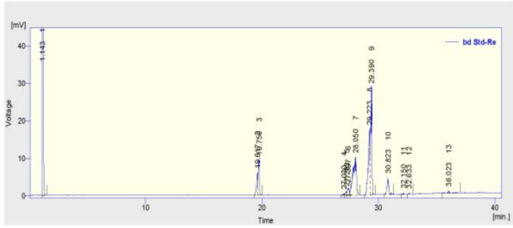
แผนภาพอุปกรณ์ชุดปฏิกรณ์ทดสอบ 1.Vessel, 2a.Reactor body, 2b.Reactor lid, 3.Stirrer, 4.Motor, 5. Motor speed controller, 6.Electrical Heater, 7.Heater Controler, 8.Insulator, 9. Thermocouple, 10.Pressure gauge, 11.CO_2 tank, 12.CO_2 regulator, 13.Reactor inlet value, 14.Reactor outlet value

Figure 2. The experimental setup of a supercritical biodiesel reactor [14].

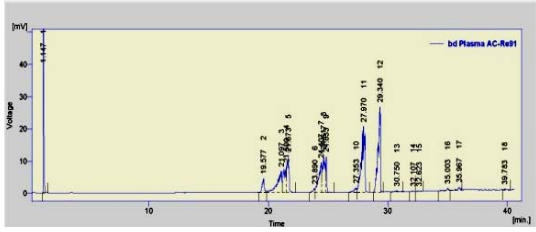
Recently, a new technique to generate biodiesel from crude vegetable oil such as palm oil, Jatropha oil and Tung oil under an electric field has been undertaken at the Department of Mechanical Engineering, Chiang Mai University [15]. A laboratory testing unit scale has been carried out and 100 ml of biodiesel could be obtained in a short period. The biodiesel had similar chemical properties to that produced from conventional processes as shown in Fig. 3. A prototype unit with a capacity of 200 L/d is undergoing design and construction.

Biodiesel produced from algae is another topic of interest. Two projects have been carried out. The first one is to cultivate microalgae in an open vertical reactor. Fig. 4 shows the open vertical photoreactor of *Chlorella spp*.

Another project involves the pyrolysis of dried microalgae. The products obtained are biofuel and biochar as shown in Fig. 5. Table 1 and Table 2 show the chemical composition of bio-oil and bio-chars [16].



Standard Biodiesel



Produced Biodiesel with Electric Field

Figure 3. Gas Chromatograph pictures of chemical compositions of biodiesel from standard methods and that from transesterification under an electric field [15].

6 days operation

30 days operation

Figure 4. Open-type vertical photoreactor of *Chlorella spp.* microalgae.

Table 1. Chemical class compositions of bio-oils from slow pyrolysis of *Spyrulina*[16].

Data	Formular	%area	MW
Toluene	C_7H_8	52.99	92.06
Ethylbenzene	C8H10	6.08	106.17
Indole	C8H7N	8.67	117.06
Hepeadecane	C17H36	32.26	240.28

Studies on emulsified oil blended from diesel, crude vegetable oil and water have also been carried out. Ultrasonic

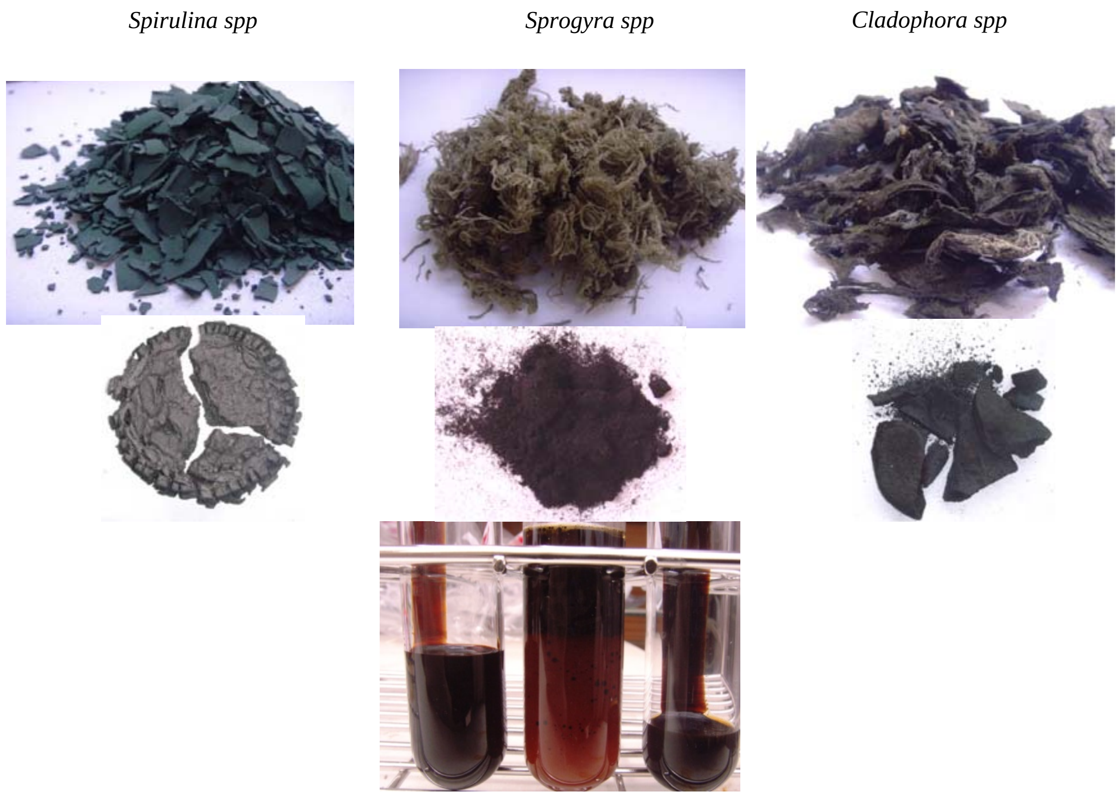


Figure 5. Biochars and bio-oils from dried microalgae under pyrolysis process [16].

Table 2. Proximate and ultimate analyses of algae bio-char compared with other solid fuels [16].

Name	Fixed Carbon (%)	Volatiles (%)	Ash (%)	S (%)	HHV (kJ/g)	C (%)	H (%)	O (%)	N (%)
Coal – Pittsburgh Seam	55.80	33.90	10.30	3.10	31.75	75.50	5.00	4.90	1.20
Peat (S-H3)	26.87	70.13	3.00	0.11	22.00	54.81	5.38	35.81	0.89
Charcoal	89.31	93.88	1.02	1.00	34.39	92.04	2.45	2.96	0.53
Oak char (565°C)	55.60	27.10	17.30	0.10	23.05	64.60	2.10	15.50	0.40
Casuarina (950°C)	71.53	15.23	13.24	0.00	27.12	77.54	0.93	5.62	2.67
Cononut Shell Char (750°C)	87.17	9393.00	2.90	0.00	31.12	88.95	0.73	6.04	1.38
Eucalyptus char (950°C)	70.32	19.22	10.45	0.00	27.60	76.10	1.33	11.10	1.02
* Spirulina char (550°C)	44.50	7.63	47.82	0.07	15.78	45.26	1.24	0.28	2.57
* *Sprogyra* char (550°C)	26.68	35.50	37.81	1.68	16.68	51.14	0.56	0.69	1.98
* *Cladophora* char (550°C)	59.66	16.81	23.53	0.53	22.96	62.37	0.37	4.07	2.11

waves have been used to blend the oils and water to various compositions. The crude vegetable oils used were crude palm oil, Jatropha oil and Tung oil. The water-in-oil emulsion could replace diesel oil in boiler burners and low speed diesel engines [17-20]. Fig. 6 shows an example of crude palm oil/diesel/water compared with diesel oil and biodiesel from crude palm oil. With appropriate compositions, the emulsified oil could give almost the same thermal performances as diesel oil in burners and low speed indirect injection diesel engines but with significantly lower emissions in flue gases.

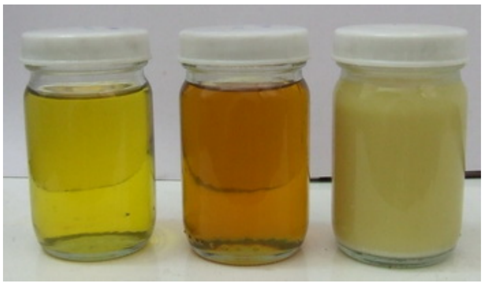


Figure 6. Comparison of emulsified oil with diesel oil and transestered biodiesel (Diesel oil, Transestered biodiesel, Tung oil/diesel/water emulsion, respectively).

4. Life Cycle Impact Asssessment

Net energy efficiency and net environmental impact assessments on biofuel production are of interest and there are a few studies on gasohol production which have been carried out [21]. Solar energy has been used to reduce the input energy and its environmental impacts during the ethanol distillation process [22].

5. Conclusions

The methods and processes of biofuel production in the terms of bioethanol and biodiesel at Chiang Mai University are reviewed in this paper. For bioethanol, selection of ethanol producing microbes and the method of the microbe cultivation to achieve high yields of ethanol are presented. For biodiesel, various methods have been used to produce biodiesel under an electric field or emulsified blended oil of diesel oil, crude vegetable oil and water to replace diesel in diesel burners and low speed diesel engines. Fewer emissions were observed when the biodiesel and the emulsified oil were utililized. Finally, a life cycle impact assessment of the biofuel production has also been undertaken.

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