

Biofuel and Glycerin Production from Waste Rice Bran Cooking Oil and Fish Byproducts Oil as a Sustainable Development and an Environmental Recycling Process

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ABSTRACT

The utilization of waste cooking oil from rice bran and fish byproducts including their wastes can contribute to mitigate the environmental burden like global warming what already being faced by our society. Converting waste oils /fat bearing materials to biodiesel fuel for recycling and reusing material, and reducing Co₂ emission equivalent to the amount that is produced when petroleum derived diesel fuel is used. Waste cooking oil (rice bran oil) and fish oil have emerged as the most promising sources for biodiesel production. This study was investigated to understand the proper transesterification, amount of biodiesel production (ester) and physical properties of biodiesel. Biodiesel production was higher in rice bran waste oil than in fish byproducts oil. However, crude glycerine was lower in rice bran oil than in fish oil. There was a difference in biodiesel production in different concentrations of methanol and catalyst used in rice bran and fish oil from byproducts. These results indicate that high quality biodiesel can be produced from waste rice bran and fish byproducts oil as environmental recycling process.

Keywords : Waste oils, glycerin, methanol, fish oil, Biodiesels

INTRODUCTION

One of the most crucial elements in reducing greenhouse gas emissions and replacing fossil fuels is bioenergy [1, 2]. Due to population growth and industrialization, the requirement for energy is always rising. Petroleum, natural gas, coal, hydropower, and nuclear energy are the main sources of this energy [3,4]. The main drawback of using fuels derived from petroleum is the pollution that petroleum diesel produces into the atmosphere. One of the main sources of greenhouse gas emissions is the burning of petroleum fuel. In addition to these emissions, NO_x, SO_x, CO, particulate matter, and volatile organic compounds are among the numerous air pollutants that petroleum diesel is a significant source of [5].

Biomass is one of the superior energy sources [5]. The widespread use of biomass energy has the potential to support sustainable development in a number of ways, including social, economic, and environmental [6]. One such alternative fuel is biodiesel (monoalkyl esters), which is made by transesterifying triglyceride oil with monohydric alcohols. Biodiesel made from canola, soybean, palm, sunflower, and algae oils has been widely recognized to be an effective alternative to diesel fuel [7,8,9]. An alternative fuel derived from renewable resources, biodiesel is harmless and biodegradable. Reliance on petroleum-based fuel could be reduced in part by producing biodiesel fuel from leftover cooking oil, such as palm, soybean, canola, rice bran, sunflower, coconut, corn oil, fish oil, chicken fat, and algae [10].

Global warming is a result of the massive amount of fossil fuels that have been used, which has raised the atmospheric concentration of CO₂. Since biomass is a renewable resource and fixes CO₂ in the atmosphere through photosynthesis, it has drawn attention as a potential alternative energy source. Because the CO₂ fixed by photosynthesis balances the CO₂ released by burning biomass, burning biomass has no effect on the atmospheric CO₂ balance if it is grown sustainably [11]. The photosynthetic efficiency of algae, including macro and microalgae, is often higher than that of other biomass [12].

According to Shay [13], one of the best sources of biodiesel is algae. Actually, the most productive feedstock for biodiesel is algae. Compared to soybeans, it can yield up to 250 times as much oil per acre. Actually, the only option to generate enough vehicle fuel to replace the current gasoline consumption is to make biodiesel from algae. Compared to palm oil, algae produce 7–31 times as much oil. The process of extracting oil from algae is fairly easy. Microalgae are the best algae to use for biodiesel. Microalgae are organisms smaller than 2 mm in diameter that are able to do photosynthesis.

Microalgae are organisms smaller than 2 mm in diameter that are able to do photosynthesis. Seaweed and other macroalgae are utilized less frequently to produce biodiesel. In addition to being faster and simpler to produce, microalgae contain a lot more oil than macroalgae [10]. The cost of manufacturing, particularly the cost of raw materials, is a significant barrier to the commercialization of biodiesel made from virgin oil as opposed to diesel fuel derived from petroleum. One of the cost-effective sources for producing biodiesel as a green energy source is used cooking oil [14]. Investors in biodiesel production plants will keep looking for financially viable supplies of vegetable oil and animal fats that may be utilized to make biodiesel [13], as biodiesel is becoming a more significant fuel source globally [15].

Among these animal fats like fish oil and chicken fat oil which is a feedstock that is reasonably priced in comparison to other sources of oil and fat, including waste cooking oil [16]. However, base-catalyzed transesterification combined with the high free-fatty acid (FFA) content of poultry fat results in by-products such as glycerin and soaps. One of the more effective and cost-effective methods to use it is to turn leftover cooking oil into biodiesel. However, waste cooking oil, such as rice bran oil and waste fish oil, can be used as objectives: to make a significant amount of biodiesel fuel, reducing the need for fuel derived from petroleum and to investigate its proper qualities by identifying different properties.

MATERIALS AND METHODS

Site: The experiment was carried out in the laboratory of Bioresource Science, Department of Biotechnology, Institute of Biological Science, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia and University of Hail, Saudi Arabia.

Collection and extraction of waste cooking oil: Waste rice bran cooking oil (after the use of oil as frying) and fish byproducts was collected from local restaurants and households in the University Malaya campus, Kuala Lumpur, Malaysia and Hail University, Saudi Arabia. Fish wastes were collected from the local fish processing market and was heated up using incubator at 100°C for 6 hours to melt down. Applying filtration technique, the melted fish fat was extracted which had been transesterified later on using alcohol and catalyst.

Transesterification: 0.5 g KOH was mixed with methanol and oil as the ratio of 4:1 and stirred properly for 20 min. The mixture of catalyst and methanol was poured into the filtered and extracted oil or fats in a conical flask. The following reaction and steps were followed:^[15] The reaction process is called transesterification. The conical flask containing solution was shaken for 3 h by electric shaker at 300rpm.

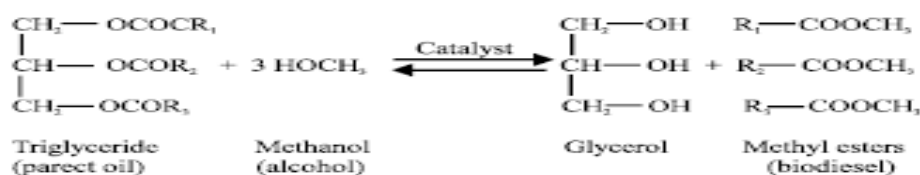


Fig 1. Transesterification Process

Settling: After shaking the solution was kept for 15 h to settle the biodiesel and sediment layers clearly.

Separation of biodiesel: The biodiesel was separated from sedimentation by flask separator carefully. Quantity sediment (glycerine, other elements, etc.) was measured.

Washing: Biodiesel was washed by 10% water until it was become clean.

Drying: Biodiesel was dried by using dryer and finally kept under the running fan for 12 h.

Storage: Biodiesel production was measured by using measuring cylinder, pH was measured and stored for analysis.

Sample analysis: Produced biodiesel or FAME (fatty acid methyl ester) were analysed and viscosity, FAME yield (%), Glycerine byproduct yield (%) and elements concentration (Fe, Pb, Cu, Al, Ca, Mg, Na, Zn, Si and P) by multi-element analyzer were measured.

RESULTS AND DISCUSSION

Biodiesel production (methyl ester) was found maximum in waste rice bran oil and then in fish oil. (Table 1). Biodiesel production (methyl ester) was lower in rice bran oil than fish oil. However, glycerine yield (%) was lower in rice bran and higher in fish oil. There was is a significant difference between them (Table 1). The viscosity (mm²/s) value was lower in rice bran biodiesel than in fish biodiesel (Table 2). Acid value was lower in rice bran oil than in fish oil bed biodiesel (Table 2).

Table 1. FAME analysis of biodiesel. Mean $\pm$ SE (n=5).

Feedstock and biofuel	FAME Conversion yield %	Glycerine yield (%)
Waste Rice bran biodiesel	96.6 $\pm$ 0.19	6.3 $\pm$ 0.05
Fish oil biodiesel	93.2 $\pm$ 0.10	9.0 $\pm$ 0.06

Table 2. Viscosity (mm²/s) and acid value of different FAMEs. Mean $\pm$ SE (n=5).

Feedstock and biofuel	Viscosity at 40 0C (mm ² /s)	Acid value (mgKOH/ml)
Waste Rice bran biodiesel	4.2 $\pm$ 0.01	0.35 $\pm$ 0.02
Fish oil biodiesel	4.6 $\pm$ 0.03	0.45 $\pm$ 0.02

Phosphorus, calcium and Magnesium were higher in both biodiesel compared to other elements in FAMEs [Table 3]. However, the lower concentration was of Zn, Na, Cu, Al and Fe in both biodiesel FAMEs.

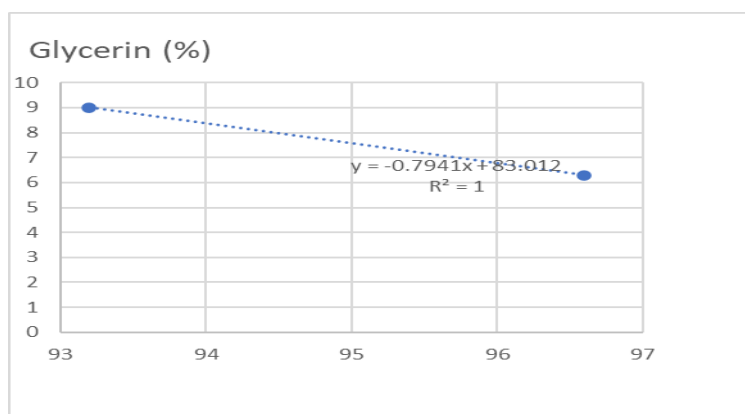
Table 3: Multi-element (chemical) content analysis in different FAME. Mean $\pm$ SE (n=5).

Elements	Waste rice bran biodiesel Content (ppm)	Fish byproducts oil biodiesel Content (ppm)
P	4.7 $\pm$ 0.014	5.0 $\pm$ 0.015
Ca	3.0 $\pm$ 0.015	3.2 $\pm$ 0.014
Mg	2.5 $\pm$ 0.013	2.3 $\pm$ 0.010
Al	2.0 $\pm$ 0.011	1.6 $\pm$ 0.010

Cu	1.5± 0.010	1.0± 0.011
Fe	2.0± 0.010	1.8± 0.010
Na	1.0± 0.015	2.0± 0.012
Zn	0.80± 0.010	0.90± 0.011
Si	0.83± 0.010	0.85± 0.02
Pb	0	0

Although there was a less significant difference in FAME production (%) from fish and rice bran biodiesel.

Fig 1 shows the correlation between the biodiesel yield and glycerin yield in waste rice bran and fish byproduct. In both biodiesel, increasing and decreasing trends were found in biodiesel and glycerin. When biodiesel yield increases the glycerin yield decreases. So there was a strong relationship between them. Fig 2 shows biodiesel production from rice bran and fish byproducts (FAME after separation) biofuel (biodiesel).



Biodiesel Yield (%)

Fig. 1. Correlation between the biodiesel yield and glycerin yield in waste rice bran and fish byproduct.

Photographs show different sources (fish byproducts and rice bran oil biodiesel) of biodiesel production and ester yield (Fig. 2).

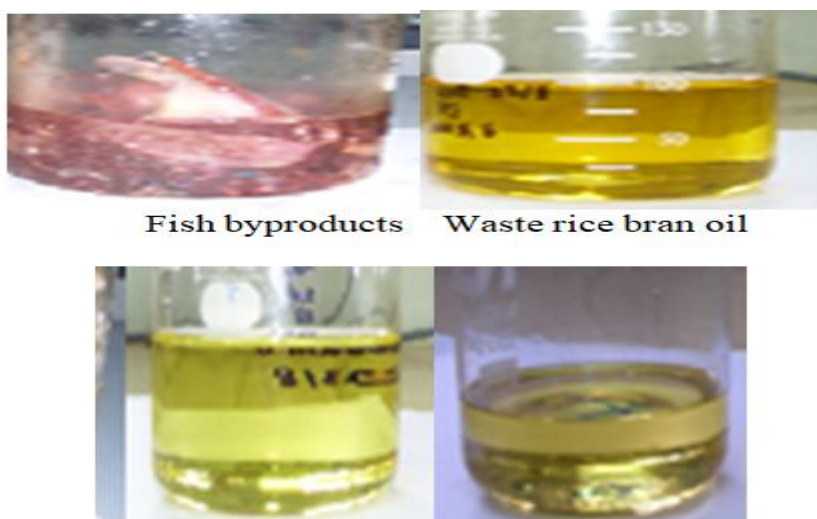


Fig. 2. Photographs show biodiesel production from rice bran and fish byproducts, biodiesel (FAME after separation) biofuel (biodiesel).

The results show that biodiesel production can be possible from both waste rice bran and fish byproducts oil. Glycerine production was significantly higher in fish biodiesel than in rice bran oil. Sijsma and Swaaf^[18] stated that docosahexaenoic acid (DHA) was a polyunsaturated fatty acid composed of 22 carbon atoms and six double bonds that belonged to the so-called -3 group. They also reported that fish oil was the major source of DHA, but alternatively it might be produced by using of microorganisms. Marine microorganisms might contain large quantities of DHA and were considered a potential source of this important fatty acid. Some of these organisms could be grown heterotrophically on organic substrates without light. It has been reported that macro algae contain lipid content of 1.3-7.8% (dw) and could produce biodiesel. In addition in heterotrophic condition lipid content can be more in algae and could produce more biodiesel^[19].

The majority of the commercial biodiesel from sunflower oil is manufactured using homogenous base catalysts such as NaOH or KOH. The transesterification of used oil collected from the cafeterias at the University of Guelph, Canada, using an acidic catalyst (H₂SO₄) and an alkaline catalyst (KOH) and was compared^[21]. Two types of used oils (partially hydrogenated soybean oil and margarine) were transesterified with methanol, ethanol, 1-propanol, 2-propanol, 1-butanol, and 2-ethoxyethanol^[21]. It has been compared between two catalysts such as KOH and a combination of barium and calcium acetate for the preparation of methyl esters from waste cooking oil. It was found that all of the catalysts showed reasonable biodiesel production.

CONCLUSION

Waste cooking oil and fish byproducts oil are possible economical choices for biodiesel production, because of their availability and low cost. Our results prove that biodiesel can be produced from these sources: waste rice bran and fish byproducts oil (96.6 and 93.2%). Also, the highest glycerin was produced by using fish byproducts. In this way, these sources can be used as an environmental recycling process and renewable energy. Further research should be done to compare the ratio of biodiesel production from these sources.

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