Effect of Catalyst on Transesterification of Waste Vegetable Oils from Food Processing Facility

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Summary

Converting waste vegetable oils from food processing facilities, restaurants and households to biodiesel by the transesterification reaction with methanol has important advantages for human health and environment. The transesterification reaction of waste vegetable oils is affected by free fatty acids and water content of oils and fats, type of alcohol, type and quantities of catalyst, reaction temperature and reaction time. Basic aim of this paper is to explore effect of type and quantities of catalyst on transesterification process of different waste vegetable oils from food processing facilities with methanol. Comparison of basic characteristics between produced biodiesel, industrially produced biodiesel and values from European standards for biodiesel fuel (EN14214) was made.

Key words

biodiesel, waste vegetable oil, transesterification, type of catalyst

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Introduction

Biodiesel can be produced from different vegetable oils, animal fat and waste vegetable oil from restaurants and facilities for food production (production of chips and snack-products, production of cakes, doughnuts etc.) (Tickell, 2003). The basic part of this process is transesterification of triglycerides with methanol and catalyst (NaOH). In the last decade World biodiesel production continuously increases. For example Germany had over 4.8 million tons installed capacity for biodiesel production in 2007 (Bockey et al., 2008). Recently we are faced with big dilemma: is it correct to use a significant areas of agricultural land for the production of raw materials (crops) for biodiesel production (rapeseed, sunflower and soy) or for bioethanol production (corn) or to use that land for food production because for example only during the past year we had a lack of food on the global market same as increasing of it's prices and that all has a major negative influence on non-developed countries.

On the other side everyday we throw out significant quantity of waste vegetable oils from the food processing facilities, restaurants and households. Those quantities of waste vegetable oils can be important sources of raw material for biodiesel production. Management of waste vegetable oils presents an acute problem from the ecological point of view. Waste vegetable oil is a risky waste. It has negative effects on the environment. In Bosnia and Herzegovina most of the quantities of waste vegetable oil are not collected and it is still going down the drain and cause a lot of problems (plugging, unpleasant smell etc.). Problems with waste vegetable oil can be permanently solved by processing it into biodiesel. That way we can solve two acute problem: waste vegetable oil disposal and production of environmentally friendly fuel. In developed countries waste vegetable oil disposal is regulated by the law. All waste cooking oil must be collected and send to the facilities for it's processing. Bosnia and Herzegovina has a large number of the "producers" of waste vegetable oil (Sprind – Sarajevo, Klas – Sarajevo, CornFlips-Srebrenik, Voćar – Čelić, Pekare Tuzla etc.). Some of them produce a significant volume of waste oil (cake factory "Gusto Sappore" produces more than 3000 liters monthly). Those oils can be important raw material for biodiesel production in Bosnia and Herzegovina. Many studies of transesterification reaction for biodiesel production from waste vegetable oil on the laboratory scale have been carried out (Freedman et al, 1984; Mittelbach, 2002; Rice et al., 1998; Çanakçi and, Özsezen, 2005). Basic aim of this paper is to explore effect of type and quantities of catalyst on transesterification process of different waste vegetable oils from food processing facilities with methanol. Comparison of basic characteristics between obtained biodiesel from WVO (waste vegetable oil), industrial produced biodiesel and values from European standards for biodiesel fuel (EN14214) was made.

Figure 1. Apparatus for biodiesel production

Material and methods

Following reactants were used in the experiments:

- Different samples of waste vegetable oils from food processing facilities
- Methanol (Merck – Germany)
- NaOH (Merck – Germany)

Apparatus for biodiesel production by transesterification reaction of waste vegetable oils is presented in Fig. 1 and it is build of:

- Three-neck glass reactor vessel
- Laboratory heater with thermoregulation
- Ceramic tank
- Laboratory mixer
- Water condenser
- Thermometer

Biodiesel production process depends of oil quality and includes:

- Filtering of waste vegetable oils
- Water removal by heating
- Waste vegetable oil analysis
- Weighing of determined amounts of reactants
- Acid esterification (for oils with higher FFA (free faty acid) content)
- Preparation of alkaline-catalyst (NaOH in CH_3OH)
- Adding of catalyst to oil
- Mixing
- Settling
- Separation of glycerin from biodiesel in separatory funnel
- Washing of biodiesel with water and removal of water excess
- Characterization of obtained biodiesel

Three different samples of waste vegetable oils were used in the experiment. Characteristics of used WVO (waste vegetable oil) are given in Table 1.

Reactants quantity and reaction condition for laboratory biodiesel production are presented in Table 2.

Table 1. Characteristics of used WVO

Exp.	Density [g/cm^3]	Flashpoint [°C]	Viscosity 40°C [mm^2/s]	Iodine Value [mg J_2/100 g]	Acid Value [mg KOH/g]	Refractive Index
OU1	0.922	198	42.54	117.4	0.85	1.4762
OU2	0.926	189	51.83	105.3	1.74	1.4765
OU3	0.928	184	60.52	99.3	3.89	1.4770

Table 2. Reactants quantity and reaction condition for laboratory biodiesel production

Exp.	Oil sample	Acid catalyst H_2SO_4 [ml]	Methanol 1 [ml]	Alkaline catalyst NaOH [g]	Methanol 2 [ml]	Volume of WVO [ml]	Time [h]	Temperature [°C]
1	OU1	0.5	40	2.3	60	500	2 + 1	35, 60
2	OU2	0.5	40	2.3	60	500	2 + 1	35, 60
3	OU3	0.5	40	2.3	60	500	2 + 1	35, 60
4	OU1			2.3	125	500	1	25
5	OU1			4.6	125	500	1	25
6	OU2			2.3	125	500	1	25
7	OU2			4.6	125	500	1	25
8	OU3			2.3	125	500	1	25
9	OU3			4.6	125	500	1	25

Table 3. Results of experiments for production of biodiesel from WVO

Exp.	Biodiesel [g]	Glycerol [g]	Midle layer [g]	Density [g/cm^3]	Flashpoint [°C]	Viscosity 40°C [mm^2/s]	Refractive Index
1	448.9	69.2	-	0.888	165	6.56	1.4645
2	442.3	72.3	-	0.886	154	5.53	1.4605
3	435.5	78.7	-	0.887	148	6.94	1.4636
4	462.5	88.3	-	0.885	168	5.88	1.4600
5	460.1	90.4	-	0.880	163	4.96	1.4589
6	459.6	93.3	-	0.890	153	7.05	1.4651
7	338.3	51.3	166.4	0.882	155	4.99	1.4567
8	427.2	109.8	18.3	0.889	151	5.89	1.4649
9	Gel formation	-	-	-	-	-	-

Results and discussion

Characterization of obtained samples of biodiesel was based on the following parameters:

- Quantity of biodiesel and raw glycerol
- Density
- Viscosity at 40 °C
- Flashpoint
- Refraction index

Results of obtained biodiesel samples characterisation are given in Table 3.

By the analysis of obtained results, optimal parameters for biodiesel production by transesterification reaction of WVO (waste vegetable oil) are chosen and produced biodiesel sample that was sent for analysis in Inspect-RGH Sarajevo laboratory in Kakanj (B&H), which holds standard ISO 17025 and is verified laboratory for fuel analyses. The results were compared with parameters of industrially produced biodiesel (bought in Hungary), as well as with EU standard for biodiesel fuels (EN14214). The results obtained, are given in Table 4.

Table 4. Comparation between laboratory produced and industrial (commercial) biodiesel

Parameter	Method	BD from WVO	BD (industrial)
Density (15 °C) on air [kg/m^3]	BAS ISO 3675 860-900	881.9	879.1
I.B.P. [°C]		271	195
Distillation 95 % [°C]	≤360	348	359
Kinematic viscosity on 40°C [mm^2/s]	BAS ISO 3104 3.5-5.0	5.128	4.214
CFPP [°C]	EN 116	-2	-7
Flashpoint [°C]	ASTM D 93 ≥130	169	139
Sulfur [% m/m]	ASTM D 4294 ≤ 0.001	<0.015	<0.015
Water content [mg/kg]	ISO 10336 ≤ 500	143	250
Cu-corrosion	BAS ISO 2160 class 1	1a	1a
Ash content [% m/m]	ISO	no	no

The most of obtained data for our biodiesel from WVO (waste vegetable oil) is comparable with results obtained for industrial biodiesel and with values given in European standard for biodiesel fuel EN14214. In comparison with EU standard EN14214, values for viscosity same as for CFPP (cold filter plugging piont) for biodiesel from WVO were increased. Those results indicated that the best way of usage of our biodiesel from waste vegetable oil would be the mixture with biodiesel from virgin oil (especially rape oil) or the mixture with fossil diesel.

Conclusion

– WVO (waste vegetable oil) presents a valuable raw material for biodiesel production
– Free fatty acid content in WVO (waste vegetable oil) has a major impact on biodiesel production process same as type and quantity of catalyst used for transesterification process.
– Feedstocks with FFA (free fatty acids) content below 1% could be converted to biodiesel by transesterification process using an alkaline–catalyzed process.
– Alkaline–catalyzed process can't be used for feedstock with higher FFA (free fatty acids) content (in our case 3.8 %) because of gell and soap formation in the reactor.
– For the WVO (waste vegetable oil) with higher FFA (free fatty acids) content best solution is combined process with acid-catalyzed pretreatment process to convert the FFA's to ester followed by alkaline-transesterification of triglycerides.

References

Bockey D., Wienke von Schenck, (2008) Status report- Biodiesel production and marketing in Germany 2007, Union zur Forderung von Oel-und Proteinpflanzen e.V. (dostupno na www.ufop.de)

Çanakçi M., Özsezen A.N.(2005). Evaluating waste cooking oils as alternative diesel fuel. G.U.Journal of science. 18(1), 81-91

Freedman B., Butterfield R.O., Frankel E.N., (1984) JAOCS, 61,1638-1643, 1984

Mittelbach M. (2002). Experiece with biodiesel from used frying oil in Austria. Working group renewable resources, Graz,

Rice B., Frohlich S., Leonard R. (1998). Biodiesel from camelina oil, waste cooking oil and talow. TEAGASC-projekt.

Tickell J.(2003). From the fryer to the fuel tank, J.Tickell publ., New Orleans.

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