CHEMICAL ENGINEERING TRANSACTIONS Volume 25, 2011
Editors Jiří Jaromír Klemeš, Petar Sabev Varbanov, Hon Loong Lam
Copyright © 2011, AIDIC Servizi S.r.l., ISBN 978-88-95608-16-7 ISSN 1974-9791
DOI: 10.3303/CET1125143

Comparative Study of Biodiesel Production from Soybean Oil and Coconut Oil Using a Multiple-Stage Ultra Shear Reactor

Nívea De Lima Da Silva*, César Benedito Batistella, Rubens Maciel Filho, Maria ReginaWolf Maciel

Laboratory of Separation process development, School of Chemical Engineering, State University of Campinas, Zip Code 13081-970, Campinas, SP, Brazil
niveals@feq.unicamp.br.

This work presents biodiesel production from soybean oil and bioethanol by multiple-stage Ultra-Shear reactor (USR). The experiments were carried out in the following conditions: reaction time from 6 to 12 min; catalyst concentration from 0.5 to 1.5 % (by weight of vegetable oil); ethanol: vegetable oil molar ratio from 6:1 to 10:1. The experimental design was used to investigate the influence of process variables on the conversion of biodiesel. Biodiesel conversions greater than 99 wt.% were obtained with both raw materials.

1. Introduction

Biodiesel is a fuel made from vegetable oils, animal fats or microbial oils (algae, bacteria and fungi). The raw materials are converted to biodiesel through a transesterification reaction involving alcohol and catalyst (Ma and Hanna, 1999; Li et al., 2008). Biodiesel fuels have various advantages such as: it is a complement or substitute to petroleum based fuel, it is a renewable fuel, it has a favorable energy balance, it presents less harmful emissions and it is a non-toxic fuel, which make them very attractive (Gómez-Castro et al., 2010; Garnica et al., 2009; Ito et al., 2005; Vyas et al., 2009).

Transesterification reaction can be catalyzed by homogeneous (alkaline and acid) and heterogeneous catalysts or without catalyst using supercritical conditions. Mixing is an important variable in the transesterification reaction because the vegetable oils or fats are immiscible with catalyst-alcohol-solution (Meher et al., 2006). Within this concept, in this work, a multiple stage high-speed mix was used for biodiesel production. This equipment has up to three sets of rotors and stators that convert mechanical energy to high tip speed, high shear stress and high shear-frequencies. The reaction takes place in the high-energy shear zone, with a small droplet size and a large surface area, helping the catalyst reaction to occur faster. This drastically reduces production time and increases production volume (Ika Guide, 2010).

The experimental design was used to verify the behavior of the following process variables: reaction time, catalyst content and vegetable oil: ethanol molar ratio. The effects of these variables on biodiesel conversion were investigated through two

Please cite this article as: Da Silva N.L., Batistella C.B., Maciel Filho R. and Wolf Maciel M.R., 2011, Comparative study of biodiesel production from soybean oil and coconut oil using a multiple-stage ultra shear reactor, Chemical Engineering Transactions, 25, 857-862
DOI: 10.3303/CET1125143

experimental designs. The experimental set was carried out using a central composite design (CCD). The CCD was used to reduce the number of observations while giving the desired information, enabling the selection of the significant variables.

2. Materials and Methods

2.1 Raw materials

The experiments were carried out with refined soybean oil obtained from a supermarket (Brazil) and coconut oil donated by Copra (Brazil). Sodium hydroxide (Synth-Brazil) was used as catalyst. Anhydrous ethanol was purchased from Synth (Brazil). All the standards were supplied by Sigma-Aldrich (St. Louis, MO), polytetrafluorethylene filter (PTFE filter) was supplied by Millipore (U.S.), and HPLC-grade THF (Tetrahydrofuran) was from B&J/ACS (U.S.).

2.2 Equipment description

The transesterification reaction was carried out in an Ultra–Shear reactor (USR). This equipment is a rotor-stator mixing with high speed and intense shear frequency (PROCESS PILOT 2000/4 of IKA WORKS Inc., USA), Figure 1 and 2. The agitation was kept constant at 7900 rpm.

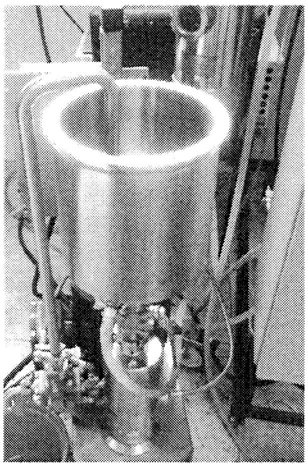

Figure 1: Ultra – shear reactor

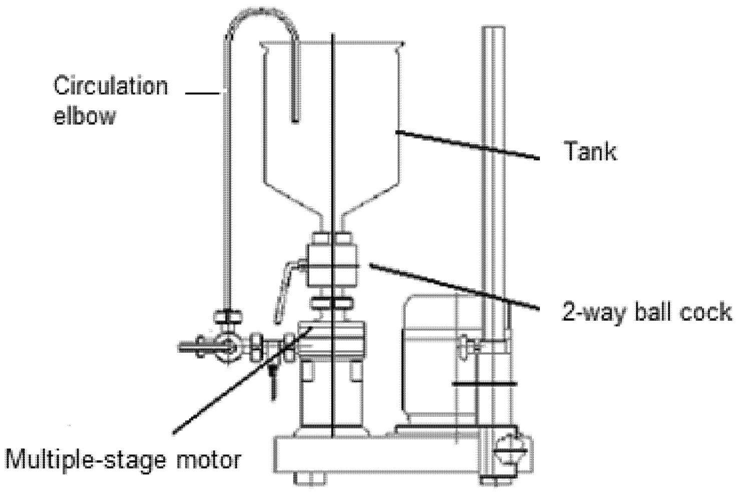

Figure 2: Details of ultra – shear reactor

The Ultra–Shear reactor has a modular design. This machine can be operated as basic device or can be turned into different operating devices using modules. The basic device is a single-stage high-performance instrument for continuous dispersion of liquids. In this work, three modules (multiple-stage) were used. The dispersing action is based on the rotor-stator principle, which means that a high-speed rotor with very narrow slots rotates in a stator. This produces high shearing energies between rotor and stator. The system consisting of rotor and stator is also called generator. In this system, a standard three-phase motor drives at 3000 rpm, and a transmission ratio of the belt drive increases the speed of the rotor shaft to 7900 rpm. A circulating elbow was used to increase the mixture of the reaction.

2.3 Biodiesel production

The USR was loaded with soybean oil, preheated to the desired temperature (78°C) and then agitation was initiated. Previous experiments showed that high agitation speed of USR leads to the ethanol reaching boiling point temperature so a water batch was used to maintain the temperature of the reactor at 78°C. The catalyst was dissolved in ethanol and the alcoholic solution was added to the vegetable oil.

2.4 Experimental Design

The effect of the process variables (catalyst concentration, ethanol:soybean oil molar ratio and reaction time) on biodiesel conversion (Y) were verified using experimental design. The experiments were done and optimized following CCD and response surface methodology (RMS). The software Statistica (Statsoft, v.7) was used to analyze the results.

3. Results and discussions

The free fatty acid content of raw materials were 0.32 to coconut oil and 0.30 to soybean oil. Low free fatty acid of vegetable oils permitted the use of basic catalysis. Experimental designs were carried out in order to optimize the process variables. The experiments were 2^3 plus three central points (CCD). The limits of the experimental design were: ethanol: vegetable oil molar ratio from 6:1 to 10:1; catalyst concentration level from 0.5 to 1.5 % and reaction time from 6 to 12 min. Table 1 shows the results of experimental design. The lower conversions were obtained in the first runs to both vegetable oil. Biodiesel conversions of 100 wt.% were obtained with coconut oil in runs 5, 6 and 8. The best soybean oil conversion was 97 wt.%.

Table 1: Experimental Design

Run	Time (min)		Molar Ratio		Catalyst (wt.%)		Soybean oil biodiesel (wt.%)	Coconut oil biodiesel (wt.%)
1	-1	6	-1	6	-1	0.5	82.58	78.49
2	1	12	-1	6	-1	0.5	95.48	80.01
3	-1	6	1	10	-1	0.5	90.07	99.41
4	1	12	1	10	-1	0.5	91.10	99.51
5	-1	6	-1	6	1	1.5	92.64	100
6	1	12	-1	6	1	1.5	97.28	100
7	-1	6	1	10	1	1.5	96.66	99.71
8	1	12	1	10	1	1.5	97.88	100
9	0	9	0	8	0	1	96.12	99.57
10	0	9	0	8	0	1	96.33	99.85
11	0	9	0	8	0	1	97.95	99.41

Figure 3 presents the Pareto graph of soybean oil biodiesel showing that the molar ratio effect, MR, the interaction between the catalyst and time (t*C), and the interaction between the molar ratio and catalyst (MR*C) were not significant, because these effects were on the left side of the p-value. This value was used as a tool to check the significance of each effect. Good conversion was obtained using the ethanol: soybean oil molar ratio of 6:1.

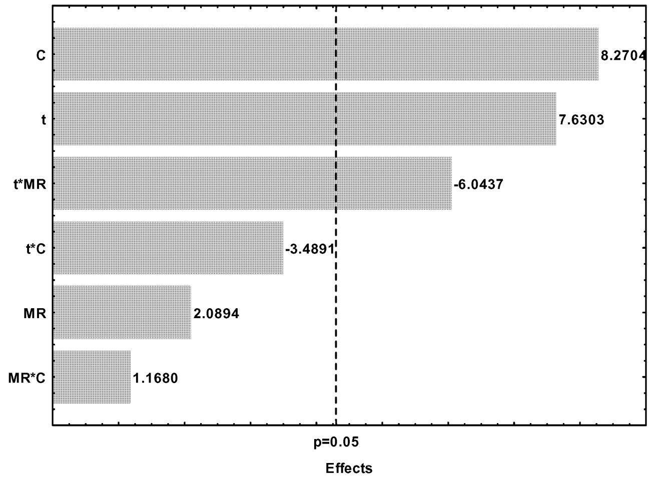

Figure 3: The Effects of the process variables on the soybean ethyl ester conversion

Figure 4 presents the Pareto graph of coconut oil biodiesel showing that the time effect, t, the interaction between the catalyst and time (t*C), and the interaction between the molar ratio and catalyst (t*MR) were not significant, because these effects were on the left side of the p-value. Good conversion was obtained using the ethanol: coconut oil molar ratio of 6:1.

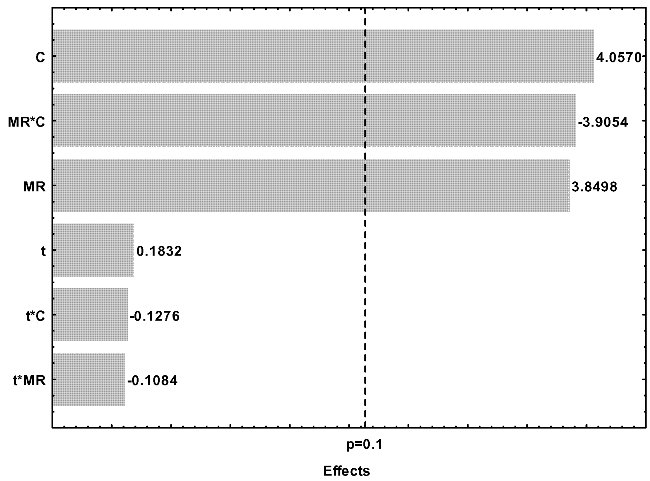

Figure 4:- The effects of the process variables on the coconut ethyl ester conversion

4. Conclusions

The results shows that a ethyl ester conversion greater than 99 wt.% can be obtained using soybean oil or coconut oil and ethanol quantity of 6:1. Both vegetable oil can be used to biodiesel production. This work presents the biodiesel production from multiple-stage ultra shear reactor. This equipment permitted the development of a fast process because the reaction takes place in the high - energetic shear zone of the mixer by reducing the droplet size of liquids with low miscibility (vegetable oil and ethanol).

5. References

Garnica J.A.G., Da Silva N.L. and Wolf Maciel M.R., 2009, Production and purification of biodiesel and glycerine, since vegetal oils and kinetic of vegetal oils transesterification reaction for wasted frying oil, Chemical Engineering Transactions 17, 433-438.

Gómez-Castro F.I., Rico-Ramírez V., Segovia-Hernández J.G. and Hernández-Castro S., 2010, Reducing costs and CO2 emissions on the production of biosiesel by the supercritical methanol method, Chemical Engineering Transactions 19, 143-149.

Ika Guide, 2010, www.ikaprocess.com/pdf/flyer-LaborPilot-e.pdf., accessed 22.02.2011

Ito T., Nakashimada Y., Senba K., Matsui T. and Nishio N., 2005, Hydrogen and Ethanol production from glycerol-containing wastes discharged after biodiesel manufacturing process, J. Biosci. Bioeng. 100, 260-265.

Li Q., Du W. and Liu D., 2008, Perspectives of microbial oils for biodiesel production, Appl.Microbiol. Biotechnol. 80, 749-756.

Ma F. and Hanna M.A., 1999, Biodiesel production: a review, Bioresource Technol. 70, 1-15.

Meher L.C., Sagar D.V. and Naik S.N., 2006, Technical aspects of biodiesel production by transesterification - a review, Renewable and Sustainable Energy Reviewer 10, 248-268.

Vyas A.P., Verma J.L. and Subrahmanyam N., 2010, A review on FAME production processes, Fuel 89, 1-9.