OPTIMIZATION IN THE PRODUCTION OF PALMA OIL BIODIESEL AND THE RELATIONSHIP BETWEEN THE MAIN VARIABLES

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ABSTRACT: The purpose of this paper was to analyze palm oil biodiesel production under different conditions and to verify the relationships between production variables to optimize biofuel production using response surface methodology (RSM). Biodiesel was produced through transesterification process by methyl route and alkali catalyst (NaOH) 1% (m/m). The analyzed variables were: four molar ratio (3:1, 4:1, 6:1 and 8:1); three temperature reaction (45, 52 and 60°C); and three time reaction (40, 60 and 80 minutes). For the palm oil biodiesel production, the highest yield was 93%, obtained by a molar rate 3:1, 52°C and 60 minutes. The results showed that the most influent factor in biodiesel production was molar rate.
KEYWORDS: methyl esters; biofuel, production efficiency.

OTIMIZAÇÃO NA PRODUÇÃO DE BIODIESEL DE ÓLEO DE PALMA E AS RELAÇÕES ENTRE AS VARIÁVEIS PRINCIPAIS

RESUMO: O objetivo deste trabalho foi analisar a produção de biodiesel de óleo de palma em diferentes condições e verificar as relações entre as variáveis de produção para otimizar a produção de biocombustíveis usando a metodologia de superfície de resposta (RSM). O biodiesel foi produzido através do processo de transesterificação pela rota metílica com catalisador alcalino (NaOH). As variáveis analisadas foram: quatro razões molares (3:1, 4:1, 6:1 e 8:1); três temperaturas de reação (45, 52 e 60°C); e três tempos de reação (40, 60 e 80 minutos). Para a produção de biodiesel de óleo de palma, o maior rendimento verificado foi o de 93% de produção, obtido por uma taxa molar de 3:1, temperatura de 52 °C e tempo de 60 minutos. Os resultados também indicaram que a variável de maior impacto na produção de biodiesel foi a taxa molar.
PALAVRAS-CHAVE: éster metílico, biocombustível, eficiência de produção

INTRODUÇÃO: In the last decades, the biodiesel has emerged as the main substitute for petroleum diesel, promoting the sustainable development through energy savings, low toxicity and low emission of polluting gases. Transesterification is a common technique used which involve the management of variables such as the molar ratio of alcohol:oil, temperature, time and catalyst amount. These variables are determinants for efficiency on biodiesel production. An alternative to analyse the production process efficiency is the response surface methodology (RSM). Optimization analysis methods improve the processes performance without increasing costs. The response surface methodology is a set of statistical and mathematical techniques used for the development, improvement and optimization of processes, in which the response is influenced by several variables and whose objective is to optimize the response (Khuri & Mukhopadhyay, 2010). Thus, this article was aimed to check the influence of production variables (molar ratio, temperature and time) in the biodiesel production process, showing the importance of this variable in optimization and efficient process for the production of renewable energy.

MATERIAL E MÉTODOS: For biodiesel production, palm oil and methanol were used by alkali transesterification reaction (NaOH). For the analyses of biodiesel production were used 3 temperatures (45, 52 and 60°C), 3 production times (40, 60 and 80 minutes) and 4 molar ratios of methanol: oil (3:1, 4:1, 6:1, 8:1). First, the quantities of palm oil, methanol and NaOH were weighed. After, the oil was heated in the corresponding treatment temperature (45°C, 52°C and 60°C) and then it was mixed with the methanol and NaOH mixture in the magnetic stirrer at the temperature and reaction time of the treatment. After the reaction time, the biodiesel was separated from the glycerol phase, washed with distilled water and hydrochloric acid, heated at 105°C and finally filtered. The mass yield production of each treatment was determined from the relation between biodiesel mass divided by oil mass. To elaborate the response surface, Matlab Software® was used. The response surface was obtained for variables molar ratio (x), reaction time (y), temperature (z), and yield (response), using linear interpolation method. Maximum yield was then obtained from the maximum value of the surface.

RESULTADOS E DISCUSSÃO: Using the 1H NMR technique, it was possible to determine whether the transesterification reaction of triglycerides in monoesters occurred directly. The result indicate the biodiesel from Palm 3:1 had conversion of 79.50%. The software used for statistical analysis was the SISVAR v. 5.6 with the Tukey test at 5% significance level ($P < 0.05$). Also, 108 samples were analyzed to estimate the effects in biodiesel production yield of the variables studied and their interactions (Table 1).

TABLE 1. Variance analysis of the effect in biodiesel production yield of variables and their interactions

Source	Degree of Freedom	Sum of squares	Mean of square	F-value	Pr > Fc
Molar ratio	3	0.2213	0.0738	313.528	0.0000
Temperature	2	0.0508	0.0254	107.849	0.0000
Time	2	0.0050	0.0025	10.592	0.0000
Molar ratio*Temperature	6	0.0233	0.0039	16.530	0.0000
Molar ratio*Time	6	0.0023	0.0004	1.653	0.1429
Temperature*Time	4	0.0051	0.0013	5.458	0.0000
Error	84	0.0198	0.0002		
Corr. Total	107	0.3277			
CV (%)	1.78				
Mean	0.8606				

All three variables studied and the interactions between molar ratio versus temperature and temperature versus time had a significant effect on biodiesel production yield. However, the interaction between molar ratio versus time did not present significant effects. The Figure 1 shows the temperature (a) and time(b) performance in the production of biodiesel from palm oil. It can be observed that the highest yield in biodiesel production (93%) was obtained in the 3:1 molar ratio with temperature of 52°C and stirring time of 60 minutes. The curves are quadratic regressions over mean yield and temperature (or time) for all sets of molar ratios experiments. For the other molar ratios, the yield was lower and decreasing as the molar ratio increased. The yield variation (temperatures and times) was lower at the 3:1 molar ratio.

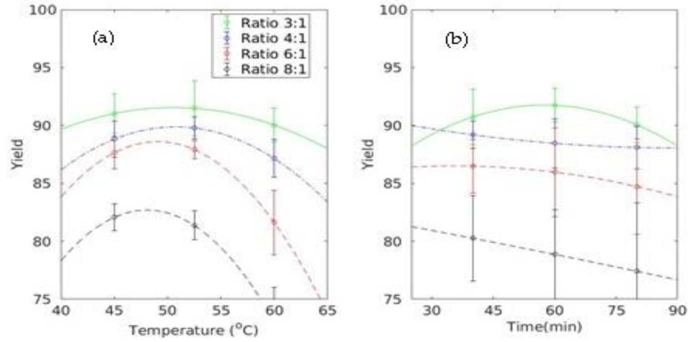

FIGURE 1. Average and standard deviation of experimental set for temperature (a) and time (b).

Feng et al (2017) indicate your work that higher temperatures correspond higther yield production. However, it is observed that the increase in temperature causes loss of reaction yield (Figure 1(a)). The Figure 1(b) shows that the yield showed a slight increase when the reaction time went from 40 to 60 minutes in the molar ratio of 3:1, however, the time increase from 60 to 80 minutes led to a reduction in the reaction yield. For the other molar ratios, the increase in reaction time resulted in decreased yield. These results differ from those of Roschat et al. (2018).The normalized distribution of production yields indicate that the lower molar ratios (3:1 and 4:1) present a higher density of values in the region of 85% to 90% yield, with emphasis on the molar ratio of 3:1, which showed greater density in the region of 90% to 95% of yield. At the highest molar ratios (6:1 and 8:1), the density of values was greater in the region of 85% to 90% yield for the 6:1 molar ratio (with a density lower than the 4:1 ratio), and in the region of 80% to 85% yield for the 8:1 molar ratio. The values for better performance of the 3:1 molar ratio were verified for the different reaction times studied. Figure 2 shows the effects of molar ratio, temperature and time over a response surface of palm oil biodiesel production yield.

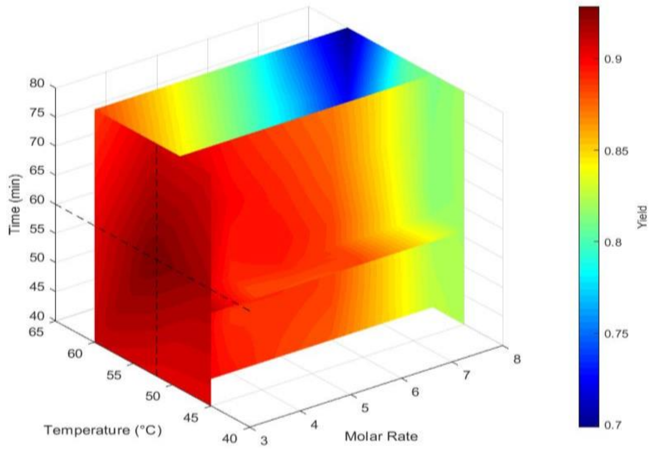

FIGURE 2. Response surface of biodiesel production yield for molar ratio, temperature and time.

A maximum yield response (dark red color) corresponds to molar ratio 3:1, temperature 52°C and time 60 minutes, whose yield is 93%. The response surface indicates that as molar ratio increases yield decreases, differing from the results observed by Feroldi (2014). Off the surface maximum, the yield decreases, especially for molar ratio 8:1 and 80 minutes (dark blue) resulting in yield of 70%. A possible cause of this effect is linked to reaction reversibility due to long reaction time, resulting in a methyl esters production decrease. Sukjit and Punsuvon (2013) determined with RSM the optimum conditions for palm oil biodiesel production at molar ratio 7:1, 60°C and 70 minutes for a proportion of 1.2% KOH catalyst resulting in a yield of 96.24%. The RSM is more reliable in predicting the nonlinear relationship between the processing variables and response. Alkabbashi et al. (2009) indicated the optimal conditions for biodiesel production with palm oil using methanol in the transesterification process were a reaction time of 60 minutes, temperature of 60°C, molar ratio 10:1 ($m.m^{-1}$) and a proportion of catalyst of 1.4% based on the oil mass, thus obtaining a yield of 93.6%. These results corroborate those obtained by Paula et al. (2017) that indicate a molar ratio of the reaction is 3:1 and although methanol is more toxic, it is more reactive and relatively cheaper than ethanol, requiring less reaction time and smaller molar proportions, justifying its use in biofuel plants that produce biodiesel.

CONCLUSÕES: Based on the used methodology and the found results, the molar ratio was the most influent variable in the production yield of palm oil biodiesel using alkali catalyst and methyl route. Through response methodology and variation of production factors (molar ratio, temperature and time), the highest yield was for molar ratio 3:1, 52°C and 60 minutes. The RSM can be used for production cost optimization. Due to the found in the technical literature, the response surface analyses can used for to search optimization on biodiesel production industrial process.

REFERÊNCIAS:

AHIEKPOR, J.C.; KUWORNOO, D.K. Kinetics of palm kernel oil and ethanol transesterification. **International Journal of Energy and Environment**, v.1, n.6, p. 1097–1108. 2010.

ALKABBASHI, A.N.; ALAM, Z.; MIRGHANI, M.E.S.; AL-FUSAIEL, A.M.A. Biodiesel production from crude palm oil by transesterification process. **Journal of Applied Science***s*, v.9, n.17, p. 3166–3170. 2009. Doi: doi.org/10.3923/jas.2009.3166.3170

FENG, Y.; QIU, T.; YANG, J.; LI, L.; WANG, X.; WANG, H. Transesterification of palm oil to biodiesel using Brønsted acidic ionic liquid as high-efficient and eco-friendly catalyst. **Chinese Journal of Chem. Eng.**, v. 25, p. 1222-1229. 2017. Doi: doi.org/10.1016/j.cjche.2017.06.027.

FEROLDI, M.; CREMONEZ, P.A.; ESTEVAM, A. Dendê: do cultivo da palma à produção de biodiesel.**Rev Monogr Ambient**, v.13,p.3800–3808.2014. doi: doi.org/10.5902/2236130814674

KHURI, A.I.; MUKHOPADHYAY, S. Response surface methodology. **WIREs Computational Statistics**, v.2, p. 128–149. 2010. Doi: doi.org/10.1002/wics.73.

PAULA, C.D.; BARROS, F.J.S.; CORREIA, L.M.; VIEIRA, R.S. Avaliação de catalisador a base de conchas de ostras para a produção de biodiesel utilizando planejamento fatorial. **Holos**, v.1, p. 316-324. 2017. Doi: doi.org/10.15628/holos.2017.5204.

ROSCHAT, W.; PHEWPHONGA, S.; KHUNCHALEEC, J.; MOONSINC, P. Biodiesel production by ethanolysis of palm oil using SrO as a basic heterogeneous catalyst. **Materials Today: Proceedings**, v. 5, p. 13916–13921. 2018. Doi: doi.org/10.1016/j.matpr.2018.02.040.

RUSCHEL, C. F. C.; FERRÃO, M. F.; SANTOS, F. P.; SAMIOS, D. Otimization of transesterification double step process (TDSP) to the production of biodiesel through doehlert experimental design. **Química Nova,** v.39, n.3, p. 267-272. 2016. Doi: doi.org/10.5935/0100-4042.20160018.

SUKJIT, T.; PUNSUVON, V. Process Optimization of Crude Palm Oil Biodiesel. **Eur Int J Sci Technol**, v. 2, p. 49–56. 2013.