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On the use of soybean oil to analyze the interaction effect of input process parameters on biodiesel yield using RSM approach

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ABSTRACT

The present research is on soybean oil for making the biodiesel from design of experiment approach using response surface methodology. The interaction effects of input process parameters on soybean biodiesel yield shows how biodiesel yield varies with one input parameter by remaining parameter remains stationary.

Keywords: RSM, soybean biodiesel yield, interaction effects, process parameters

INTRODUCTION

Trans-esterification process and statistical techniques are used for the production of biodiesels from various edible and non-edible oils (Anubhaya et al. 2013, Azcan & Danisman, A. 2007, Bouaid et al. 2007, El Boulifi et al. 2010, Hameed et al. 2009, Kaieda et al. 2001, Roy et al. 2013; Dhingra et al., 2013a; Dhingra et al., 2013b; Dhingra et al., 2014a; Dhingra et al., 2014b; Dhingra et al., 2014c; Dhingra et al., 2014d; Dhingra et al., 2015; Dhingra et al., 2016). Biodiesel production is highly influenced by the input process parameters such as type and amount of alcohol, catalyst concentration, reaction temperature, reaction temperature, reaction time, mixing speed etc.

Experimentation

This section concentrates on the main experimentation and analysis of its results in predicting the optimized trans-esterification process parameters for enhancing the biodiesel yield. To check the adequacy of the model and to predict non-linear regression analysis using ANOVA, Design Expert 6.0.8® software is used. The optimization is carried out using desirability approach. The biodiesel yield is measured by performing the experiment thrice at optimized combination of proposed process parameters for maximum value of desirability.

The effect of input process parameters on the soybean biodiesel yield has also been studied. The soybean biodiesel yield varies from 30 % to 90 % (by weight) at various combinations (22) of process parameters as shown in the seventh column of table 1.

Table 1: Average biodiesel yield of soybean oil based on actual process parameters using RSM design matrix

S. No.	EC	Rt	RT	CC	MS	SOYBY
1.	22.5	50	44	2	240	80
2.	22.5	30	56	2	240	90
3.	17.5	50	56	1	465	85
4.	22.5	50	56	1	240	45
5.	22.5	50	44	1	465	65
6.	22.5	30	44	2	465	75
7.	17.5	30	56	2	465	30

8.	17.5	50	44	2	465	75
9.	22.5	30	56	1	465	65
10.	17.5	50	56	2	240	75
11.	17.5	30	44	1	240	55
12.	15	40	50	1.5	350	65
13.	25	40	50	1.5	350	85
14.	20	20	50	1.5	350	75
15.	20	60	50	1.5	350	65
16.	20	40	40	1.5	350	85
17.	20	40	60	1.5	350	65
18.	20	40	50	0.5	350	75
19.	20	40	50	2.5	350	85
20.	20	40	50	1.5	150	75
21.	20	40	50	1.5	550	65
22.	20	40	50	1.5	350	

Legend: EC: Ethanol concentration (% by weight of oil), Rt: Reaction time in minutes, RT: Reaction temperature in ˚ C, CC: Catalyst concentration on % by weight of oil, MS: Mixing speed n rpm, SOYBY: Cottonseed biodiesel yield

Regression Analysis

The multiple regression analysis helps to create an equation 1 by the use of response surface methodology based on CCRD. The quadratic nature of equation shows there is somewhere optimum point exist at which maximum biodiesel yield is predicted.

SOYBY (wt. %) $= 866.8 - 9.74\times EC - 12.56\times Rt - 17.85\times RT + 2.9\times CC - 0.06\times MS - 0.25\times EC^2 + 4.23\times10^{-3}\times Rt^2 + 0.067\times RT^2 + 0.69\times CC^2 + 0.24\times EC\times Rt + 0.24\times EC\times RT - 1.78\times EC\times CC + 2.41\times10^{-3}\times EC\times MS + 0.11\times Rt\times RT + 0.34\times Rt\times CC + 3.21\times10^{-3}\times Rt\times MS + 1.18\times RT\times CC + 1.44\times10^{-3}\times RT\times MS - 0.09\times CC\times MS$ ...(1)

Optimization using desirability approach and confirmatory experiments

By analysing the coefficient of determination (R^2), the goodness of fit is checked. The value of R^2, adjusted R^2 and predicted R^2 closer to each other (near to 1) indicates that the response models are significant. Adequate precision is a measure of signal to noise ratio and value greater than 4 shows better precision and reliablility of the experiments. Standard deviation and coefficient of variation (C.V) are also observed to be in desirable range. The mathematical models for biodiesel yield of soybean oil as predicted by RSM are shown in equation 1. Each term of the biodiesel model has been checked for significant test (p- test). It has been observed that all f the above parameters are automatically predicted by the software and are found to be in desirable range (as shown in table 2). Hence the predicted model is found to be significant.

Table 2: Precision index values of regression model of soybean biodiesel produced

Model	**Precision index values**							
	R^2	**Adj. R^2**	**Pred. R^2**	**PRESS**	**Adeq. precision**	**Std. deviation**	**Mean**	**C.V**
Soybean	0.99	0.99	0.86	141.89	115.964	0.20	85.35	0.24

The predicted model is verified by performing the experiments thrice at recommended combination of trans-esterification process parameters (S. No. 1 of table 3). An average yield of 96 % (by weight) is observed against the predicted value of 98.84 % (by weight) and an error of 2.95 % is observed which is within the adequate limits. Thus it is concluded that the model is well fitted for predicting the maximum amount of soybean biodiesel.

Table 3: Optimum solution sets of trans-esterification process parameters of karanja oil using desirability approach

S. No.	**EC**	**Rt**	**RT**	**CC**	**MS**	**SOYY (Predicted)**	

1.	**17.5**	**30**	**45.00**	**1.25**	**270**	**98.84**	**Selected**
2.	14.86	47.01	52.27	0.578	194.25	91.03	
3.	13.8	42.95	55.6	0.62	208.14	90.572	
4.	15.29	20	51.58	0.64	155.65	89.8	
5.	15.12	56.17	57.03	0.5	407.67	88.88	
6.	15	46.79	55.21	0.66	289.6	86.1049	
7.	16.29	53.71	49.59	0.55	275.64	85.6	
8.	15	42.8	57.06	0.62	312.18	83.43	
9.	18.27	45.35	51.96	0.58	262.1	77.94	
10.	19.55	52.55	54.21	0.69	327.51	74.06	

The confirmatory experiments/tests have been conducted to verify the accuracy of the predicted models. The biodiesel is produced at the optimized process parameters as proposed by desirability approach. The experiments are performed thrice and the average value is taken as the actual biodiesel yield. The confirmatory experimental results of soybean biodiesel at optimized process parameters (as predicted by desirability approach) are shown in table 4. These results reveal that actual biodiesel yield is near to predicted values verifying the authenticity of the models.

Table 4: Confirmatory experiments/tests of soybean biodiesel

Type of oil	**Process parameters**					**Biodiesel yield (wt. %)**		**Error (%)**
	EC	**Rt**	**RT**	**CC**	**MS**	**Predicted**	**Actual**	
Soybean	17.5	30	45	1.25	270	98.84	96	+2.95

CONCLUSION

(i) The regression model is found to be quadratic in nature.

(ii) The statistical parameters are in desirable ranges (as shown in table 2)

(iii) The biodiesel yield of 96 % (by weight) is obtained for soybean oil using RSM technique. The optimized process parameters are shown in table 4.

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