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Optimization of Biodiesel Synthesis using Heterogeneous Catalyst (SiO_2) from Karanja Oil by Taguchi Method

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Abstract: ***Biodiesel is renewable and environmental friendly fuel which has the capable to gain comparable engine performance. In this experimental study, Karanja oil synthesized by using Transesterification process. Transesterification of Karanja oil to biodiesel using SiO_2 as a heterogeneous catalyst is studied using five different parameters and levels each. Minitab is used to fix the orthogonal arrays and Taguchi method is used to analyze the interaction effect for the transesterification reaction. The five different parameters responsible for biodiesel yield are molar ratio of methanol to oil, catalyst concentration, reaction temperature, reaction time and stirring speed. Effect of these parameters has studied on small scale. The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.***

Index Terms -Transesterification, Biodiesel, SiO_2, Heterogeneous catalyst,

I. INTRODUCTION

The world today is getting evolved and needs are growing day by day about everything. The nature has a fixed stock of natural resources but human population is increasing at a tremendous rate. In various zones diesel fuels are utilized and have contribution for the economy of the nations. Due to the rise in environmental consciousness and decrease of petroleum reserves, there is needed to use of alternative fuels [3]. Because of increase in Global warming and more requirements of energy huge research and development is going on for renewable energies [3]. The properties like non-toxic, degradability, less carbon monoxide emission, particulate matter and unburned hydrocarbons, the biodiesel has gained an international focus as an alternative to diesel fuel [3]. The conventional compression engine does not require any modification to use the biodiesel as fuel. The yields of Karanja oil biodiesel were obtained by 25 different sets of different experimental conditions and noted.

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All experiments were performed as per array obtained by Taguchi method under the different experimental conditions as mentioned here. The analysis of the results has done by Taguchi method using Minitab for optimization of input parameters. The different graphs have plotted here from results obtained during the analysis. The optimum conditions For different input parameters have identified for maximum yield of biodiesel production from Karanja oil using Heterogeneous catalyst.

II. OPERATING CONDITIONS

There the Transesterification process for biodiesel production from Karanja oil using heterogeneous catalyst.

Effect of different input parameters have studied as follows.

1) Variation of Molar Ratio in reaction.
2) Effect of amount of catalyst.
3) Effect of temperature on reaction.
4) Effect of stirring speed on reaction.
5) Effect of reaction time of reaction

The range of operating conditions for each parameter have as follows.

Table 1. Optimizing parameter conditions

A:Molar Ratio %	B: Catalyst %	C: Reaction Temp. ºC	D:Reaction Time	E: Reaction Speed
A1 = 5	B1 = 1.5	C1 = 55 ºC	D1 = 60 min.	E1 = 300rpm
A2 = 10	B2 = 2.0	C2 = 60 ºC	D2 = 90 min.	E2 = 400 rpm
A3 = 15	B3 = 2.5	C3 = 65 ºC	D3 = 120 min.	E3 = 500 rpm
A4 = 20	B4 = 3.0	C4 = 67 ºC	D4 = 150 min.	E4 = 600 rpm
A5 = 25	B5 = 3.5	C5 = 70 ºC	D5 = 180 min.	E5 = 700 rpm

III. EXPERIMENTAL RESULTS SIO2 AS A CATALYST

Initially the esterification process is done, the color of Karanja oil after esterification changed from deep brown to reddish yellow. The transesterification process produces methyl ester (Karanja oil biodiesel) and glycerol form upper and lower layers respectively. Due to more density of glycerin, it was settled at bottom. The catalysts and unused methanol were in the lower glycerol layer. The results shown that, using SiO_2 catalyst the biodiesel production is a considerable potential .

Twenty-five experiments for transesterification process were conducted using Karanja oil with methanol under different conditions of reactions to produce biodiesel. Input parameters and % of yields were noted. Sample readings are given below.

Taguchi Design
Design details

Array obtained by Taguchi Method L25 (5^5)
Factors: Five numbers
Runs: Twenty five
Columns of L25 (5^6) array: 1 2 3 4 5

Molar ratio	Catalyst %	Reaction temp	Reaction time	Reaction speed	Yield %	SNRA1	SRES
5	1.5	55	60	300	50	33.9794	-0.06531
5	2	60	90	400	52	34.3201	-1.24764
10	3.5	55	90	500	72	37.1466	1.83866
15	3	55	120	700	68	36.6502	-0.5516
15	3.5	60	150	300	73	37.2665	0.16741
20	2.5	55	150	400	67	36.5215	-0.94569
20	3	60	180	500	77	37.7298	1.62962
20	3.5	65	60	600	74	37.3846	-0.4575
25	1.5	70	150	500	68	36.6502	0.85144

In above table the row which is highlited by yellow colour gives the optimal values of input parameters for maximum biodiesel yield because of high value of SN ratio. The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.

TAGUCHI ANALYSIS WITH SiO_2 CATALYST

Taguchi Analysis: yield % versus Molar Ratio %, Catalyst ... reaction Speed
Response Table for Signal to Noise Ratios
Larger is better

Table 3.Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %	Reaction Temp.ºC	Reaction Time	Reaction Speed
1	35.18	35.34	36.24	36.17	36.26
2	36.06	35.75	36.31	36.24	36.06
3	36.39	36.42	36.20	36.13	36.50
4	36.72	36.80	36.12	36.31	36.35
5	37.12	37.17	36.60	36.62	36.31
Delta	1.93	1.82	0.47	0.49	0.44
Rank	1	2	4	3	5

Main Effects on yield by SN ratio for Individual Parameter: For examine differences between level for one or more factors the main effect plot is used. The graphs shows the response mean for each factor level. [1]

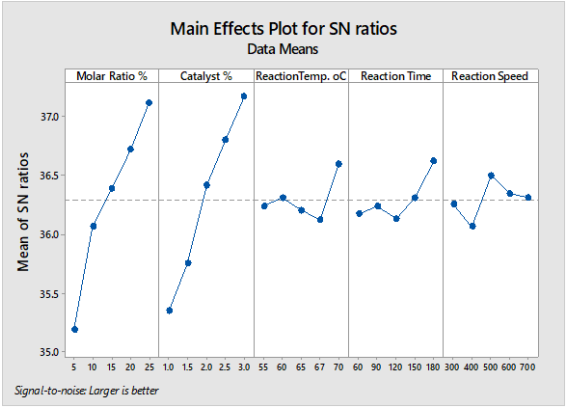

Fig. 1.Main Effects Plot for SN ratios

This figure shows that, the two graphs are steeper than others. First is the mean of S/N ratios vs molar ratio and second is the mean of S/N ratios vs. catalyst%. So, it is concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %. The effects of other three parameters can be neglected

IV. INTERACTION PLOT FOR PARAMETER A AND B (FOR MOLAR RATIO AND CATALYST %):

Analysis by Taguchi : % yield vs Molar Ratio, Catalyst %
Response Table for Signal to Noise Ratios
Larger is better

Table 4. Response Table for Signal to Noise Ratios

Level	Molar Ratio %	Catalyst %
1	35.18	35.34
2	36.06	35.75
3	36.39	36.42
4	36.72	36.80
5	37.12	37.17
Delta	1.93	1.82
Rank	1	2

Interaction Plot for SN ratios: Main effects were generally focused by Taguchi method, but suspected interactions are important to test. To measure whether the effect of one factor on response characteristic depends on the level of other the interaction plot is used. [1]

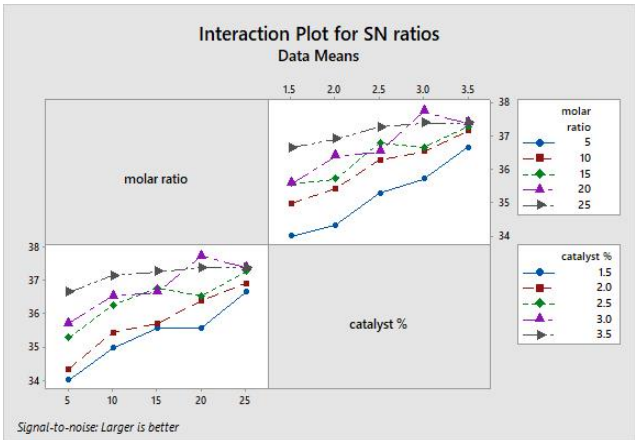

Fig.2. Interaction Plot for parameter A and B (For molar ratio and Catalyst %)

Simultaneously the interaction plots shows, the variation of yield with effect of molar ratio and catalysts are as shown in figure. This shows that the yield has maximum value for 20 % molar ratio and catalyst 3%.

V. REGRESSION ANALYSIS FOR SIO_2

Regression Analysis: yield % versus Molar Ratio %, ... , Reaction Speed Analysis of Variance.

Table 5. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	1165.96	233.191	42.00	0.000
Molar Ratio %	1	544.50	544.500	98.08	0.000
Catalyst %	1	598.58	598.580	107.82	0.000
Reaction Temp. oC	1	1.66	1.657	0.30	0.591
Reaction Time	1	19.22	19.220	3.46	0.078
Reaction Speed	1	2.00	2.000	0.36	0.555
Error	19	105.48	5.552		
Total	24	1271.44			

Model Summary: R square value in model summary provides the measure of, how perfect the model is fitting with the actual data. R square value 91.70% shows that the obtained model is fitted to actual data.

Table 6. Summary of Model

S	R-sq	R-sq(adj)	R-sq(pred)
2.35622	91.70%	89.52%	86.30%

Regression Equation: It is a statistical model that determine the specific relationship between the input and output parameters. It gives the outcome with a relatively small amount of error.

yield % =35.39 + 0.6600 A + 6.920 B + 0.0484 C + 0.0207 D + 0.00200 E

Residuals Normal plot for Yield %: Graphical tool for comparing a data set with the normal distribution is the normal probability plot. The data fit in the normal probability distribution is shown by a straight line in this plot. All residuals obtained are almost along the line and very low residual values .

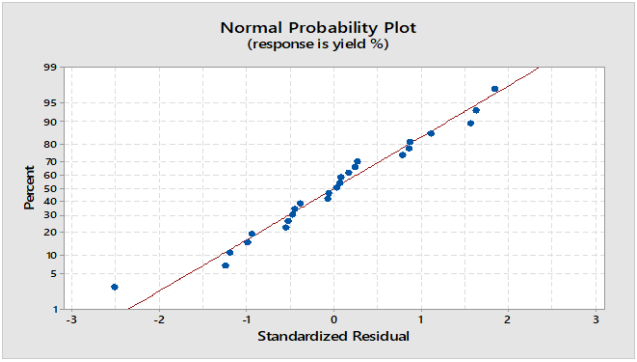

Fig.3. Normal Probability plot

VI. CONCLUSION

The analysis of optimizing the transesterification process has been carried out by Taguchi method for production of biodiesel from Karanja oil [1].

The different input parameters as in above table have been optimized using SNR , The conclusion are as follows;

1) The biodiesel yield obtained experimentally at optimum conditions are 20% methanol to oil molar ratio, 3% SiO2 catalyst addition, 65ºC reaction temperature, 180 min reaction time and 500 rpm stirring speed is 77%.

2) Main effective plot has concluded that the two parameters affecting the yield mainly are the molar ratio and catalyst %.

3) The interaction plot shows that the yield has maximum value for 20 % molar ratio and catalyst 3%.

4) R square value 91.70% shows that the obtained model is fitted to actual data.

5) The data fit in the normal probability distribution is shown by a straight line. All residuals obtained are almost along the line and very low residual values.

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