PARAMETER DESIGN FOR OPTIMUM PERCENTAGE YIELD FOR BIO-DIESEL FROM LINSEEDSEED USING DOE (TAGUCHI TECHNIQUE)

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Abstract: *The use of renewable energy is the prime resolution for global warming, globalization and industrialization. Basically, biodiesel is less pollutant and biodegradable. It can be used as alternative fuel in engine with less modification. Biodiesel is a renewable, non-polluting fuel formed mainly from vegetable oils and fats. Chemically, it is known as free fatty acid methyl ester (FAME). It can be used in normal diesel engines. It has all the ecological benefits over the mineral diesel, as it neither pollutes nor adds to the global warming. The objective of this study was to investigate optimized setting for the maximum production of biodiesel from linseed oil. In the current research work biodiesel is generated from linseed oil by performing transesterifiation. Trans-esterification process is applied to reduce poly-unsaturation of the oil [1]. This process was optimized by involving Taguchi Method. The effect of Molar Ratio of methanol to triglyceride, Reaction Temperature, Reaction time and Catalyst Concentration were investigated experimentally. The optimal condition for yield of biodiesel was found to be Molar ratio 6:1, reaction temperature 60˚C, reaction time 60 minute and Catalyst Concentration 1%. The optimized condition was validated with the actual Biodiesel yield of 95 %. The calculation of ANOVA was performed on Minitab 16.*

Keywords: Biodiesel, linseed oil, Global warming, Taguchi Methodology, Tran's esterification etc.

1. INTRODUCTION

The excess use of fossil fuel causes to various environmental issues and depletion in the ozone layer [1]. The consumption of fossil fuels (like petrol and diesel) has been grown tremendously in transport section and industries. These two sectors are very necessary for economic development of any country. It is truth that the demand of fuel is increasing day by day. This leads to the depletion of petroleum products in nearby future. Petroleum products emit harmful emissions like CO, NOx, CH_4 and CFC which causes ozone layer depletion. The rise in price of petroleum products and harmful impact on human health leads to intensive studies on alternative fuels. The biodiesel has higher cetane number as compare to the diesel. It has greater lubricity and superior detergency. The flash point is also higher in case of biodiesels. Biodiesel is produced from renewable materials such as leaves, palm oil and cotton oil etc. Bio-diesel is an ideal synergistic partner for oxidation catalytic converter. Bio-fuels reduce Carbon Di-oxide (CO_2) emissions by 78 per cent when compared to conventional diesel fuel. Bio-diesel is an oxygenated fuel with oxygen (O_2) content of about 10 percent and therefore gives better emission characteristics in term of carbon mono oxide (CO), Hydrocarbons, Particulate matter. Also, Bio-diesel has a higher Cetane number (CN), ensuring low noise and smooth running, during engine combustion. Furthermore, the by-product resulting after extracting bio fuel is an excellent source of nitrogen rich organic fertilizer. The amount of particulate materials in biodiesel is very least. In this regard, **S.K Padhi and R.K Singh [6]** produced biodiesel from Mahua oil by esterification followed by trans-esterification. Kinetic studies to optimize the preparation of Mahua Oil Methyl Ester (MOME) were carried out by varying different parameters like methanol / oil molar ratio, % of excess alcohol, reaction time, temperature and concentration of acid catalyst. **Prakash C. Jena et al [9]** deliberated a proper process comprising acid pretreatment followed by main base trans-esterification reaction was developed to produce biodiesel from mixture of Mahua and Simarouba oils with high free fatty acids (FFA).

2. MATERIAL AND METHODOLOGY

2.1 MATERIAL

The linseed is purchased from market and stored at room temperature. The methanol used in this process in methanol. The catalyst used in this research is NaOH. The trans-esterification process is chemical reaction between biodiesel and alcohol in the presence of catalyst. The catalyst is basically used to increase the rate of reaction. This process leads to the formation of biodiesel and glycerol. The process of conversion of triglyceride and alcohol in the presence of catalyst into monoglyceride and glycerol is called trans-esterification [4]. Glycerol is the byproduct of this conversion process. Trans-esterification process is very sensitive the molar ratio of methanol to biodiesel, reaction temperature, reaction time and catalyst concentration. Trans-esterification process is used to reduce the viscosity and density of biodiesel [7, 8].

2.2 Production of biodiesel from experiment

Steps involved in production of biodiesel are explained here. A sample of biodiesel (100 g) is taken in first beaker and heated up to 100^0C. This heating process helps to reduce the moisture contents present in biodiesel. Take another beaker and put methanol in it. Then add catalyst in it. Mix the solution of raw oil with methanol and put it on mechanical stirrer machine for predefined time. Store the solution in separating funnel for 3 hours to settle down. Separate glycerol from biodiesel. Then water washing of biodiesel is done. Again the solution heated to remove moisture contents present in biodiesel [10, 11 and 12]. By repeating the steps for particular setting given by Taguchi method reduce the chances of errors in experiments. The experiment procedure for the production of biodiesel from linseed oil is shown in figure1 [2, 3 and 5].

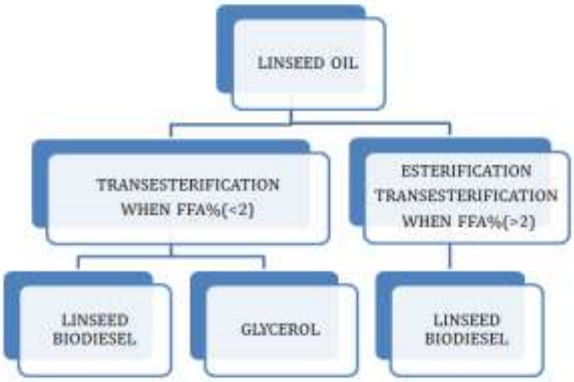

Figure 1: The production process of biodiesel from Linseed oil

3. DESIGN AND ANALYSIS OF EXPERIMENT

3.1 Design of experiment

The parameters involved in experiment are shown in table1.

Table 1: EXPERIMENTAL PARAMETERS AND LEVELS

Parameters	Level 1	Level 2	Level 3
Molar Ratio[A]	6.0:1	4.5:1	3.0:1
Reaction Temperature (^{0}C) [B]	40	50	60
Reaction Time (min) [C]	30	45	60
Catalyst Concentration (%) [D]	0.5	0.75	1

The various parameters that are affecting the yield of biodiesel are characterized in their respective levels also. Taguchi method is used to reduce the number of experiments, time and cost. It helps to achieve the optimum setting for maximum yield. The setting for four factors is done by L9 orthogonal array and it is revealed in table2. In the Taguchi method, firstly all the factors affecting the performances are collected. There are some noise factors also. By seeing the orthogonal array, the experiment is conducted. After that ANOVA on obtained observation is performed. Then validation of experiments is conducted.

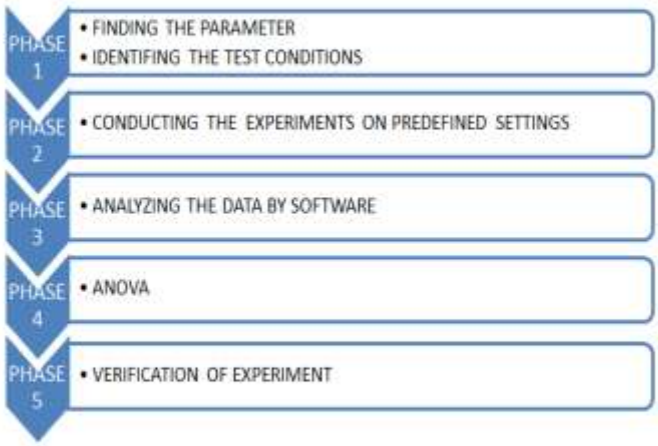

Figure 2: Pictorial depiction of steps involved in Taguchi Method

Table 2: LAYOUT OF L_9 ORTHOGONAL ARRAY

Exp. No.	Levels of Molar Ratio	Levels of Reaction Temperature	Levels of Reaction Time	Levels of Catalyst Concentration
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 3: Plan for the Experiments in terms of Parameters and the Levels

Exp. No.	Molar Ratio	Reaction Temperature	Reaction Time	Catalyst Concentration
1	6:1	40	30	0.5
2	6:1	50	45	0.75
3	6:1	60	60	1
4	4.5:1	40	45	1
5	4.5:1	50	60	0.5
6	4.5:1	60	30	0.75
7	3:1	40	60	0.75
8	3:1	50	30	1
9	3:1	60	45	0.5

The records are collected from experiments setting is presented in Table 4. It is the percentage of biodiesel produced. It is calculated by dividing the biodiesel produced to the raw oil taken at beginning of experiment.

@ Here E stands for Experimental Observation

Table 4: Details of Percentage Yield at each Experimental Setting

Exp. No.	E1	E2	E3	E4	E5	E6
1	88.36	89.5	86.32	84.71	86.21	87.24
2	94.25	95.60	94.90	90.12	95.41	92.63
3	95.10	96.20	93.79	92.98	96.78	96.76

4	80.64	82.31	83.41	80.10	82.31	84.24
5	91.61	90.62	92.72	89.21	90.31	90.71
6	92.25	90.41	92.93	93.41	89.72	91.24
7	91.53	89.25	90.92	88.72	89.79	86.93
8	88.32	89.40	86.35	84.24	90.02	91.43
9	90.10	91.32	86.25	88.21	87.71	86.42

The S/N ratio is discussed by Taguchi. The Signal to Noise ratio is derived from the Taguchi loss function. There are three types of S/N ratio.

1. Largest the best one
2. Smaller the best one
3. Nominal is the best

Here the purpose is to maximize the yield of biodiesel, so the first one is applied here. The formula for S/N ratio for this process is shown by equation1.

$$\eta = -10 \log_{10}\begin{pmatrix}\text{Mean sum of square of resiprocal} \\ \text{of the measured data}\end{pmatrix} \quad (1)$$

The average of the observations at every experimental settings and their respective S/N ratio is presented in table5.

Table 5: Average of Percentage yield and S/N ratio of each Experimental Setting

Exp. No.	Average Percentage yield	S/N Ratio
1	87.06	38.79
2	93.82	39.44
3	95.27	39.57
4	82.17	38.29
5	90.86	39.16
6	91.69	39.24
7	89.52	39.04
8	88.29	38.91
9	88.33	38.92

The effect of a factor at each level is deviation it causes from the overall mean. The overall mean value of η is denoted by m and it is calculated as follows,

$$m = \frac{1}{9}\sum_{i=1}^{9} n_i = \frac{1}{9}(n_1 + n_2 + n_3 + \cdots + n_9) \quad (2)$$

Here, m= 39.04

The effect of the molar ratio at level A1 (at experiments 1, 2 and 3) is calculated as the difference of the average S/N ratio for these experiments (mA1) and the overall mean.

The effect of molar ratio at level 1

$$A_1 = m_{A1} - m = \frac{1}{3}(n_1 + n_2 + n_3) - m$$

The effect of molar ratio at level 2

$$A_2 = m_{A2} - m = \frac{1}{3}(n_4 + n_5 + n_6) - m$$

The effect of molar ratio at level 3

$$A_3 = m_{A3} - m = \frac{1}{3}(n_7 + n_8 + n_9) - m$$

The percentage yield is obtained by equation3. The experimental result is shown with the help of preservative model by equation4.

$$\% \, Yield = \sqrt{10^{\frac{\eta}{10}}} \quad (3)$$

$$\eta(A_x, B_y, C_z, D_t) = m + a_x + b_y + c_z + d_t + e \quad (4)$$

Here, m indicates the overall mean $of\,\eta$ whereas the terms a_x, b_y, c_z and d_t show the deviations from absolute value caused by the setting A_i, B_j, C_k, and D_l of factors A, B, C and D, respectively. Here e indicates the error.

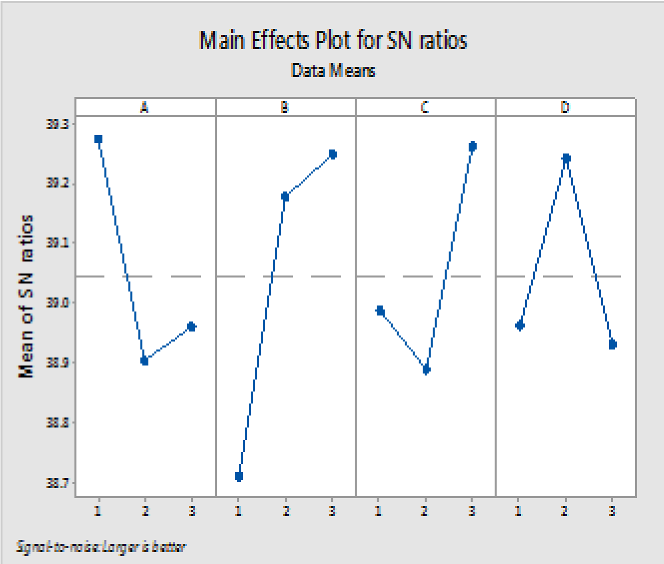

Figure 3: Main effects plot for S/N ratio

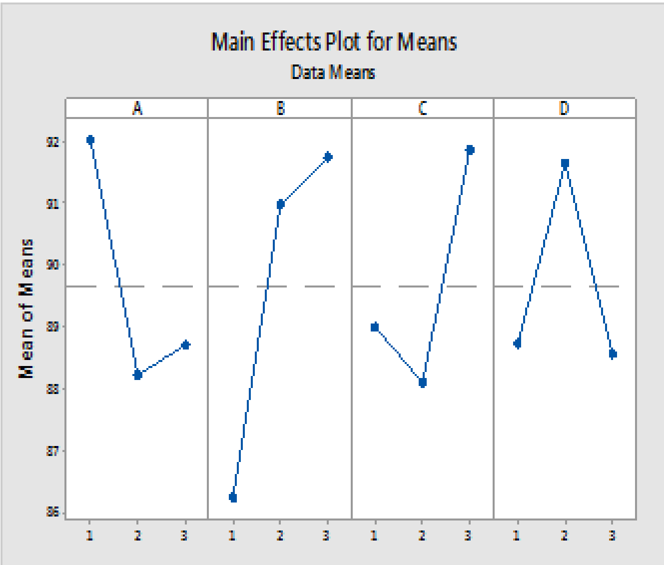

Figure 4: Main effects plot for Means

The main effects plot of S/N ratio is showing that factor (A) is more effective at level 1, factor (B) is more effective at level 3, factor (C) is more effective at level 3 and factor (D) is more effective at level 2.

3.2 ANALYSIS OF VARIANCE (ANOVA)

The ANOVA is performed on the basis of S/N ratio. ANOVA helps to give the percentage contribution of each factor. Here the factors (Molar ratio, Reaction time, Reaction temperature and Catalyst concentration) are affecting the yield of biodiesel from linseed oil. Computation of mean sum of square is done by dividing total sum of squares of each factor by degree of freedom for that respective factor. ANOVA has been performed by Minitab16.

Here, mean sum of square is shown by MS.

Degrees of freedom for:

• Total =N - 1.

• Factor = Number of levels of that factor - 1.

•Error = (N-1) - sum of the degrees of freedom for the various factors.

Table 6: ANOVA

Factors	DOF	Sum of Square	MS	Contribution (%)
Molar Ratio	2	0.2391	0.1183	20.58
Reaction Temperature	2	0.5141	0.2532	44.280
Reaction Time	2	0.22861	0.1112	19.690
Catalyst Concentration	2	0.173	0.059	15.44
Error	0	0.0	—	—
Total	8	1.1617	—	—

3.3 DISCUSSION ON ANOVA

The result of the ANOVA is explained in this section. By watching at the Table 6, one can conclude that the Reaction temperature largely contribute in the variation in S/N ratio for the percentage yield. However, the other factors (Molar ratio, Reaction time and Catalyst concentration) are contributing less in the variation in S/N ratio.

4. CONCLUSION

Yield with different parameters clearly indicate that optimum conditions in this biodiesel production are: oil to alcohol molar ratio 6:1, reaction temperature 60˚C, and reaction time 60 min and Catalyst Concentration 1%. At these conditions, the conversion yield was found maximum (95%). The ANOVA table also depicts the higher contribution of parameters in affecting yield. So, effect of reaction temperature on the conversion yield is greater than the effects of other parameters.

5. SCOPE IN FORTHCOMING WORK

Here the optimization of experiments is performed by Taguchi Methodology. However Factorial Design, Grey relational analysis and Response surface method also may be used to get maximum yield.

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REFERENCES

1. S. Jaichandar and K. Annamalai,"The status of Biodiesel as an Alternative Fuel for diesel engine", Journal of Sustainable Energy and Environment, 2011; 2, pp.71-75.

2. Rasha, A. R., Isam, J., and Chaouki, G., 2012, "Transesterification of Biodiesel: Process Optimization and Combustion Performance", Int. J. of Thermal & Environmental Engineering, Vol. 4, No. 2, pp. 129-136.

3. Saeikh, Z. H. and Madhu, V., 2014, "Parametric effects on kinetics of esterification for biodiesel production: A Taguchi approach", Chemical Engineering Science, Vol. 110, pp. 94–104.

4. Mustafa Balat, Havva Balat, 24 March 2008 "A critical review of bio-diesel as a vehicular fuel" Energy Conversion and Management 49, Page 2727–2741,.

5. Vineet Kumar, Manish Jain, Amit Pal, An experimental study on biodiesel production from cotton seed oil through conventional method, International Journal of Engineering Technology, Management and Applied Sciences (2014), Volume 2 Issue 7, ISSN 2349-4476

6. S.K. Padhi, R.K Singh. "Optimization of esterification and transesterification of Mahua (Madhuca Indica) oil for production of biodiesel", J. Chem. Pharm. Res., 2010, 2(5):599-608
7. Ayhan Demirbas, "Progress and recent trends in biodiesel fuels", Progress in Energy and Combustion Science, 2007; 33, pp. 1-16.

8. Jon Van Gerpen, Biodiesel processing and production, Elsevier Fuel Processing Technology 86 (2005) 1097– 1107

9. Prakash C. Jena, Hifjur Raheman, G.V. Prasanna Kumar, Rajendra Machavaram, Biodiesel production from mixture of mahua and simarouba oils with high free fatty acids , Elsevier, Biomass and Bio energy,34(2010)1108-1116.

10. Shashikant Vilas Ghadge, Hifjur Raheman, "Process optimization for biodiesel production from mahua (Madhuca indica) oil using response surface methodology". Bioresource Technology 2006; 97: 379–384

11. Anh N. Phan and Tan M. Phan, "Biodiesel production from waste cooking oils", Fuel, 2008; 87, pp. 3490–3496.

12. J. Van Gerpen, B. Shanks, and R. Pruszko, "Biodiesel Production Technology" National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401-3393, 303-275-3000.