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

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Abstract: *This is truth that one world has to stop using fossil fuels. So many researchers are trying their best to produce biodiesels from various sources. Biodiesel are basically a chain of fatty acid methyl ester. This paper is based on production of biodiesel from cotton seed oil. For this purpose, trans-esterification of cotton oil is done with methanol. This process was optimized by relating Taguchi Method. The additive model was obtained to predict the yield of biodiesel as a function of Molar Ratio, Reaction Temperature, Reaction time and Catalyst Concentration. 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, cotton seed oil, Parameter Design, Taguchi Methodology, Tran's esterification etc.

INTRODUCTION

Diesel fuel is base of the economy of the country because it is used in various fields. It is used in transportation, railroad, agricultural works and construction equipment. Fossil fuels have different types of hydrocarbons (toluene and xylenes), sulphur and aromatics rings. In recent times, there has been a growing alarm about the increasing air pollution originated by the combustion of petro diesel. In addition, diminishing resources of conventional fuels has triggered intensification in its price [5]. Biodiesel is a renewable fuel which can be used as either direct substitute, extender or as an additive to fossil diesel fuel in compression ignition engines. The most promising feature of biodiesel is that it can be utilized in existing design of diesel engine with very little modifications. Biodiesel contain 10% oxygen by weight [13]. Biodiesel enhances the combustion efficiency and emission characteristics. Generally the scientist prefers the biodiesel for alternate fuel as it is biodegradable, renewable and non-toxic. It produces less particulate. It has higher cetin number than simple diesel. And also it fulfills the rising demand of the world. Biodiesel is derived from vegetable oil and animal fats using trasnesterification [1]. The oil is reacted with alcohol. The process of producing biodiesel from the vegetable oil using alcohols in the presence of catalyst (such as NaOH and KOH) is called trasnesterification. Alcohol breaks molecule of triglycerides into alkyl esters [9]. The reaction needs heat and a strong catalyst to complete the conversion of oil into the chain of esters and glycerin. The by-product of this conversion is glycerine. Generally there are various types of alcohols used for trans-esterification. Various researches had done to produce high yield of biodiesel by various method based on optimized parameters in terms of

Molar Ratio, Reaction Temperatures, Time and Catalyst Concentration. In this study, Taguchi Methodology was applied to optimize the process with methanol in the presence of sodium hydroxide to produce biodiesel with the highest yield. **Anh N. Phan et al** [10] produced biodiesel from waste cooking oils by alkali catalyzed trans-esterification. The results demonstrated that the biodiesel experienced a higher but much narrower boiling range than conventional diesel. **J. C. Thompson et al. [11]** debated the characterization of crude glycerol obtained from different seed oil feed stocks of mustard, rapeseed, canola, soybean and waste cooking oils. Batch processes of biodiesel production were used as the means of crude glycerol preparation using unrefined vegetable oils, methanol, and sodium methylate as the catalyst. After departure from biodiesel, the crude glycerol from each of the oils was analyzed using ASTM and other standard test methods. Elemental impurities, nutritional value, and other chemical properties were tested. **M. Canakci, J. Van Gerpen [12]** investigated the use of low–cost, high FFA feed stocks to produce fuel–quality biodiesel.

2. MATERIAL AND METHODOLOGY

2.1 MATERIAL

The cotton is basically a member of Malvacea. This work considers the optimization of percentage yield of bio-diesel derived from cottonseed oil by parameter setting. The cotton seed is crushed then biodiesel is produced by suitable technique. Generally cotton seed oil has oleic acid (15-20%) and linoleic acid (49-58%) [13].

The cotton seed oil has higher density than diesel [14]. The flash point play very important role in case of combustion of any fuel. Flash point for cotton seed oil (207 °C) is really much higher than that of diesel. Also, it contains less percentage amount of ash and sulphur content. The cetane number is volume percent of n-hexadecane in the blend of n-hexadecane and 1-methylnaphthalene [11, 12].

In trans-esterification process, triglyceride is ultimately converted into methyl or ethyl ester of oil, which is named as biodiesel. Triglycerides are esters of saturated and unsaturated monocarboxylic acids which found in common feedstock oils along with trihydric alcohol glyceride. Triglyceride reacts with alcohol in presence of the catalyst and converts into diglyceride and then into monoglyceride into consecutive processes. The chemical reaction is shown as follows [5]:

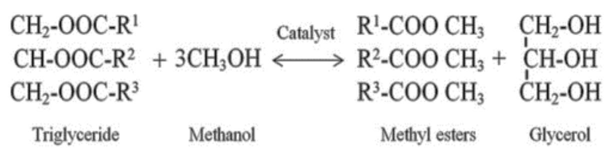

Figure 1: The trasnesterification process

The major factors that dictate the percentage yield are: reaction temperature, reaction time, reaction temperature and the concentration of the catalyst. In the present experiment, a sample of 100 g cotton oil is first taken in a stainless steel container and heated up to 100^0C by putting the container onto a hot plate, in order to remove moisture contents from the oil. The weighting is done by weighting machine as shown in figure 2. After this, the Cottonseed oil is allowed to cool up to a pre-decided temperature. Taking methanol (11

g) in another beaker and add KOH (0.5%), put it on mechanical stirring machine for 30 minutes. Mix the oil with methanol solution. Thereafter, the container is put on a steering machine where the Cottonseed oil is steered at controlled speed and temperature for stipulated time. When steering is over, the raw bio-diesel is separated by means of gravity. The steering machine used in this work can be viewed in Figure 3. This machine is equipped with temperature and speed controlling mechanism. Normally, in the process of production of bio-diesel, first, the cottonseed oil is mixed with the suitable catalyst and then steered at particular temperature and rpm up to certain time. Repeat the steps for specified settings given by Taguchi Method.

Figure 2: The weighting machine

Figure 3: The steering machine used in this work

The bio-diesel is obtained from this raw bio-diesel after its washing with distilled water. The separation and purification process can be visualized in Figure 4 and 5. The experiments have been conducted considering the parameters and methodology mentioned before and the details of the design of experiment are presented in the next section 3.

Figure 4: The Snap Shot of Separation Process

Figure 5: The Snap Shot of biodiesel after Purification Process

3. DESIGN AND ANALYSIS OF EXPERIMENT

3.1 Design of experiment

In order to find the parameters setting at which yield attains its maximum value, Taguchi methodology has been used in this work. Here, the four parameters at three levels have been considered. The levels have been chosen after conducting many trial Experiments [6, 7]. The details of the factors and their levels taken into the consideration are presented in the Table 1.

The experiments are designed taking the L_9 orthogonal arrays as has been proposed by the Taguchi. The plan for the experiments in terms of level indicator and in terms of value of levels of the experiment is presented in the Table below. Taguchi has visualized how the statistical design of experiments using orthogonal array can help the experimenters in evaluation of parameters setting for finding optimum objective. His approach is primarily put focus on determining the optimal factor settings of a process and thereby achieving improved process eliminating the variability caused by uncontrollable/noise variables. Basically, finding of parameters setting leads to robust design. Taguchi gave the way to increase the production in lesser time and at low cost [4, 9].

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

Table 1: PARAMETER AND LEVELS

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 2: Plan for the Experiments in terms of Level Indicator

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

Table 3: Plan for the Experiments in terms of Value of the Levels

For each setting (Exp. No. 1 to 9), six readings have been taken and the corresponding percentage yield of bio-diesel is recorded. The yield is in gram but for convenience it has been changed into percentage yield.

3.2 Result and Analysis

The data obtained for yield for the experimental setting is presented in Table 4.

Exp. No.	O1	O2	O3	O4	O5	O6
1	91	90	95	93	92	93
2	96	95	95	96	90	93
3	95	96	95	96	96	96
4	91	94	94	93	94	94
5	90	91	92	90	91	90
6	90	91	93	92	94	91
7	84	93	85	90	91	90
8	86	93	93	92	93	90
9	82	92	90	87	85	90

@ Here O stands for Observation

Table 4: Details of Percentage Yield at each Experimental Setting

From the data available in the average and S/N ratio is calculated. The average is calculated using the usual formula. However, S/N ratio is calculated using equation (1) as suggested by Taguchi for dealing with the optimization situations of kind maximum is the best[2, 3]. Here, objective is to maximize the percentage bio-diesel yield.

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

The average percentage yield and S/N (Signal to Noise) ratio is tabulated in the Table 5.

Exp. No.	Average Percentage yield	S/N Ratio
1	92.3	39.3
2	94.2	39.5
3	95.7	39.6
4	93.3	39.4
5	90.7	39.1
6	91.8	39.2
7	88.8	39.0
8	91.2	39.2
9	87.7	38.9

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

Using the S/N ratio data available in Table 5, ANOVA can be done successfully

3.3 THE ADDITIVE MODEL

From Table 5 it can be noted that the S/N ratio varies with change in the level of parameters and the model proposed in this work establishes an approximate relationship between percentage yield and η. The model is given in equation (2). Here, then is approximated by the additive model as given in equation (3).

$$\% \, Yield = \sqrt{10^{\frac{\eta}{10}}} \qquad (2)$$

$$\eta(A_x, B_y, C_z, D_t) = m + a_x + b_y + c_z + d_t + e \qquad (3)$$

Here, m refers to the overall mean *of η for the experimental region* whereas the terms a_x, b_y, c_z and d_t refer 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. The term *e* stands here for the error. In this additive model the cross product terms involving two or more factors (i.e. interaction effect of two factors) are explicitly not considered. This fact is detailed in ANOVA.

3.4 ANALYSIS OF VARIANCE (ANOVA)

The experimental result displayed in Figure 5clearly visualizes the fact that different factors (Molar Ratio, Reaction Temperature, Reaction Time, and Catalyst Concentration) affecting the percentage yield of bio-diesel and thereby the S/N ratio varies. The extent that these factors affect the S/N ratio can be seen in Table 6. Further, the relative effect of the different factors on S/N ratio can also be better visualized by decomposing the variance that is commonly called as analysis of variance (ANOVA). This is done first by computing the total mean of sum of squares due to all factors together, mean sum of squares due to all factors individually and mean sum of squares due to error and after that analysis of these variance has been done by Minitab 16. The mean sum of squares is computed by dividing the sum of squares by the corresponding degree of freedom (DOF). Here mean sum of square is represented by MS.

Percentage contribution is calculated as the ratio of factor mean square to the error mean square.

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.

3.5 DISCUSSION ON ANOVA

The interpretation of the ANOVA is presented in this section. By looking at the Table 6, one can infer that the Molar Ratio and catalyst concentration largely contribute in the variation in S/N ratio of the percentage yield. However, the other factors (Reaction Temperature and Reaction Time) contribute acutely. Molar ratio contributes 67.8% and Catalyst concentration contributes 28.4%.

Factors	Degree of Freedom	Sum of Square	MS	Contribution (%)
Molar Ratio	2	0.31	0.157	67.8
Reaction Temperature	2	0.0044	0.002232	1.0
Reaction Time	2	.00008181	0.01612	0.0
Catalyst Concentration	2	0.13	0.068	28.4
Error	0	0.0	—	—
Total	8	0.457	—	—

Table 6: ANOVA

Taguchi's method used for optimization of process parameters also generates main effect plots of yield with respect to different process parameters individually.

4. CONCLUSIONS AND SCOPE FOR FURTHER WORK

Main effects plots for yield with different parameters clearly depict that optimum conditions in this solar assisted 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 P-values for every process parameters. Lower the P-value, higher is the contribution of parameter in affecting yield. So, Effect of oil to methanol molar ratio on conversion yield is higher than the effects of other parameters. The optimized design is obtained by Taguchi Methodology. However, Grey relational analysis and Response surface method also may be used to predict perfect results.

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