REDUCTION OF FREE FATTY ACID OF JATROPHA OIL USING TAGUCHI APPROACH

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ABSTRACT

Taguchi approach is used to optimize the four important reaction variables for reduction of free fatty acid (FFA) content of the oil to around 1.5. Jatropha oil is esterified using acid catalyst (P-T-S-A) by esterification process and reduces the free fatty acid content of Jatropha oil. Important variables are studied that affect acid value during esterification such as temperature, catalyst concentration, oil to ethanol ratio and reaction time. Initial free fatty acid of Jatropha oil was found 8% and reduces below 2% in 2h under the conditions of Molar ratio 5:1, 1% P-T-S-A of oil at 65°C by using taguchi approach.

Keywords: Basic catalyst, Acid value, Jatropha oil, ethanol, Taguchi method, esterification.

INTRODUCTION

Economic development of any country in the world is depends on the optimum utilization of its natural resources. India is ranked fourth at the global level on the overall consumption of fossil fuel. Fossil fuel are non renewable in nature and India imports almost 85% of its crude oil consumption by spending billon of dollars and uncontrolled burning of fossil fuel contributes significantly to the environment pollution and global warming. All these lead to us to search for eco-friendly and sustainable alternative. Biodiesel as fuel is very essential for future energy sustainability. Feedstock selection is an important consideration for biodiesel preparation because of high amounts of free fatty acid content that hinders conversion [1]. Some oil has higher value of acidity, which need to minimize to produce biodiesel. It is possible to produce biodiesel from seeds of vary familiar tree species such as pongamia, neem, mahua, jatropha etc.

Jatropha is the one of the oil producing resource which can replace diesel oil [2]. Also jatropha is used for making biodiesel fuel without impact on food consumption. Many researches reveal that Jatropha is an oil bearing plant, which can be used directly with diesel engine without modifying the engine but has to reduce the viscosity [3]. This can be done by blending the diesel oil or without blending to it. Therefore the oil from Jatropha oil is one of the best alternatives to produce fuel and replace the oil imported from aboard. This is because Jatropha can be planted in almost any regions and give quick yield, which is very beneficial to the farmer for home usage or village usage. Especially agriculturists with low income can grow Jatropha and make diesel oil form Jatropha oil for small engine. This help agriculturist to reduce the fuel cost and become independent.

1. Esterification process:

Esterification process is the reaction of triglyceride (fat/oil) with an alcohol in the presence of acidic as a catalyst to reduce free fatty acid number of oil. The presence of strong acid accelerates the reaction [4]. The main purpose of esterification is to reduce FFA. In this study, FFA is reduced by reacting Jatropha oil with ethanol in the presence of acid catalyst (P-T-S-A). The Jatropha oil is first filtered to remove solid impurities then it is preheated at100°C for half an hour to remove moisture. A two stage process is used for producing biodiesel of Jatropha oil. The first stage is esterification to reduce free fatty acid content in Jatropha oil with ethanol (99% pure) and acid catalyst (98% pure) heated for two hour at 65oC in magnetic stirrer to reduce FFA below 2% [5]. After esterification, the esterified oil washed using water. The washing is carried out in a separating funnel. The hot water having temperature as that of esterified oil added in a separating funnel. Impurities like dust, carbon content; sulfur content is washed away with water. Four factor of three level which is used in experiment are given below.

Table I. Four parameter and three variables for design of experiment

Parameter	Level		
	1	2	3
Time(min)	60	90	120

Temp (°C)	55	60	65
Catalyst conc. (% wt.)	0.5	1.0	1.5
Molar ratio	4:1	5:1	6.67:1

2. Material:

Jatropha oil and chemical likes P-T-S-A, NaoH, Ethanol, isopropyl alcohol, Phenopthelene indicator is collected from the chowari bazaar. The esterification reaction used Para-toluene sulfuric acid (HPLC grade, 99.8%, Pharmco-AAPER) as the catalyst and ethanol (HPLC grade, 99.9%, Pharmco-AAPER) as the reactant.

3. Design Of Experiment:

Design of experiment consists of a set of experiments which is the setting of several products or process parameters to be studied that are changed from one experiment to another. Design of experiments is also called matrix experiment, parameters are also called factors and parameter settings are also called levels. Conducting matrix experiment using orthogonal array is an important technique. It gives more reliable estimates of factor effects with fewer numbers of experiments when compared with the traditional methods such as one factor at a time experiments [6]. The design of experiment via Taguchi method uses a set of orthogonal array for performing of the fewest experiments. Taguchi method involves the determination of large number of experimental situation, described as orthogonal array, to reduce errors and enhance the efficiency and reproducibility of experiments [7]. The columns of an orthogonal array are pair wise orthogonal that is for every pair of column, all combination of factor levels occur at an equal numbers of times. Although, in the taguchi software there is a different type of Array but I have used L-9 Array that is suitable for four parameter and three level which is used in this paper.

The columns of an orthogonal array represent factors to be studied and the rows represent individual experiments. This study is associated with four factors with each at three levels. The orthogonal array used to find the effects of four parameters namely the molar ratio of oil to ethanol, time, and catalyst concentration and reaction temperature on the reduction of FFA. The four selected parameters at three levels i.e. L-9 experimentally studied are shown in this table I.

Table II shows the orthogonal array used to design experiments with four parameters at three levels. In this study, Taguchi approach is software for automatic design was used to analyze the results and optimize the experimental conditions for setting the control variables.

Signal to noise ratio

$$\frac{S}{N_{(Smaller)}} = -10 \log\left(\frac{\sum y_i^2}{n}\right)$$

If smaller is better then used this formula.

Where n is no. of experiment perform for one solution, in this case it is equel to 1 and y is the S/N ratio for the each set L-9 array [8].

Table II. L-9 Array for Design of Experiment

Exp no.	Column number and parameter assigned			
	Molar ratio	Catalyst conc.	Temp	Time
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

RESULT

1. S/N plot:

According to Taguchi approach smaller value of mean of S/N ratio corresponding each factor is the best value for maximum reduction in FFA. From the figure I it is observed that the optimum level of molar ratio, reaction time, and reaction temperature and catalyst concentration are 3, 2, 3, 1, i.e. 6.67:1, 90 min, 65°C, and 1.0% of oil. Hence we can conclude that it can give the lowest FFA of oil i.e.0.8

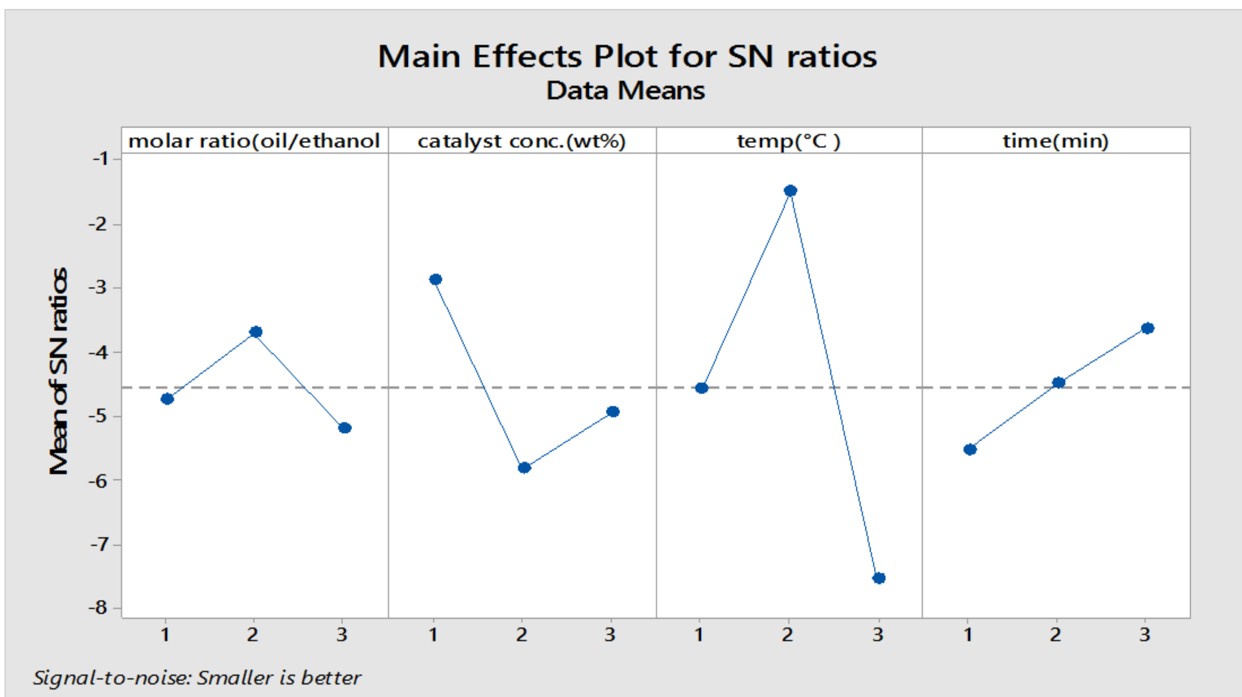

Figure I. Main effects plot of the control parameter

2. Anova table:

Different parameters affect the free fatty acid of oil to a different degree. The relative magnitude of the parameter effects are listed in table. A best feel for the relative effect of the different factors is obtained by the decomposition of variance, which is generally called as analysis of variance (ANOVA). This is obtained by the formula given below. Total sum of squares = Sum of square due to parameter A [(total number of experiments at level A1) x (mA1-m)] + [(total number of experiments at level A2) x (mA2-m)] + [(total number of experiments at level A3) x (mA3-m)].

Now all these sum of squares are listed in Table III. This is known as the ANOVA table.

Table III. Analysis of Variance

Source	DF	Adj. SS	Adj. MS	F-value	P-value
Molar ratio(oil/ethanol)	2	0.01556	0.00778	78.34	0.00012
Catalyst conc. (Wt. %)	2	0.42889	0.21444	7.33	0.042
Temp(°C)	2	2.06889	1.03444	21.33	0.022
Time(min)	2	0.16222	0.08111	0.06	0.18
Error	0	0	0		
Total	8	2.67556			

The larger the contribution of a particular parameter to the total sum of squares, the larger the ability is of that factor to affect the S/N ratio. More ever, the lower P- value, the larger will be the factor contribution in the reduction of FFA. For the molar ratio, catalyst conc. and reaction temperature P-value is very small; hence it has more contribution in the reduction of FFA.

CONCLUSION

The main effect plot for S/N ratio is shown in the Figure I. The average S/N ratio for maximum percentage yield of Jatropha oil ethyl ester is obtained at Molar ratio 5:1, catalyst% is 1%, reaction Temperature 65°C and reaction time 120min.That is the optimum parameter setting for high percentage reduction of FFA i.e. (0.8%) for highest yielding biodiesel.

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