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OPTIMIZATION OF BIODIESEL PRODUCTION FROM WASTE COOKING OIL BY USING ORTHOGONAL ARRAY

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ABSTRACT

Waste Cooking Oil has recently attracted researchers and mechanical engineers as a low cost source for biodiesel production. This is because of the fact that it has a very rich oil content and eco-friendly in nature. In the present research, an orthogonal array has been used for optimizing production of biodiesel from waste cooking oil using trans-esterification process of conversion. Five independent variables were identified having impact on dependent variable yield of biodiesel(Y). Five independent variables are Stirring Speed(S), Concentration of catalyst(C), Methanol to oil ratio (M), Time of transesterification reaction (T), and working temperature (W). LP16 matrix was constructed to understand and statically examine the effects of 5 independent variables. Results of the Statistical analysis revealed that Y was maximum (74.2%) for S = 200 RPM, C = 1.60 % by Weight, M = 10:1, T = 40 Minutes and W = 328 degree Kelvin.

KEYWORDS: Waste Cooking Oil, Optimization, Orthogonal array, Biodiesel, Yield.

I. INTRODUCTION

At present, India has 5-6 great capacity plants (10,000 to 250,000 MT / year)for production of biodiesel; presently utilizing 28 % of the installed capacity to manufacture 130-140 million liters of biodiesel from various raw materials like non-edible vegetable oils, Waste Cooking Oil (WCO), and animal fats. The biodiesel as a result produced locally (or imported) is mainly sold to SME, also sold to unorganized sector such as brick manufacturers, mobile communication towers, developed farmers, and to organizations running DG Sets for power back-ups. Moreover, Biodiesel is also sold to various state transport corporations, automotive and transportation company (sponsored by states or private units), and is being retailed at private outlets ***(GAIN Report No. IN 6088, 2016)***.

Biodiesel, whether conventional or superior, cannot be viewed as a panacea so far addressing the issue of energy security, environmental concerns, and the public of large country like India. Since, large population of India is living below poverty line (BPL), so use of edible oil as feedstock for biodiesel is not advisable. So, main focus of ***Biofuel policy 2009*** of India is on using non edible oils like Jatropha. This state of affairs has initiated the investigation for alternative fuel in place of petroleum products. An alternative fuel to diesel need to be practically feasible, economically viable, eco-friendly, and easily available. Biodiesel is basically mono-alkyl ester of long chain fatty acids, is a probable replacement of petro diesel ***[Lin R et. al.,] Hassan SZ and Vinjamur M].*** The edible, inedible, algae and waste cooking oils can be substantial source for production of biodiesel ***[Dwivedi G. et. al., Ali SH et. al.].*** In the light of major utilization, the center of attention has shifted to inedible oils as prospective feed stocks. Directly Employing raw vegetable oils (SVOs) in compression ignition engines have grave engine troubles owing to high viscous nature and decrease in viscosity can be achieved by transesterification of oil for producing biodiesel which has fuel properties comparable to petro diesel by use of appropriate catalyst [***Agarwal AK].***

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II. PRODUCTION OF BIODIESEL

Approximately, 20 litre WCO was collected as residue oil from a marriage function in Morena, MP India. In this investigation biodiesel was produced from waste cooking oil by the process of alkali based transesterification in the presence of alcohol. The production process of biodiesel is consists of 3 steps.

Figure -1: Waste Cooking Oil

(i) Pre-treatment of WCO: Since WCO is full of impurities, so first step in pre treatment is filtration of oil so that foreign particles, food sediments, unburnt carbon particles can be removed. For this purpose paper filter of pore size 11 µm was used. A quantity of 20 litre WCO was filtered slowly in 4-5 days because filtration was carried out in quantities of 2 liters in each step of step.

(ii) Chemical Reaction: Then free fatty acid (FFA) investigation was carried out in a private lab of Jaipur. FFA percentage was 0.2449 %. If FFA < 2.5 % then it is excellent for conversion into biodiesel in single step, otherwise 3-step method is followed. 1 litre of WCO was taken and then after stirring and it was heated on a electric heater in chemistry lab to temperature of 55 °C concurrently in one more beaker Anhydrous methanol 300 ml was mixed with 200 ml of NaOH. Actually different ratios of methanol and catalyst were used in this research. Details will be discussed later. Other beaker was also heated as a result of which methoxide was formed. Slowly and slowly, methoxide was poured in hot WCO. Mixture was stirred gently using a magnetic stirrer. After that it was left to cool for a period of 15 Hours.

(iii) Post treatment: post treatment of products is equally important because Products of the chemical reaction not only include biodiesel, but also by-product like soap, traces of water glycerol and surplus alcohol. Every one of these byproducts needs to be removed to meet the standards. Glycerol is denser and heavier than biodiesel, because of this density difference is glycerol settles in the bottom of container and then it was drained in a plastic bottle. By the process of water washing other by products were removed. Final pH of biodiesel was 6.52. Measurements of pH Value provide at least a rough measure of the development of the chemical reaction in biodiesel production ***[Clark, W.M., et al.].***

III. TAGUCHI METHOD

The Taguchi method mainly focuses on producing high quality product with optimum use of resources involved ***[Srinivas Athreya and Dr Y.D.Venkatesh***]. In the present research, focus was on increasing yield of biodiesel. On the basis of literature survey, Five independent variables: Stirring Speed(S) in RPM, Concentration of catalyst(C) in wt %, Methanol to oil ratio (M), Time of transesterification reaction time (T) in minute, and working temperature (W) in degree Kelvin were identified as controlling factors. Each parameter was maintained at 7 levels: lower, low, high, higher denoted by 1, 2, 3, 4, and 5 respectively.

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Table -1: Reaction Parameters and levels				
Reaction Parameters	Levels			
	LV1	LV 2	LV 3	LV 4
W	298	313	328	343
T	20	40	60	80
M	2.5:1	5:1	7.5:1	10:1
C	0.8	1.2	1.6	2.0
S	200	300	400	500

Orthogonal Arrays are basically special experimental design which requires only small range of experimental run so that main factors affecting output can be analyzed. For selecting an OA, minimum numbers of trial run to be performed are calculated using the formula:

$$T = 1 + NP(LV - 1)$$

Where , T = Number of Experimental Trials to be performed

NP = Number of Parameters

LV = Number of Levels

For the current research NP = 5, LV = 4 So, T = 16. Therefore, at least 16 experiments are to be performed. We manufactured biodiesel in 16 trials with different levels of variables.

IV. ORTHOGONAL ARRAY ANALYSIS

LP 16 was prepared by taking all possible combinations of different parameters. Percentage Yield of biodiesel(Y) was calculated by the following relation ***[M. Rakib Uddin et al.]***:

$$Y = \frac{W_{BD}}{W_{WCO}} \times 100, Where\ W_{BD} = Weight\ of\ Biodiesel, \quad W_{WCO} = Weight\ of\ Waste\ Cooking\ Oil$$

Table -2: Percentage Yield of Biodiesel in LP16							
Run No.	Factors					Level of Error in Experiment	Yield of BD in %
	W	T	M	C	S		
1	298	20	2.5:1	0.8	200	1	27.5
2	298	40	5:1	1.2	300	2	71.5
3	298	60	7.5:1	1.6	400	3	65.5
4	298	80	10:1	2.0	500	4	72.9
5	313	20	5:1	1.6	500	1	69.3
6	313	40	2.5:1	2.0	400	2	58.9
7	313	60	10:1	0.8	300	3	63.7
8	313	80	7.5:1	1.2	200	4	71.4
9	328	20	7.5:1	2.0	300	1	70.8
10	328	40	10:1	1.6	200	2	74.2
11	328	60	2.5:1	1.2	500	3	34.5
12	328	80	5:1	0.8	400	4	64.3
13	343	20	10:1	1.2	400	1	68.2
14	343	40	7.5:1	0.8	500	2	68.7
15	343	60	5:1	2.0	200	3	64.3
16	343	80	2.5:1	1.6	300	4	68.3

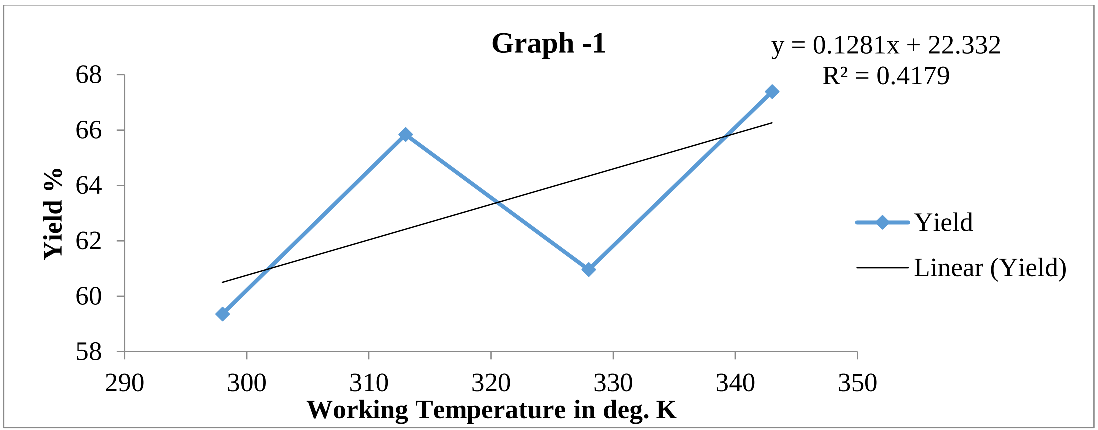
On the basis of above LP16 Matrix, values in different cells of table -3 were calculated and tabulated as follows:

Table -3 : Range Analysis of % Yield data of Biodiesel

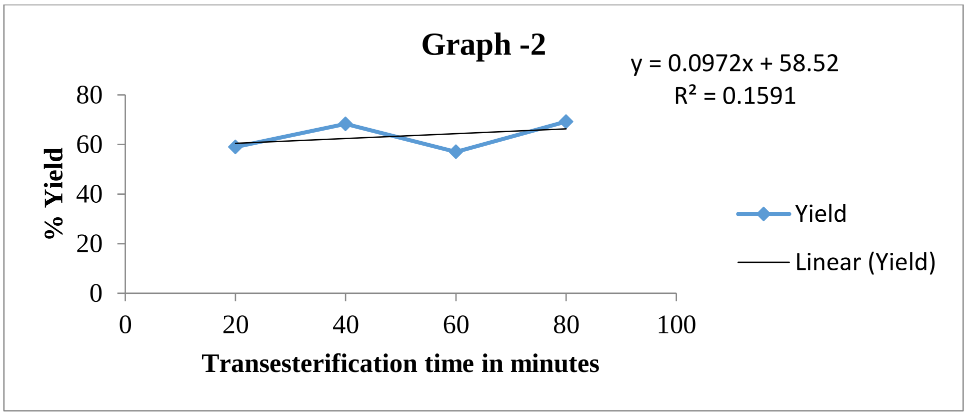
	W (working temperature in degree Kelvin)	transesterification reaction time (T) in minute	Methanol to oil ratio (M)	Concentration of catalyst(C) in wt %	Stirring Speed(S) in RPM
Y_{i1}	59.35	58.97	47.30	56.05	59.35
Y_{i2}	65.83	68.33	67.35	61.40	68.58
Y_{i3}	60.95	57.00	69.10	69.33	64.23
Y_{i4}	67.38	69.23	69.75	66.73	61.35
Range R_j	8.03	12.23	22.45	13.28	9.23

It can be portrayed from table -3 that Methanol to oil ratio has the maximum impact on the yield of biodiesel while it was least affected by working temperature variations. These results can be interpreted with the help of following graphs;

1. Impact of working temperature in degree Kelvin on Average Yield % of Biodiesel:



2. Impact of transesterification reaction time (T) in minute on Average Yield % of Biodiesel:



3. Impact of Methanol to oil ratio Average Yield % of Biodiesel:

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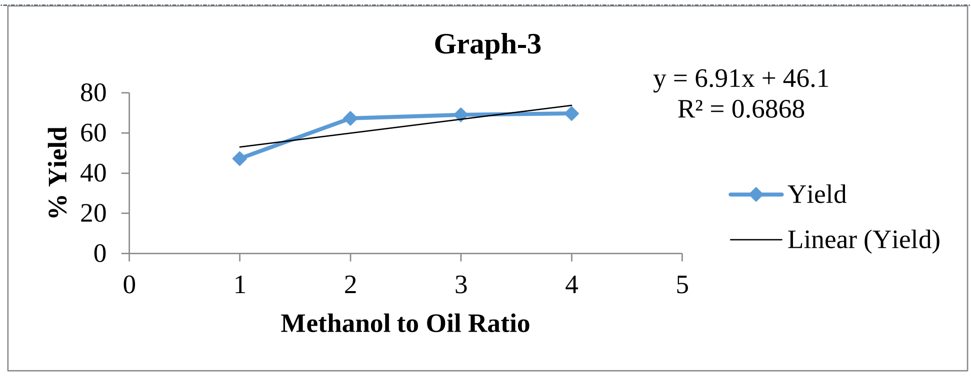
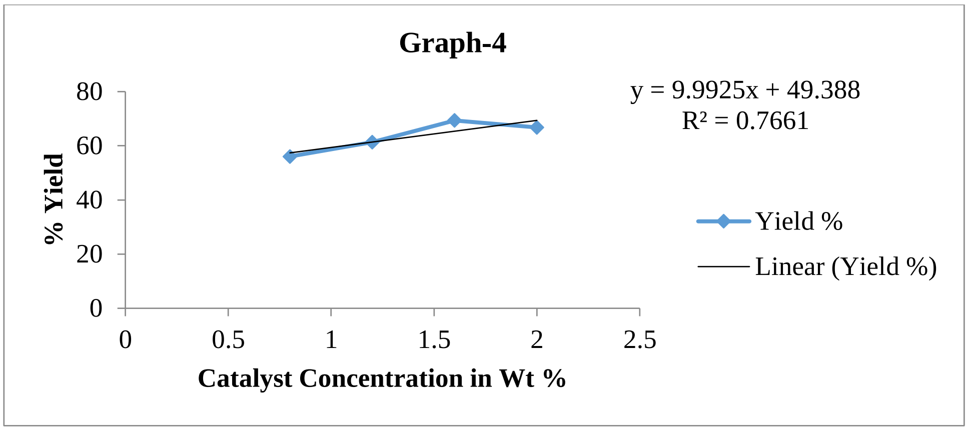
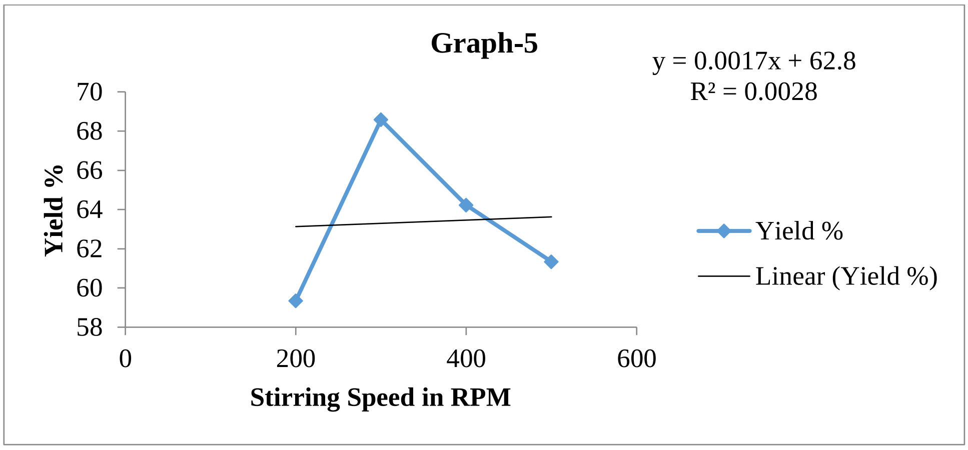


4. Impact of Concentration of catalyst(C) in wt % on Average Yield % of Biodiesel:



5. Impact of Stirring Speed on Average Yield % of Biodiesel:



V. CONCLUSION

Production of Biodiesel from transesterification by homogeneous catalyst was carried out. Before transesterification FFA Test was conducted. On the basis of orthogonal array analysis of different independent variables following concluding remarks can be listed:

1. It is crystal clear that % Yield of Biodiesel in transesterification reaction depends on number of variables. Here 5 independent variables were identified, so mathematical relation exists between dependent variable and independent variables.

$$Y = f(\mathrm{W, T, M, C, S})$$

2. Methanol to oil ratio and catalyst concentration was found to be most influencing parameters in the production of biodiesel.
3. An Optimum level of all the variables must be selected to obtain best possible % Yield of Biodiesel.

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