OPTIMIZATION OF TRANSESTERIFICATION PROCESS PARAMETERS FOR THE PRODUCTION OF BIODIESEL FROM WASTE ANIMAL FAT USING RSM

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Abstract: Modern society is highly dependent on fossil fuels for its energy requirements, however fossils fuel sources are limited and their use causes the negative impact on the breathing air quality. At the same time, the demand for energy is increasing at a faster rate due to rapid increase in number of industries and shifting of people from villages to cities. Hence, efforts are being made to find to a suitable to alternative to diesel oil which must be renewable and eco-friendly. Biodiesel is one of the best and suitable alternatives to diesel oil because it is obtained from renewable sources like vegetable oil, animal waste fat and used cooking oil. In this work, an effort has made to produce biodiesel from animal waste fat through single stage transesterification process. This work also involves the optimization of transesterification parameters such as catalyst concentration, molar ratio of oil: alcohol, and reaction time through the use of response surface methodology (RSM). The maximum biodiesel yield (94.6%) was obtained experimentally at catalyst concentration 4:1 methanol to oil ratio and reaction time of 65 minutes. Predicted yield 94.28 % was obtain at catalyst concentration of 6.5:1 methanol to oil ratio and reaction time of 65 minutes. 0.32% variation is obtained between experimental and predicted yield.

***Index Terms* - Waste animal fat (WAF), Transesterification, Biodiesel, Response Surface Methodology (RSM),**

1 Introduction

The yearning of the advanced human culture for vitality is huge, which is expanding with the expanding population and with the quest for higher expectations for everyday comforts [1]. The scan for stable vitality supplies from different vitality assets together with the related move toward sustainable power sources is fundamental, in light of the fact that most vitality assets at present depend on petroleum products, which are of limited accessibility [2]. A noteworthy extent of this vitality request is made up by the diverse energizes which guarantee portability. In light of ecological and fiery contemplations, a bigger extent of this vitality is endeavoring to be secured with sustainable power sources all in all world [3]. As mechanical advancements are going on at a quick pace, vitality is assuming a more imperative part in the day by day lives surprisingly and social practical improvement of each nation. Biomass has been successfully utilized throughout the decades to generation of elective fills for land transport. Likewise; biomass has been the best probable used for avionics part which is one of typically the basic of transportation. A few agribusiness along with animal encourage based natural materials with sugar are considered biomass vitality assets. In coming years, elective powers utilized as a part of both land and air transportation will bolster the vitality approach of nations. Because of temperate and ecological detriments of non-renewable energy sources, elective vitality assets have additionally been examined to lessen reliance on oil based fills and secure condition [1].

The generation and utilization of non-renewable energy source in motors with inner burning reason natural issues, for example, rising level of CO_2 in the climate, expanding the normal surrounding Earth's hotness [4]. Present ongoing generation coal, oil, and gaseous petrol still assume an essential part in our worldwide vitality blend. While researchers and designers have grown clean coal advances, for example, carbon catch and capacity, it is essential to address whether such innovations can balance the developing carbon impression caused by the utilization of carbonaceous energizes. This test is confused by the development in size of aggregate worldwide world vitality request, the size of monetary speculation required to actualize such advancements, and the race against time to limit the harm coming about because of proceeded with utilization of petroleum product vitality.
India is the world's fourth biggest vitality customer; it has the most reduced per capital vitality utilization of the nations talked about in this area. However India's vitality and atmosphere impression is bifurcated huge urban focuses are in charge of large amounts of coal-based outflows; and rustic regions have next to zero vitality get to. Monetary development in India has been unfaltering over the previous decade and the greater part of India's financial yield is owing to the administration business. Yearly GDP development in light of obtaining power equality for the period 2015-2030 is assessed to 5.9% in India

The overall interest for vitality in the transportation segment is relied upon to develop consistently around 1.2% and 1.4% for each annum and the number of inhabitants on the planet likewise expanding by 1.8% step by step [2]. In 2015, petroleum products represented 86% of the world's vitality utilization and atomic included another 4%, in light of information from measurable audit of World Energy.

2 Experimental method

Initially the collected waste animal fat is chocked into small places and all pieces are heated to 90–100 ^{0}C in a container for 30 minutes. At a regular interval of time the level of oil is observed and found that there is increase in oil level, reaching maximum level at 30 minutes. After 30 minutes there is no appreciable increase in the level of the oil. The oil at the top separated from the bottom heavy residual by using filter cloth. The filtered pure fat oil is kept in glass container of 5 liter capacity which is used as a source for the production of biodiesel. Table 2.1 shows FFA distribution of waste animal fat oil it is clear that animal waste fat oil contains 64.57% of saturated (Palmatic acid 28.95%,Myrestic acid 7.06%, Stearic acid 26.63%) and 27.11 % of unsaturated (Olic acid 23.51%,Linolic acid 2.53%) fatty acid. It is clear that animal waste fat oil contains higher percentage of saturated fatty acid than unsaturated. Presence of higher percentage fat acid makes excellent biodiesel but the main drawback is high melting point. Therefore it may solid at room temperature. Biodiesel produces from a source which has higher percentage of fatty acid possess better oxidation stability and generates lower NO_x emission.

Table 2.1: FFA distribution of waste animal fat oil

Components	**% in 100 by 100 ml**
Palmitic acid (16:0)	28.95%
Myrestic acid (16:1)	7.06%
Stearic acid (18:0)	26.63%
Olic acid (18:1)	23.51%
Linolic acid (18:2)	2.53%

In this work, alkaline catalyzed transesterification process is used as the FFA value of animal fat oil is found 0.4%. During this process a known quantity of animal waste fat oil is treated with known quantity of methanol in presence of known quantity of NaOH Catalyst. The reaction is carried out at different reaction time by keeping reaction temperature constant (60 ^{0}C). Table 2.2 shows Independent parameter used in central composite design (CCD) for the optimization of animal waste fat oil transesterification reaction. Experiments were conducted as per experimental design matrix table 3 which is obtain through design expert software.

Table 2.2 Independent parameter used in central composite design (CCD) for the optimization animal waste fat oil

Parameter	**Units**	**Symbol**	**Level**				
			-α	**-1**	**0**	**+1**	**+α**
Molar ratio	-	A	2.29	4	6.5	9	10.7
Catalyst	wt%	B	0.12	0.4	0.8	1.2	1.47
Reaction time	min	C	22.95	40	65	90	107.04

The optimization trail was done by the help of DESIGN EXPERT software for the square least quadratic module procedure by various equations which is analyzed from the software itself. DESIGN EXPERT can be used for the failure analysis and ANOVA analysis

Alkaline base catalyst single stage transesterification process has conducted with the help of 20 different samples and its acid value level 0.4. The many regressions (experiments) resourceful were obtained by means of employing least square method to guess a quadratic polynomial model of waste animal fat yield. Then has to undergo for all the runs with different varying concentration of parameters shown in Table 2.3 which was obtained by CCD and its shows the yield from waste fat of animals.

3 Statistical Analysis

The predicted model for percentage of animal waste fat oil methyl ester yield in terms of coded factors is given in Eq (1) Interaction of parameters affecting the biodiesel yield was analyzed by using response surface methodology (RSM) The positive sign represents synergistic effect on biodiesel yield, whereas negative sign represents antagonistic effect. The model Eq 1 represents those positive coefficients A,B,C results in linear effect to increase the FAME yield. The quadratic terms effects on yield which decreases methyl ester yield

Yield = $(94.28+6.79\ A+ 3.82\ B+ 4.21\ C-0.7500\ AB-3.50\ AC-4.75\ BC-5.99\ A^2 - 6.52\ B^2 -2.63\ C^2)$ ………… Eq (1)

The **Predicted R^2** of 0.9967 is in reasonable agreement with the **Adjusted R^2** of 0.9989; i.e. the difference is less than 0.2. **Adeq Precision** measures the signal to noise ratio The experimental model have establish through correlation coefficients of determination i,e R^2 have the rate (value). The yield of expected value is obtained from the DESIGN EXPERT The statistical model has expected that the higher yield of animal fat biodiesel (B100) is 94.28 in volume of oil has obtain at optimistic values of CH_3OH 6.5 (35ml by volume), base alkaline NaOH of 0.8 by weight along with response time of 65 minutes.

Table 2.3. Experimental design matrix through design expert software.

Exp. No.	A	B	C	Molar Ratio	NaOH in gm	Reaction Time in min	Yield %	
							Experimental	Predicted
1	-1	-1	-1	4	0.4	40	55	55.30
2	1	-1	-1	9	0.4	40	77	77.38
3	-1	1	-1	4	1.2	40	74	73.95
4	1	1	-1	9	1.2	40	93	93.02
5	-1	-1	1	4	0.4	90	80	80.23
6	1	-1	1	9	0.4	90	88	69.40
7	-1	1	1	4	1.2	90	80	79.87
8	1	1	1	9	1.2	90	85	84.95
9	-1.68	0	0	2.29552	0.8	65	66	65.91
10	1.68	0	0	10.7045	0.8	65	89	88.74
11	0	-1.68	0	6.5	0.127283	65	70	69.40
12	0	1.68	0	6.5	1.47272	65	82	82.25
13	0	0	-1.68	6.5	0.8	22.9552	80	79.74
14	0	0	1.68	6.5	0.8	107.045	94	93.91
15	0	0	0	6.5	0.8	65	94	94.28
16	0	0	0	6.5	0.8	65	94.5	94.28
17	**0**	**0**	**0**	**6.5**	**0.8**	**65**	**94.6**	**94.28**
18	0	0	0	6.5	0.8	65	94	94.28
19	0	0	0	6.5	0.8	65	94.5	94.28
20	0	0	0	6.5	0.8	65	94	94.28

Fig.1 shows the predicted v/s actual experimental values. It indicates that the values in predicted and actual is in reasonable agreement with each other which means the data fit well in the model and good response in maximizing yield

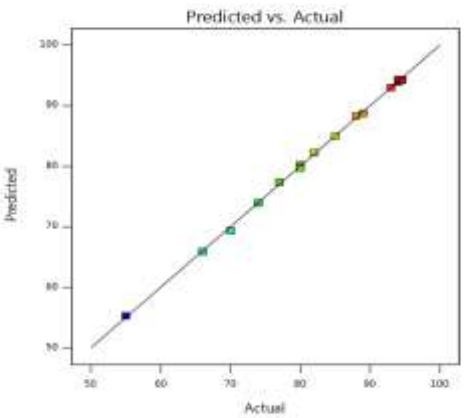

Figure 1 Actual v/s Predicted values

4 Results and Discussion

Fig.2 along with Fig.3 shows that percentage of ware animal fat methyl ester yield has minimum value catalyst concentration and higher values for maximum value of methanol ratio with constant reaction time and temperature. Lower the value is at lower rate of molar ratio also higher the value of catalyst concentration. This has to maintain with constant time and temperature.

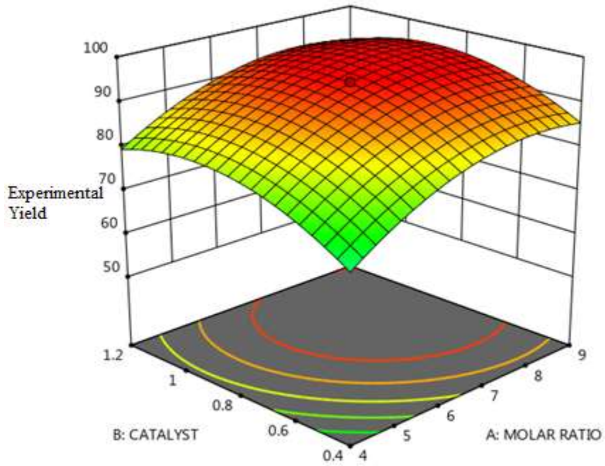

Figure.2 Effect of molar ratio and catalyst concentration on biodiesel yield (3D)

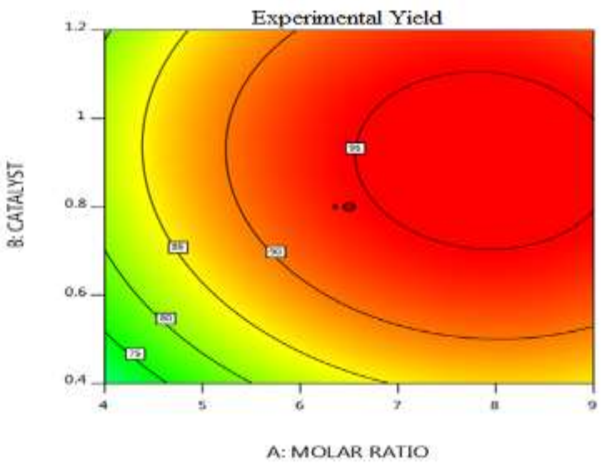

Figure.3 Effect of molar ratio and catalyst concentration on biodiesel yield (2D)

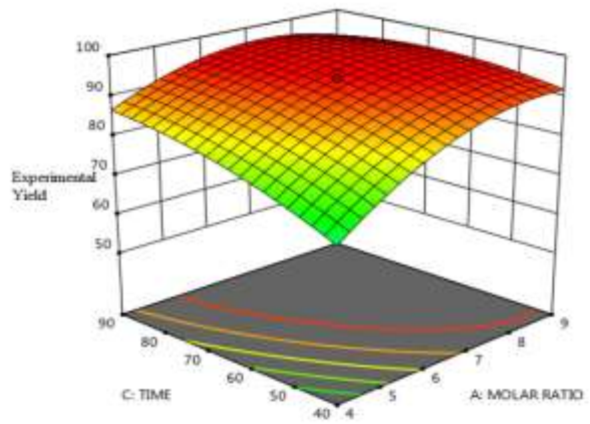

Figure.4 Effect of molar ratio and reaction time on biodiesel yield(3D)

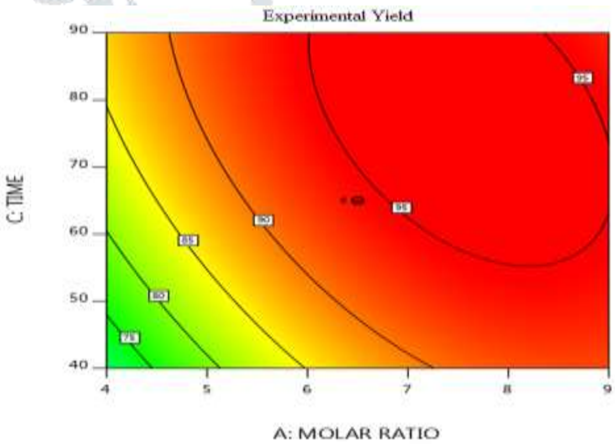

Figure.5 Effect of molar ratio and reaction time on biodiesel yield (2D)

From Fig.4 and Fig.5 shows that percentage of waste animal fat methyl ester yield has minimum value reaction time and higher values for maximum value of methanol with constant catalyst concentration and temperature. Lower the value is observed in lower value of methanol ratio and highest rate of reaction time maintaining at constant temperature and catalyst concentration

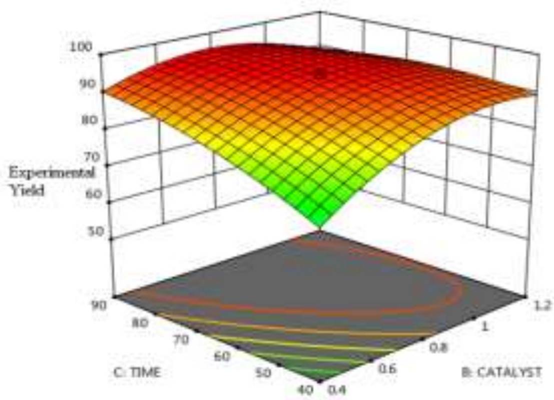

Figure.6 Effect of reaction time and catalyst loading on biodiesel yield(3D)

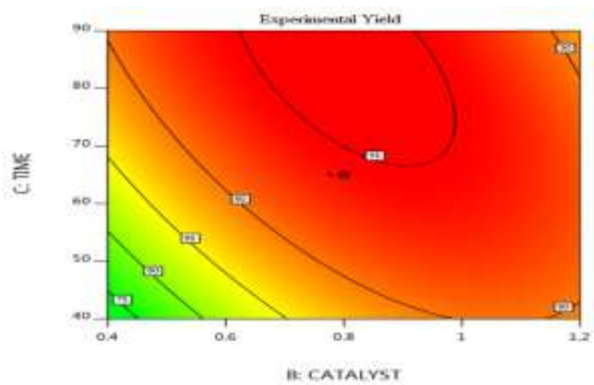

Figure.7 Effect of reaction time and catalyst loading on biodiesel yield(2D)

Fig.6 and Fig.7 shows that percentage of waste animal fat methyl ester yield has minimum value catalyst concentration and higher values for maximum value of reaction time with constant reaction time and temperature

5. Conclusion

The various methods to produce biodiesel production but the production of biodiesel from waste animal fat is very easy. Initial FFA of crude oil is 0.4 and hence single stage transesterification is performed by using NaOH as a catalyst. RSM is the most effective method for optimization of transesterification process parameters for biodiesel production. Predicted maximum yield of Biodiesel production for 0.8gm catalyst and 35ml methanol quantity and 65minutes reaction time were 94.28% at a reaction temperature of 60-65^{0}C and compared to experimental yield of 94.6%. Fitness of the model regression, counter and 3D graphs were plotted for the comparison different parameter to maximize the yield.

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