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Comparative Evaluation of Performance and Yield Characteristics of Corn/Palm Biodiesel using Fit Regression Model

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***Abstract*—In this study, we've studied the optimization of two stage transesterification process of palm/corn oil and determining and optimizing emissions of CO, HC, CO2, and O2 emissions for diesel, palm biodiesel and corn biodiesel using Taguchi and regression method in mini tab. The molar ratio, quantity of catalyst used and quantity of methanol used are considered as factors effecting yield while optimizing two stage transesterification. With the help of regression, the F and P values for emissions of CO, HC, CO2, and O2 for palm/corn oil are determined as F of 389.5 and 37.56, P of <0.328 and <0.123 for palm & corn oil respectively.**

Keywords —Palm oil, corn oil, transesterification, Minitab, Taguchi, regression, emissions, normal probability, equity of variance.

I. INTRODUCTION

M.M. Rahman et al [1]., identified that bio-diesel from vegetable oil with ethanol using three different Catalysts (egg shell, NaOH and KOH) through transesterification reaction. Though, recently, heterogeneous catalyst is being considered to be a cheaper alternative to homogenous catalyst, homogenous Catalyst are currently mostly used to produce biodiesel. M.Canakci, j. Van Gerpan [2] condensed that vegetable oil and animal fats can be transesterified to bio-diesel for use as an alternative diesel fuel. Conversion of low cost feedstock such as used frying oils is complicated if the oils contain large amounts of free fatty acids that will from soaps with alkaline catalysts. The objective of this study was to investigate the effect of process variables on acid -catalysts transesterification. The molar ratio of alcohol, reaction temperature, catalyst amount, reaction time, water content and free fatty acids were investigated to determines the best strategy for producing biodiesel. The acid catalyst also requires the concentration of the water to be less than 0.5%, which is almost the same as is required for alkaline catalysts. Water formed by the esterification of free fatty limited their presence in the oil to 5%. C. Venkateswaralu et al [3] was investigated that bio diesel is an alternative to petroleum - based fuel resultant from vegetable oils and from animal fats and waste Cooking oils including triglycerides. Transesterification process used to recovery of high quality glycerol from biodiesel. M Yazdanpanah [4] was authorized, Biodiesel is a renewable energy and One of the promising solutions in substitution for fossil fuels. The parameters include effect of temperature ethanol /oil molar ratio. Catalyst and free fatty of the acid Concentration. Two-stage Transesterification is developed as an effective process for increase the process yield and reaction rate. Venkata Ramesh Mamilla et al [5] was investigated Biodiesel prepa69/red from the edible of palm oil by transesterification of the crude oil with methanol in the presence of naoh as catalyst. Important fuel properties of methyl esters of biodiesel produced from palm oil like viscosity, flash point, fire point, calorific value etc., was found out and compared to the properties of Indian standard biodiesel.

Felixishola, , angelamamudu[b][6] summed up that Unrefined palm oil (UPO) is a major output of the country's commercially accessible oil palm plantations. The manufacture of biodiesel from refined, bleached, and deodorised (RBD) palm olein extracted from UPO derived from batch reactors is investigated in this work. The transesterification of RBD palm olein with methanol in the presence of a potassium hydroxide (KOH) catalyst yielded biodiesel with a yield of 62.5 percent, proving its mass production capability. The resulting biodiesel meets the ASTM D792 standard for biodiesel fuels in terms of characteristics.N. Kumar and S.K. Mohapatra [7] ran an experiment to optimise the methanol to oil molar ratio, catalyst concentration, reaction time, and reaction temperature in the biodiesel process. To affect process parameter, the Taguchi design technique is employed using L9 orthogonal array. Biodiesel, according to Satish A. Patil and R.R. Arkerimath [8], is a sustainable and environmentally benign fuel. They used the Taguchi technique to optimise the transesterification process for the generation of biodiesel, taking into account parameters including the molar ratio of methanol to oil, catalyst concentration, reaction temperature, reaction duration, and stirring speed, all of which have an impact on biodiesel yield. The results revealed that a 20:1 molar ratio of methanol to oil, a 3% Al2O3 catalyst, a reaction temperature of 65°C, a reaction period of 60 minutes, and a stirring speed of 600 rpm yielded an 80% yield.

Eligharbawy. Et al [9]., outlined, bio diesel represents a closed carbon dioxide cycle because it is derived from renewable biomass sources. The present study was carried out. In order to identify an effective treatment of used cooking oil to get ideal specifications condition to obtain high yield of biodiesel and get the best conversion ratio of used cooking oil to bio diesel. The linear regression analysis concluded that methanol to oil ratio and catalyst concentration have a high positive statically significant effect. E. Kurniashi, P Pardi, [10] summarized that the Taguchi technique is an experimental design that focuses on a variable approach to improving product quality through control operations. Temperature, mole ratio, time reaction, and heterogeneous catalyst ratio are four independent variables with two levels in the Taguchi technique (4x2). The Taguchi method can give a detailed examination of the impact of each process variable.

The suitability of biodiesel production utilizing Benne seed oil was researched, as well as the parameters that govern its production, according to N. V. Mahesh Babu Talupula. [11]. Several methods, such as linear and nonlinear optimization methods, were utilized to find the optimum values, which were then tested using experimental results.

The Taguchi method of optimization is being applied in the current experimental inquiry on biodiesel synthesis using Benne seed oil.

A study was carried out by Elgharbawy, A. S*, Sadik, W. A., and Sadek [12] in order to find an effective treatment of used cooking oil in order to acquire the optimal specification condition for high biodiesel yield and the best conversion ratio of used cooking oil to biodiesel. According to the results of the linear regression analysis, the methanol to oil ratio and catalyst concentration have a substantial positive statistical influence. Temperature has a statistically significant favorable influence. The mixing rate had a highly negative statistical significant effect on the biodiesel production, while the process time had a non-statistically significant negative effect. E Amruth and Sudev L J [13] investigated that Fish oil was employed in a transesterification process using methanol as a solvent and concentrations of sodium hydroxide and di-sodium orthophosphate as catalysts to make biodiesel (mixed base catalyst). The Response Surface Methodology (RSM) tool was used to enhance the transesterification reaction parameters. The Methanol to Oil Ratio (MOR), Reaction Time (RT), and Reaction Temperature (RT) were all evaluated as process factors (RTE). Twenty tests were devised and carried out to obtain the highest production of fish oil biodiesel (FOB). A 94.6 percent FOB yield was achieved. Mohammad Anwara and et al [14], The manufacture of second-generation biodiesel from Australian native stone fruit using an alkali catalyzed transesterification process was optimized using response surface methods in this work. This procedure was optimized by adjusting three variables at three distinct stages. The optimization procedure used methanol: oil molar ratio, catalyst concentration (wt%), and reaction temperature as inputs, with biodiesel production as the main model output. MINITAB 18 was used to create both 3D surface plots and 2D contour plots in order to forecast the best biodiesel yield. Biodiesel characterization included gas chromatography (GC) and Fourier transform infrared (FTIR) examination of the final biodiesel.

II. Materials and Methodology

Palm oil can be produced in a way that is both environmentally friendly and useful to communities. India, as the world's largest importer, is well positioned to stimulate demand for sustainable palm oil and make it mainstream. Palm biodiesel is a biofuel made from palm oil that may be used in compression ignition engines, such as diesel engines, without any modifications. It refers to methyl esters made from palm oil using the 'transesterification' method. Palm oil has a variety of advantages when it comes to biofuel production. Biodiesel is a clean-burning, renewable alternative to petroleum diesel that is manufactured domestically. Using biodiesel as a vehicle fuel improves air quality and boosts energy security.

Corn is a common ethanol feedstock in the United States because of its abundance and simplicity of conversion to ethyl alcohol. Although corn and other high-starch cereals have been transformed to ethanol for thousands of years, its use as a fuel has only recently exploded. Grinding, heating with enzymes, fermentation with yeast, and distillation to remove water are all steps in the conversion process. Two more procedures are included in the production of gasoline ethanol: removing the remainder of the water with a molecular sieve and denaturing the ethanol to render it undrinkable. Corn grain is an excellent biofuel feedstock because of its high starch content and ease of conversion to ethanol.

Properties of the biodiesel

Table 1. Properties of Diesel and Corn/Palm Oil

S. No.	Fuel Property	Diesel
1	Density at 33°C Kg/m^3	862
2	Gross Calorific Value, KJ/Kg	43000
3	Viscosity at 33°C, cSt	3.45
4	Cetane Number	45

5	Ramsbottom Carbon Residue, Wt%	0.1
6	Flash Point, ºC	50
7	Pour Point, ºC	Winter 3 Max, Summer 15 Max
8	Acid Number, mg KOH/gm	0.2 Max

Direct injection (DI) Diesel Engine

The experiment is carried out with a DI diesel engine (made by the Kirloskar business in Pune). The engine's specifications are shown below. The experiment is carried out with a DI diesel engine (made by the Kirloskar business in Pune). The engine's specifications are shown below.

Table 2. Specifications of the DI- Diesel Engine

Rated Horse power:	***5 hp (3.73 kW)***
Rated Speed:	*1500rpm*
No of Strokes:	4
Mode of Injection and injection pressure	Direct Injection, 200 kg/cm^2
No of Cylinders:	1
Stroke	110 mm
Bore	80 mm
Compression ratio	16.5

III. EXPERIMENTATION:

Transesterification is defined as the process in which triglycerides from a variey of feedstock such as nonedible oil seeds, vegetable oils, animal fats or tallow, waste cooking oil, and microbial lipids or single cell oil (from algae, oleaginous yeast, filamentous fungi and bacteria) are converted into fatty acid methyl esters (biodiesel) in the presence of alcohol (methanol or ethanol).the two-stage transesterification procedure which included base transesterification followed by acid transesterification was indicated clearly in some studies [15,16,17]. Microalgae was considered as an alternative feedstock from biomass used for the two-stage direct transesterification process [15]. This technology has overcome disadvantage of the traditional method of lipid estimation proposed by Bligh and Dyer [18]. This decreases using chloroform and methanol, leads to reduce adverse effects on health and environment [19]. A two-stage direct transesterification method using NaOH in first stage and H2SO4in second step was reported by Kumar et al. [11].

Table 3. Properties of palm Biodiesel, Corn Biodiesel & Diesel

Properties	Palm biodiesel	Corn biodiesel	DIESEL
Viscosity at 40°(cST)	4.5	4.14	4.0
Viscosity at 100°(cST)	6.0	8.3	11
Fire point(°c)	133	150	78
Flash point(°c)	174.0	277	98.0
Pour point(°c)	16.0	6	15.0
Acid value(mg KOH/g)	0.336	0.23	0.50
Cetane number	65	58	53
Calorific value(MJ/Kg)	41.3	37.27	46.8
Ash content	0.2	0.17	1.16
Carbon residual(wt %)	0.02	0.05	0.14
Specific gravity	0.88	0.92	0.82
Cloud point	16.0	5	18.0
Density at 40°(Kg/L)	0.855	0.865	0.823

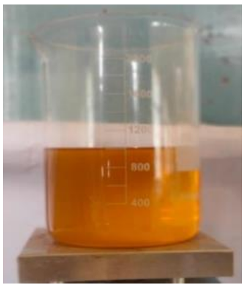


Figure-1: Neat Palm Oil

Figure-2: Neat Corn Oil

Figure-3: Palm Biodiesel

Figure-4: Corn Biodiesel

The ester content can be gained up to 94.5% in optimum condition, including methanol to biomass weight ratio 51.59 (wt/wt) and 51.3 (wt/wt), catalyst to biomass weight ratio 0.67 (wt/wt) and 3.81 (wt/wt), reaction time 19.33 min and 10 min at 90 oC for the first stage and second stage, respectively.The significant development of this technology was mentioned in two researches of Samios et al which was called under a terminology, Transesterification Double Step Process (TDSP). The process includes continuous homogeneous base–acid catalyst steps and is also proven the effectiveness by high reaction rate, easy separation process as well as high conversion. The ester content can be higher than 97% at 60ºC in 60 min for each step and adding 10 and 15 of MeOH/Oil molar ratio, 1.15 wt% of KOH and 15.9 wt% of H2SO4 to oil for first stage and second stage, respectively. The improved TDSP process involves to the reduction of reaction conditions (catalyst content in both stages, MeOH/Oil molar ratio in second stage, reaction time in first stage) and the direct adding of MeOH/H2SO4 solution without cooling the reaction system between the first and the second step.

Minitab is a well-known manufacturer of statistical software for quality improvement. Thousands of universities utilise Minitab software for teaching, and a large number of enterprises trust it. MiniTab is located in State College, Pennsylvania, and has operations in the UK, France, and Australia. Minitab is a statistics tool created by some academics to assist six sigma experts in analysing and interpreting data to aid in the business process. The data input has been streamlined to make it easier to use for statistical analysis and to manipulate the dataset. If trends, patterns, or charts are provided, they are evaluated and interpreted in order to reach a final decision. The answers are presented, and the goods are used to magnify them.

Regression analysis is a proven way for determining which variables have an impact on a certain issue. Regression analysis allows you to safely establish which elements are most important, which factors may be ignored, and how these factors interact. The relationship between one or more predictor variables and the response variable is described by a regression equation. To perform a regression analysis, you must first establish a dependent variable that you believe is influenced by one or more independent factors. After that, you'll need to create a thorough dataset to work with. Using surveys to get data from your target consumers is a great way to get started.

Smoke meter, also known as opacity meters, detect and measure the quantity of light obscured in smoke produced by diesel engines in automobiles, trucks, ships, buses, motorbikes, locomotives, and massive industrial stacks. The smoke meter reading shows the density of smoke, which is a measure of combustion efficiency. As a result, the smoke meter is an ideal diagnostic tool for ensuring regular diesel engine maintenance for greater fuel efficiency and environmental protection.

IV. Results and discussion:

Table 4: Palm Biodiesel samples

S.No	Raw Palm Oil (ml)	Acid Transesterification		Base Transesterification		Yield (ml)
		Methanol(ml)	Acid(ml)	Methanol(ml)	Base(gms)	
1	1000	125	3	127	5.7	762
2	1000	127	2.5	129	6	776
3	1000	120	2.6	132	5.5	799
4	1000	123	2.8	133	5.7	813
5	1000	126	3	120	6	830
6	1000	128	2.7	139	5.9	871
7	1000	130	2.6	127	5.8	864
8	1000	124	2.5	129	6	850
9	1000	127	3.2	128	5.7	839
10	1000	136	2.4	125	6	822

Table.5: Iterations of Palm biodiesel in Taguchi

S.No	Raw Palm Oil (ml)	Methanol (acid)	H2SO4	Methanol(base)	NaOH	Yield
1	1000	120	2.4	120	5.5	762
2	1000	120	2.6	125	5.7	776
3	1000	120	3.0	130	6.0	799
4	1000	120	3.2	133	5.9	813
5	1000	125	2.4	125	6.0	830
6	1000	125	2.6	120	5.9	871
7	1000	125	3.0	133	5.5	864
8	1000	125	3.2	130	5.7	850
9	1000	130	2.4	130	5.9	839
10	1000	130	2.6	133	6.0	822
11	1000	130	3.0	120	5.7	815
12	1000	130	3.2	125	5.5	806
13	1000	136	2.4	133	5.7	783
14	1000	136	2.6	130	5.5	762
15	1000	136	3.0	125	5.9	749
16	1000	136	3.2	120	6.0	733

Table 6: Corn Biodiesel samples

S. No	Raw Palm Oil (ml)	Acid transesterification		Base transesterification		Yield (ml)
		Methanol(ml)	Acid(ml)	Methanol(ml)	Base(gms)	
1	1000	125	3	127	5.7	375.53
2	1000	127	2.5	129	6	395.295
3	1000	130	2.6	132	5.5	416.1
4	1000	133	2.8	133	5.7	438.6
5	1000	136	3	120	6	459.4
6	1000	128	2.7	139	5.9	482.89
7	1000	130	2.6	127	5.8	492
8	1000	134	2.5	129	6	507
9	1000	127	3.2	128	5.7	481.99
10	1000	136	2.4	125	6	467.86

Table7: Iterations of Corn Biodiesel run in Taguchi

S.No	Raw Corn Oil(ml)	Methanol(acid)	H2S04	Methanol(base)	NaOH	Yield
1	1000	125	2.5	125	5.5	375.530
2	1000	125	2.8	129	5.7	395.295
3	1000	125	3.0	133	5.9	416.100
4	1000	125	2.4	139	6.0	423.500
5	1000	127	2.5	129	5.9	429.380
6	1000	127	2.8	125	6.0	438.600
7	1000	127	3.0	139	5.5	459.400
8	1000	127	2.4	133	5.7	482.890
9	1000	130	2.5	133	6.0	492.000
10	1000	130	2.8	139	5.9	507.000
11	1000	130	3.0	125	5.7	481.990
12	1000	130	2.4	129	5.5	467.860
13	1000	133	2.5	139	5.7	459.870
14	1000	133	2.8	133	5.5	432.640
15	1000	133	3.0	129	6.0	429.120
16	1000	133	2.4	125	5.9	407.320

Fig-1: Main Effect Plot for Means of Palm Oil

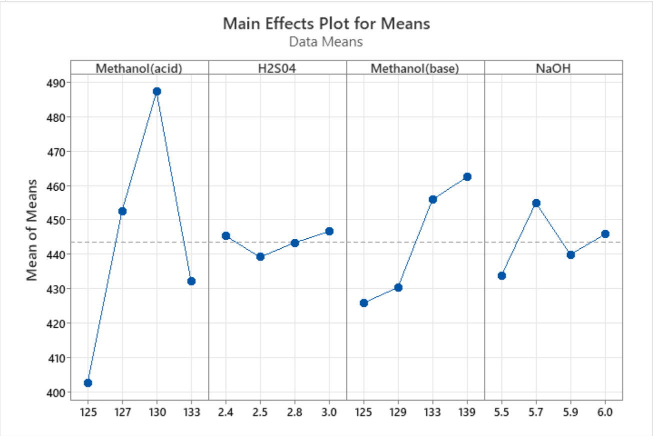


Fig-2: Main Effect Plot for Means of Corn Oil

We can see from the methanol versus yield graph (figure-1) that using 125ml of methanol with acid and 133ml of methanol with base during two stage transesterification results in a high yield.

Response Table for Signal to Noise Ratios

Nominal is best (-10×Log10(s^2))

We can see from the methanol versus yield graph (figure-2) that using 130ml of methanol with acid and 139ml of methanol with base during two stage transesterification results in a high yield

Analysis of Regression Equation

Yield = 815 - 2.57 Methanol(acid) - 3.5 H2SO4
+ 2.18 Methanol(base) + 8.9 naoh

Variance

Table 8: Variance for regression analysis of Palm oil

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	5638.9	1409.73	0.78	0.560
Methanol(acid)	1	3716.5	3716.45	2.06	0.179
H2SO4	1	19.6	19.60	0.01	0.919
Methanol(base)	1	1856.1	1856.15	1.03	0.332
Naoh	1	46.7	46.72	0.03	0.875
Error	11	19834.8	1803.17		
Total	15	25473.8			

Regression Equation

Yield = -528 + 3.93 Methanol(acid) + 5.5 H2S04 + 2.88 Methanol(base) + 12.6 NaOH

Analysis of Variance

Table 9: Variance for regression analysis of Corn oil

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	5934.0	1483.50	1.12	0.395
Methanol(acid)	1	2265.1	2265.09	1.71	0.217
H2S04	1	27.2	27.16	0.02	0.889
Methanol(base)	1	3547.6	3547.60	2.68	0.130
NaOH	1	94.1	94.14	0.07	0.795
Error	11	14548.9	1322.62		
Total	15	20482.9			

A graphical technique for detecting if a data set is nearly uniformly distributed is the normal probability plot. The dots represent an approximate straight line, and the data is shown against a theoretical normal distribution. Anomalies from the norm can be seen as deviations from the straight line. Deviations from the straight line show deviations from the norm with the dots forming an approximate straight line, the data is plotted versus Methanol, catalyst, and yield. Deviations from the norm are shown by deviations from the straight line for a palm biodiesel. The points on this normal probability plot (figure-3) of 16 normal random numbers form a nearly linear pattern, which indicates that the normal distribution is a good model for this data set.

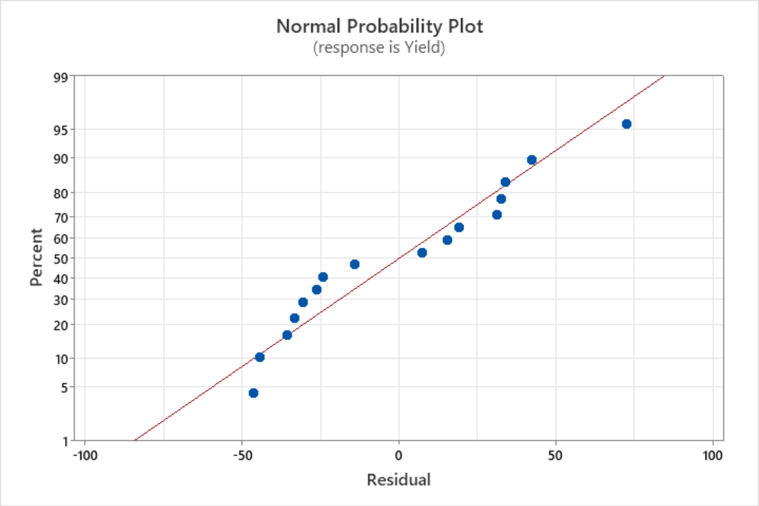
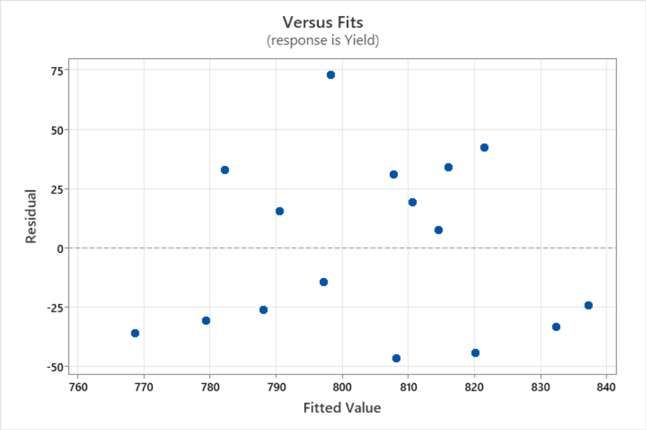


Fig-3: normal probability plot for Palm Oil



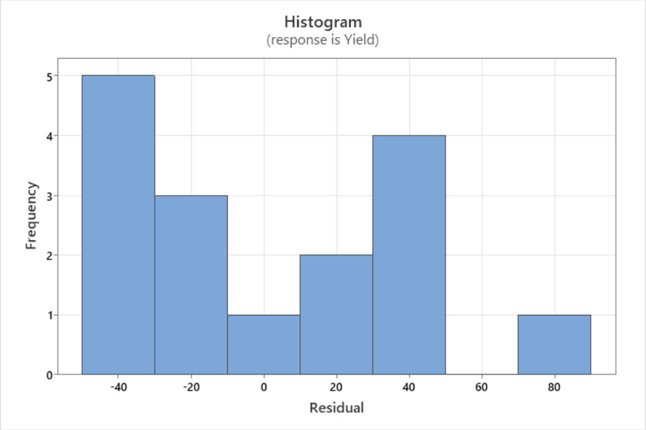


Fig-4: Equity of variance plot for Palm Oil **Fig-5: Histogram for Palm Oil**

From the above normal probability graph we can observe that the residues lie near to the diagonal line which represents that the normal probability plot is good to consider but we should also check with the equity of variance plot pattern, which indicates that the normal distribution is a good model for this data set.

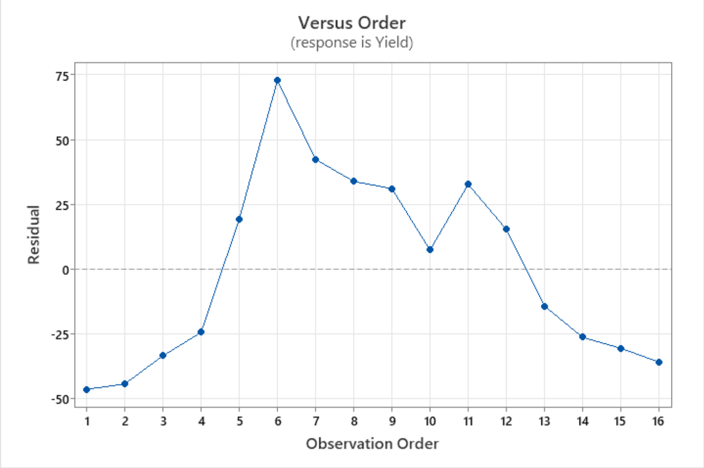


Fig-6: Versus Order plot for Palm Oil

From the above versus fit plot we can observe that the residues are scattered randomly which is not a good model to consider as it represents inequality of variance

The p value of less than 0.56 for regression in the Taguchi output at the conclusion of our Taguchi table indicates that there is a significant difference between at least two levels of regression; to verify this, we must examine the criteria of normality and equality of variance. versus fit plot (figure-4) demonstrates the variance of residuals, which are not identical, by looking into separate plots. As a result, we cannot assume equal variance between levels; on the normality plot (figure-3), the residuals are near to the diagonal line, which reflects an ideal normal distribution. As a result, the aforementioned hypothesis is ruled out. In order to consider both the normal probability and equity of variance needs to be satisfied.

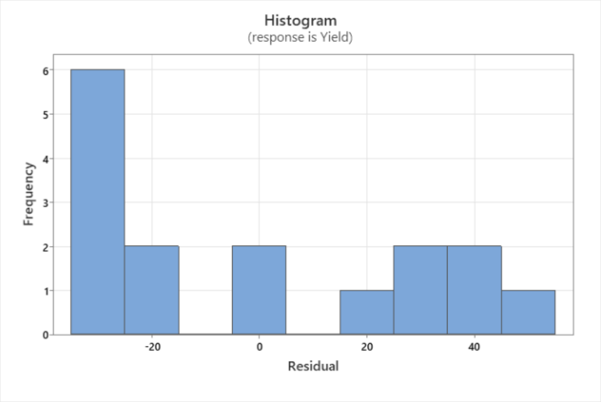


Fig-7: Normal Probability plot for Corn Oil

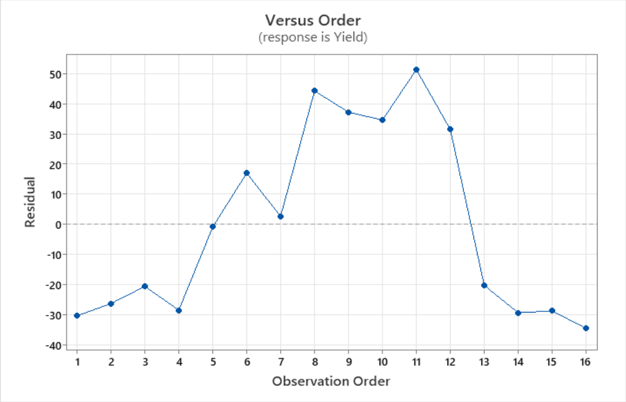


Fig-8: Equity of variance plot for Corn Oil.

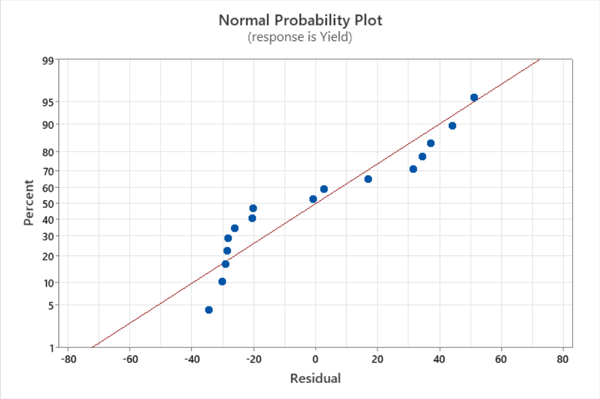


Fig-9: Histogram for Corn Oil

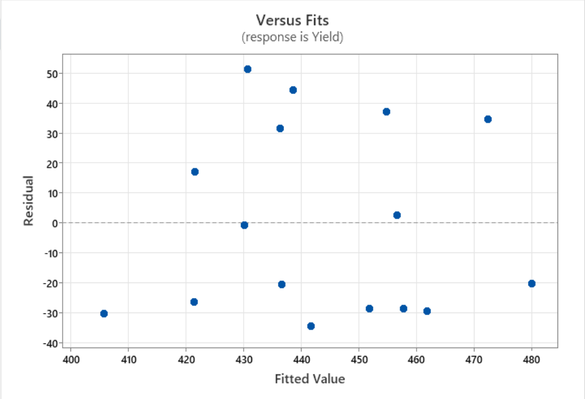


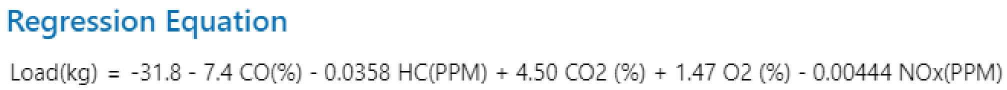
Fig-10: versus for order Corn Oil

From the above normal probability graph we can observe that the residues lie near to the diagonal line which represents that the normal probability plot is good to consider but we should also check with the equity of variance plot. From the above versus fit plot we can observe that the residues are scattered randomly which is not a good model to consider as it represents inequality of variance.

The p value of less than 0.395 for regression in the Taguchi output at the conclusion of our Taguchi table (Table-9) indicates that there is a significant difference between at least two levels of regression; to verify this, we must examine the criteria of normality and equality of variance. The versus fit plot (figure-8) demonstrates the variance of residuals, which are not identical, by looking into separate plots. As a result, we cannot assume equal variance between levels; on the normality plot (figure-7), the residuals are near to the diagonal line, which reflects an ideal normal distribution. As a result, the aforementioned hypothesis is ruled out.

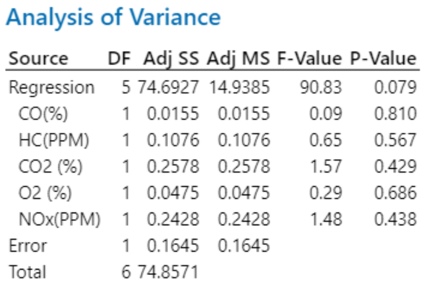
Table 10: Variance of emissions of diesel with load conditions

S.No	Load(kg)	CO(%)	HC(PPM)	CO2 (%)	O2 (%)	NOx(PPM)	RESI
1	0	0.143	13	1.9	17.74	354	-0.060378
2	1	0.130	18	2.57	17.07	541	0.136469
3	3	0.078	9	3.63	15.48	717	0.224747
4	6	0.057	11	4.77	13.73	715	0.123442
5	7	0.043	12	5.03	13.51	717	0.217350
6	8	0.040	20	5.69	12.57	703	-0.169351
7	9	0.052	10	5.90	12.37	718	-0.022785



Regression Equation

Load(kg) = -31.8 - 7.4 CO(%) - 0.0358 HC(PPM) + 4.50 CO2 (%) + 1.47 O2 (%) - 0.00444 NOx(PPM)



Analysis of Variance

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Source      DF  Adj SS  Adj MS  F-Value  P-Value
Regression   5 74.6927 14.9385    90.83    0.079
  CO(%)      1  0.0155  0.0155     0.09    0.810
  HC(PPM)    1  0.1076  0.1076     0.65    0.567
  CO2 (%)    1  0.2578  0.2578     1.57    0.429
  O2 (%)     1  0.0475  0.0475     0.29    0.686
  NOx(PPM)   1  0.2428  0.2428     1.48    0.438
Error        1  0.1645  0.1645
Total        6 74.8571
```

Table 11: Variance of emissions of palm biodiesel with load conditions

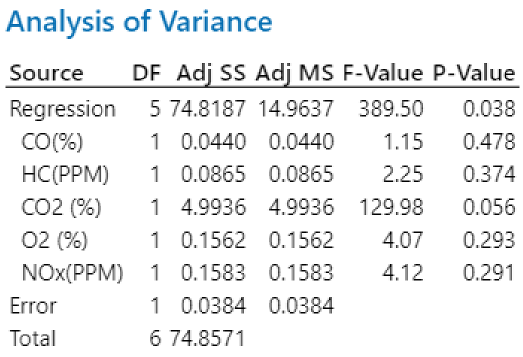
S.No	Load(kg)	CO(%)	HC(PPM)	CO2 (%)	O2 (%)	NOx(PPM)	RESI_2
1	0	0.144	11	2.17	15.74	340	0.027470
2	1	0.133	16	2.77	15.07	511	0.064112
3	3	0.081	8	3.83	13.48	685	-0.110310
4	6	0.051	9	4.97	11.73	689	0.134346
5	7	0.045	10	5.23	13.51	685	0.005690
6	8	0.039	18	5.89	10.57	664	-0.056650
7	9	0.055	9	6.10	10.37	690	-0.009720

Regression Equation

Load(kg) = -10.06 + 8.42 CO(%) - 0.0337 HC(PPM) + 3.034 CO2 (%) + 0.232 O2 (%) - 0.00290 NOx(PPM)

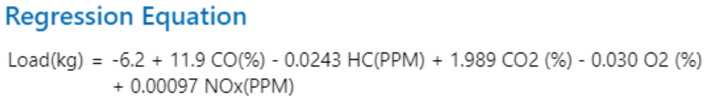
Table 12: Variance of emissions of corn biodiesel with load conditions

S.No	Load(kg)	CO(%)	HC(PPM)	CO2 (%)	O2(%)	NOx(PPM)	RESI
1	0	0.148	8	2.37	15.34	361	0.025682
2	1	0.0139	14	2.97	14.97	533	-0.091747
3	3	0.093	6	3.91	14.48	691	0.226341
4	6	0.061	7	5.97	12.73	707	-0.532301
5	7	0.051	8	6.23	14.21	703	0.143160
6	8	0.043	16	6.89	11.57	684	0.0588587
7	9	0.062	8	7.10	10.37	698	0.170007



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	74.8187	14.9637	389.50	0.038
CO(%)	1	0.0440	0.0440	1.15	0.478
HC(PPM)	1	0.0865	0.0865	2.25	0.374
CO2 (%)	1	4.9936	4.9936	129.98	0.056
O2 (%)	1	0.1562	0.1562	4.07	0.293
NOx(PPM)	1	0.1583	0.1583	4.12	0.291
Error	1	0.0384	0.0384		
Total	6	74.8571			



Regression Equation

Load(kg) = -6.2 + 11.9 CO(%) - 0.0243 HC(PPM) + 1.989 CO2 (%) - 0.030 O2 (%)
+ 0.00097 NOx(PPM)

The p value of less than 0.079 for regression of diesel at the conclusion of our Taguchi table indicates that there is a significant difference between at least two levels of regression; to verify this, we must examine the criteria of normality and equality of variance. From the above normal probability graph we can observe that the residues lie near to the diagonal line which represents that the normal probability plot is good to consider but we should also check with the equity of variance plot pattern, which indicates that the normal distribution is a good model for this data set. From the above versus fit plot we can observe that the residues are scattered almost equally which represents a good model to consider as it represents equality of variance. So the hypothesis can be considered for diesel.

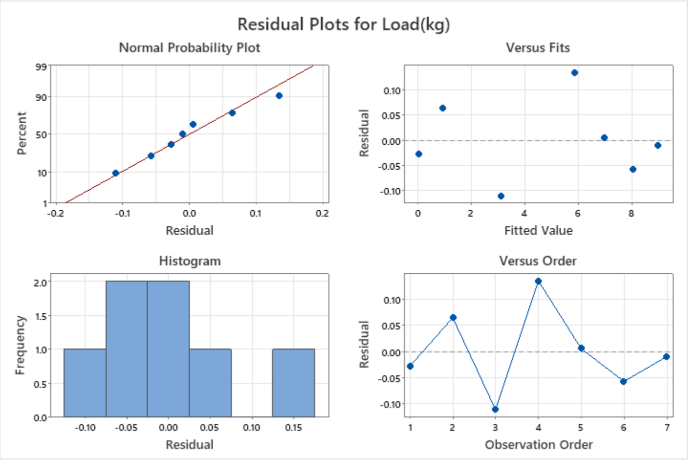


Fig-11: Regression graphs for palm biodiesel

The p value of less than 0.038 for regression of palm biodiesel at the conclusion of our Taguchi table indicates that there is a significant difference between at least two levels of regression From the below normal probability graph we can observe that the residues lie near to the diagonal line which represents that the normal probability plot is good to consider but we should also check with the equity of variance plot pattern, which indicates that the normal distribution is a good model for this data set. From the below versus fit plot we can observe that the residues are scattered equally which is a good model to consider as it represents equality of variance. So the above hypothesis can be considered for palm biodiesel.

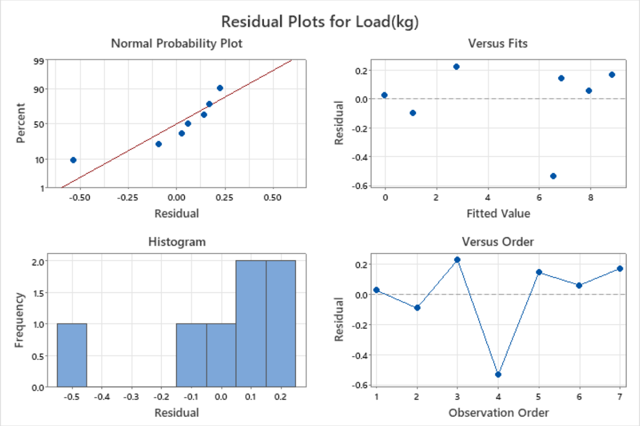


Fig-12: Regression graphs for corn Biodiesel

The p value of less than 0.123 for regression of corn biodiesel at the conclusion of our Taguchi table indicates that there is a significant difference between at least two levels of regression From the above normal probability graph we can observe that the residues lie near to the diagonal line which represents that the normal probability plot is good to consider but we should also check with the equity of variance plot pattern, which indicates that the normal distribution is a good model for this data set. From the above versus fit plot we can observe that the residues are scattered normally which is a good model to consider.

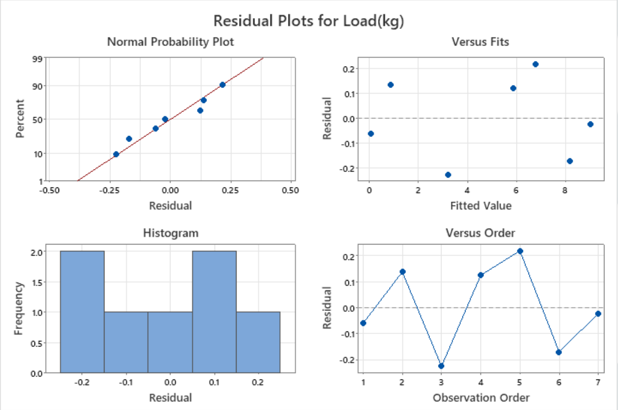
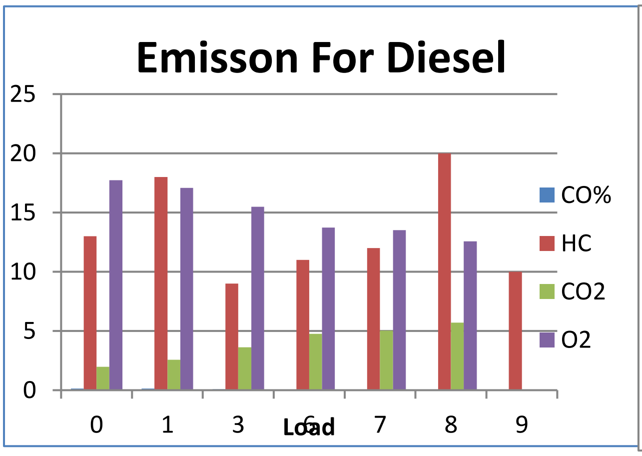
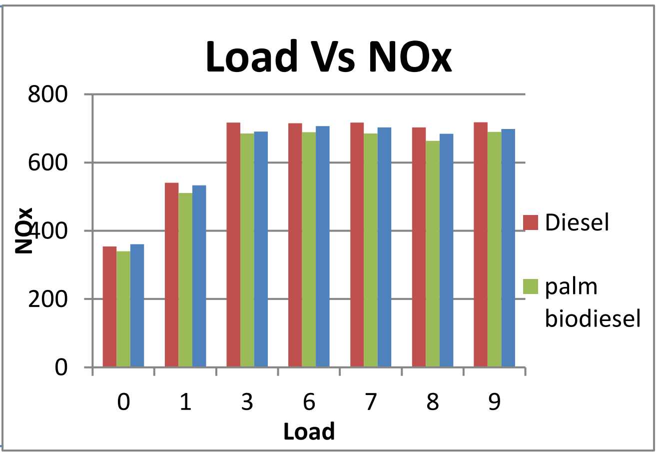


Fig-13: regression graphs for diesel

Diesel: -

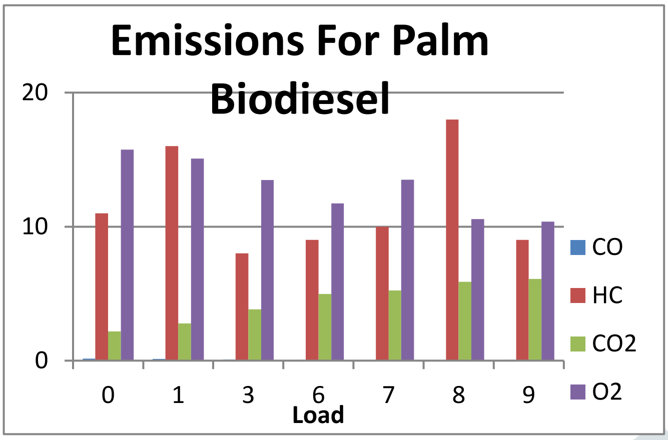


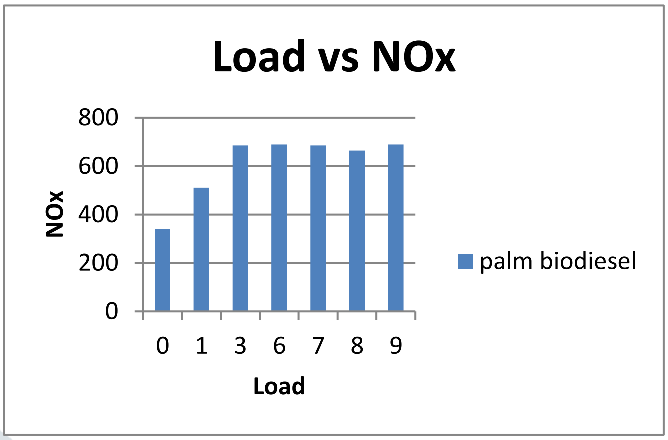


From the histogram of emission for diesel. The x axis depicts load, and the y axis reflects CO, HC, CO2, and O2 emissions in the provided graph of diesel emissions. It is clear that the CO% is minimal, and that maximum emission levels of HC and CO2 are recorded at load value of 8, and that as load increases, the emission of O2 levels declines. The maximum level of O2 emissions occurs when there is no load.

From the histogram of load vs NOx. The x axis depicts load, and the y axis reflects NOx levels of Diesel, palm biodiesel and cord biodiesel emissions in the provided graph of diesel emissions. The maximum level of NOx emissions for diesel can be seen at full load, while the maximum level of NOx emissions for corn biodiesel was seen at half load. For palm biodiesel, the maximum level of NOx emissions was shown at load levels of 6 and 8.

Palm Biodiesel: -

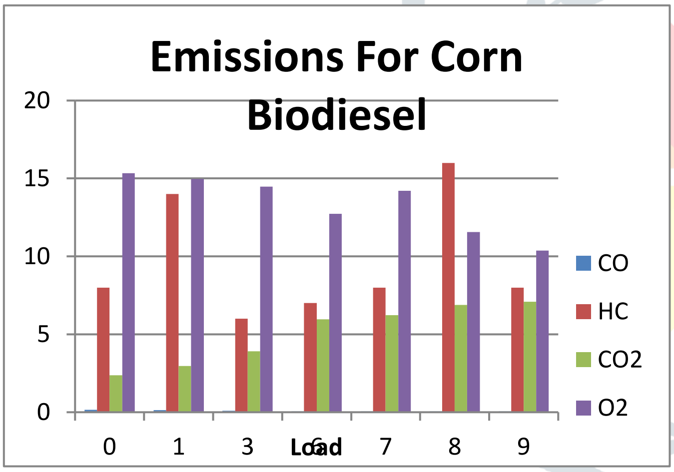


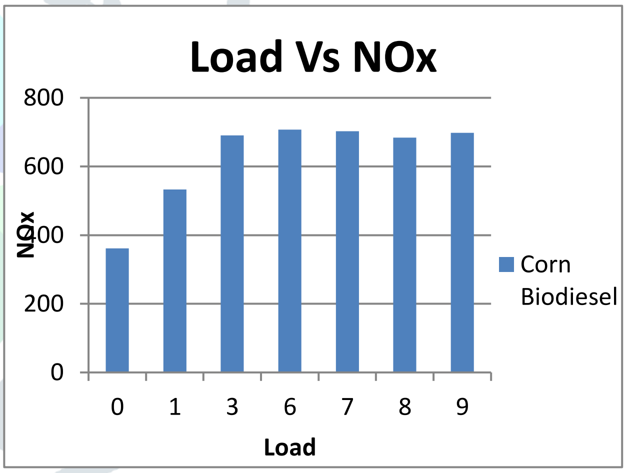


From the histogram of emission for palm biodiesel. The x axis depicts load, and the y axis reflects CO, HC, CO2 and O2 emissions in the provided graph of palm biodiesel emissions. According to the above emissions for palm biodiesel histogram, at load levels of 8, the maximum level of HC is seen, and at full load, the emission of CO2 for palm biodiesel is maximum, and as the load increases, the emission of O2 gradually decreases and is maximum at no load condition.

From the histogram of load vs NOx for palm biodiesel The x axis depicts load, and the y axis reflects NOx levels of palm biodiesel emissions in the provided graph of diesel emissions. The load vs. NOx histogram clearly shows that with palm biodiesel, NOx emissions are highest at full load.

Corn Biodiesel: -





From the histogram of emission for corn biodiesel The x axis depicts load, and the y axis reflects CO, HC, CO2 and O2 emissions of corn biodiesel in the provided graph of diesel emissions. According to the above emissions for palm biodiesel histogram, at load levels of 8, the maximum level of HC is seen, and at full load, the emission of CO2 for corn biodiesel is maximum, and as the load increases, the emission of CO2 gradually increases and is maximum at full load condition. The emission levels of CO are negligible. At no load condition the emission levels of O2 are maximum.

From the histogram of load vs NOx for corn biodiesel The x axis depicts load, and the y axis reflects NOx levels of corn biodiesel emissions in the provided graph of diesel emissions. The load vs NOx histogram clearly shows that with palm biodiesel, NOx emissions are maximum at load level of 6 and 7.

Conclusion:

From the above load Vs NOx graph it is clear that at every load condition the emission of NOx for palm biodiesel is low when compared to corn biodiesel. The NOx emissions depend upon the O2 content present in the fuel. In palm biodiesel the O2 levels are less than that of diesel and corn biodiesel which results in less emission of NOx.

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