(Optimization of transesterification process for linseed oil applying response surface method (RSM) and its application in diesel engines)

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ABSTRACT

The objective of this study was to investigate in transesterification study of linseed with methanol in the present of potassium hydroxide (KOH) for the production of biodiesel fuel. Experiments were conducted using milled linseeds, methanol as a solvent and potassium hydroxide as a catalyst. The influence of methyl alcohol: oil ratio (molar ratio) (6-12), catalyst concentration (.5-1.5 %wt. oil content), stirring rate (12000 rpm), reaction temperature (55-65C^{o}) and reaction time (90min) was examined to define optimum biodiesel yield and biodiesel quality after water washing and drying. The reaction time and stirring rate were fixed by preliminary tests. molar ratio, reaction temperature and catalyst concentration parameters were investigated by a set of experiments that designed by "Design Expert software (edition 11; Stat-Ease, Inc., USA) in response surface methodology (RSM) based box-Behnken design (BBD) method with duplication of each test due to improve confidence limit. In the long run, optimal conditions were: 0.92% of catalyst KOH, 8.68 for molar ratio, reaction temperature of 61.57 C^{o}, reaction time of 90 minutes, and agitation rate of 12000 rpm. In the lab scale and using these conditions, 94.1241% yield of biodiesel. Then applied this Biodiesel oil in diesel engine which Pour point and cloud point of the fuel has been measured to be 6.25 C^{o} and 3.17 C^{o}respectively Flash point 151C^{o} Carbon residue 0.018%mass Ash content 0.0013 %mass The in-cylinder pressure and HRR were lower for linseed biodiesel compared with diesel fuel. This is ascribed to the low energy content and high latent heat of vaporization that cause a deterioration in the combustion process.

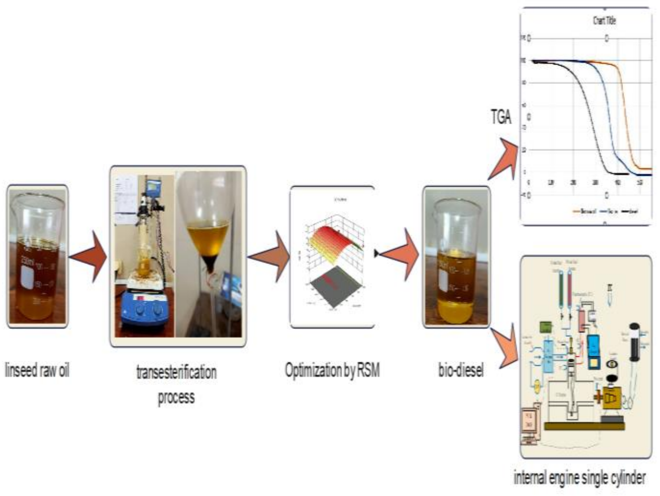
The BTE reduced while the BSFC increased for the linseed biodiesel compared with the diesel fuel. The smoke opacity, UHC, and CO.

levels were lower for linseed biodiesel compared with diesel oil. The NO_x level increased for the linseed biodiesel compared with diesel oil.

Keywords: Biodiesel; Optimization; Response surface methodology; Diesel engine; linseed oil.

I. INTRODUCTION

There is no doubt that nowadays, energy plays the key role in our societies. No one can deny the direct and indirect influences of energy on the economy, health, transportations and etc. Transportation is almost dependent on the fossil-based liquid fuels such as gasoline, diesel, and jet fuel. The increasing need for energy, especially in the transport sector has caused most of the developed countries or developing ones are thought about other new energy sources. The present orientation of climate change towards the global warming has resulted in diverse changes in the geologic, climatology, social, economic and biologic processes universal. The greenhouse gas emissions from transport are one of the reasons for global warming[1]. Not only those countries that have oil importing but also those that have oil reserves such as Iran, United Stated, Russia have a problem with energy production for their industrial, transport and etc. Thus, depletion of the fossil oil, pollution caused by the combustion of the fossil oils, and increasing energy costs force the countries to think about renewable energy sources such as solar, the wind, and biodiesel. Biodiesel is a renewable energy source unlike other petroleum products that will last million years to come into existence. Biodiesel has been found to be a promising future fuel. Biodiesel proposes many benefits in terms such as environmental than diesel. For example, it is made from renewable resources and also it is biodegradable unlike petroleum-based diesel[2]; it is readily mixed with diesel in any ratio; Biodiesel can be used in 100% (B100) or in blends with petroleum diesel. For e.g.: B20 is called as 20% blend of biodiesel with 80% diesel fuel;[1] it decreases dependency on imported oil; it is non-toxicant and non-flammable; it has slight amount of Sulfur; it has high Cetane number and flash point, it can also be used in existing oil heating systems and diesel engines without making any or slight alterations; it has good lubricity. Furthermore, one of the main biodiesel fuel advantages is that it is less polluting than petroleum diesel. There are some disadvantages of using biodiesel that must be considered such as higher cloud point and pour point, higher nitrogen oxide emissions, lower engine power and speed, cold start problem and so on. Also, biodiesel demonstrates higher density and viscosity than diesel. There are many methods for biodiesel production. But transesterification is the industrial and economical method. Transesterification method is a chemical way to synthesize biodiesel. In this method, fatty acids and alcohol are reacted in present of catalyst and at the end of the process, the two main by products are derived, glycerin (used in soaps) and methyl esters or biodiesel[2]. The stoichiometry of transesterification reaction involves 3 mol of methanol/mol of triglyceride ensuing in 3 mol of ester and single mol of the glycerol. Therefore, the degree of transesterification and other associated side reactions are dependent on the type of feedstock, catalyst concentration, alcohol/oil molar ratio and temperature of the reaction. Linseed belonging to Linaceae is an annual dicotyledonous crop, which is cultivated in Pakistan either for seed oil or fiber. Linseed oil is considered as drying oil and frequently used in varnishes and paints. Although linseed oil is edible, its utilization is very limited due to its strong odor and flavor[3]. The aim of the current investigation was to determine the optimum conditions for the production of linseed oil fatty acid methyl esters via base (KAOH) catalyzed transesterification, and its optimization by analytical techniques like RSM method. Oil pH was determined by placing 2 gm of the oil sample into a clean dry 25 mL beaker. 25 mL of hot distilled water was added to the sample in the beaker and stirred slowly for a few min. The stirred mixture was cooled to 25 C in a water bath. The pH electrode was standardized with buffer solution, immersed into the sample and the pH value was Recorded. For biodiesel production, the crude oil was subjected to base catalyzed transesterification. The pellets of potassium hydroxide at 0.5, 1 and 1.5% (w/w oil) were dissolved in methanol and stirred on a magnetic stirrer. The molar ratio of methanol to oil was (6,9,12):1. Reaction was conducted at temperatures varying from 55, 60, and 65o C. The reaction was proceeded for 90min. After the completion of transesterification reaction, the mixture was placed overnight to separate the biodiesel and glycerin phases. To remove the excess of methanol, catalyst and soap produced during the reaction, biodiesel phase was washed with warm distilled water and subsequently dried by using hot plate at 120 rpm for 20min at 100o C. The yield of biodiesel was determined on % w/w conversion of linseed oil to biodiesel. then combustion, performance and emissions were investigated in a single cylinder, four stroke, DI diesel engine fueled with linseed oil biodiesel diesel fuel mixtures (L10, L20 and L30) at various engine loads including 0 , 25 , 50 , 75 , 100 Nm [4]. The test engine was operated at 1500 rpm and various engine loads including 0 , 25 , 50 , 75 Nm and full load. Fuel injection advance was kept constant at 24 °CA BTDC that is the original value of the test engine. Full load means that diesel fuel pump throttle position is at maximum level. The chemical specification of the test fuels are given in Table 2. Fuel consumption was measured with precision scale and time interval recorder.



2.MATERIALS AND METHODS

2.1. Materials

Vegetable oils (linseed oil) was purchased from the local market; KOH Pellets (99%purity grade) and methanol (99% pure)

2.2. Design of experiment

The biodiesel production from linseed oil using KOH catalyst condition was optimized using RSM methods. Table 2 shown the process parameters (independent variables) and the range of levels used for experimentation. RSM-based BBD was used for studying the effects of process parameters on biodiesel yield. In the BBD approach total of fifteen experimental runs were designed. A steady reaction time of 90min and range of three levels were chosen based on preliminary performed experimentation.

Table.1. Properties of linseed raw oil.

Properties	Unit	Linseed raw oil
Density (15 C)	gm/cm^3	0.893
Kinematic viscosity (40 C)	mm^2/sec	26.24
Flash point	(C)	265
Cloud point	(C)	3.5
Pour point	(C)	14.65

2.3. Response surface methodology (RSM)

Response surface methodology (RSM) is a collection of statistical mathematical methods beneficial for evolving, refining, and optimizing process. The objective of the correct design of experimentation is to enhance a response that is influenced by numerous self-governing parameters. Based on the controlled value of independent variables the output is obtained from well-designed regression analysis. The design of the experiment (DOE) and response surface methodology (RSM) are broadly utilized in the optimization of the biodiesel production process. DOE technique is valuable for acquiring most extreme data from a negligible number of all-around arranged investigations by shifting at the same time all the cycle factor, while the RSM is an assortment of numerical and measurable parameters for building an experimental model associating result with the powerful process factors. RSM has two models based on linearity or polynomial behavior that is a first-order model and the second-order model. Here, the regression analysis was performed on the experimental yield data to assess the response of biodiesel yield as y function (refer eq. (3)) fitted for a quadratic second-order polynomial equation, given by;

$$y = B_0 + \sum_{i=1}^{n} B_i X_i + \sum_{i=1}^{n} B_{ii} X_i^2 + \sum_{i=1}^{n}\sum_{j=1}^{i-1} B_{ij} X_i\, X_j + \varepsilon_i \qquad (1)$$

where y is the predicted response value, B_i and B_{ij} are regression coefficients obtained and interaction effect of x_1, x_2, and x_3 ..., while n is the number of independent variables and ε is the random error. Box-Behnken design (BBD) is the type of design methods of RSM. The BBD has treatment combinations at the mid-level of the edge of the experiment space and requires at least three continuous factors. The BBD ensures that all factors are not set to their high levels at the same time. For the development of BBD, the number of experiments (N) is obtained by expression N = 2n (n-1) + m; where 'n' is the number of independent variables and 'm' denotes the number of center points. Here, both 'n' and 'm' have a value of 3. This makes BBD to have 15 experimental runs for 3 levels and 3 factors as shown in Table 3. Using Design- expert software (edition 11, stat-Ease Inc., USA), experimental yield data of BBD (15 experimental runs) was used as input to examine optimized biodiesel yield. ANOVA was carried out on the experiment yield values to determine the coefficient of the second-order polynomial model. ANOVA results give a relationship among the variations caused by experimental values and assert suitability of the predicted model. This is verified by analyzing the values of terms such as sum of the square root (SS), the mean square (MS), p value, the fischer test (F-test), and the 'lack of fit' test (LOF). The evolution of the model is done by the coefficient of determination (R^2) and the accuracy of the obtained quadratic polynomial model is also evaluated. Significance of model coefficients are checked by F-test.

2.4. Experimental Procedure

Firstly, the required amount of oil was filtered and weighed. Oil and the reactor were preheated up to the reaction temperature to remove moisture, if present. The measured amount of alcohol (methanol) and catalyst (KOH) were mixed properly, at room temperature, to prepare a homogeneous solution. Preheated oil and homogeneous solution were poured inside the reactor. Experiments were designed to study the effects of reaction parameters and to determine kinetic rate law constants (Table3).The system was then closed and stirred at a fixed stirring rate. The reactions were performed at atmospheric pressure. All reactions and sample-estimations were repeated to ensure reproducibility. For preliminary runs, the total reaction was carried out for 90 min. Samples collected were kept in ice cold water to arrest the further progress of the reaction. The mixture was poured into the separating funnel and hung out for sufficiently long time (24 h) to separate due to gravity difference. The upper layer contains predominately the linseed methyl esters (LME), biodiesel (light yellow color), and the lower layer contains the glycerol (dark color). The biodiesel was washed with warm water to remove the unreacted dissolved catalyst. Unreacted methanol in biodiesel was recovered using simple distillation where biodiesel was heated to 100 C for 30 min. Purified biodiesel was dried and the product weight was measured for yield calculate

Table 2 Independent variables and range of levels used for experimentation.

Process Variables	Levels for Variables		
	-1	0	1
Molar ratio (A)	6	9	12
KOH (B)	.5	1	1.5
Temp (c)	55	60	65

It was observed that after the completion of the reaction, the reaction mixture gets separated into two layers. The top layer comprises FAME with a trace of unconverted oil and the lower thick brown-colored layer is of glycerol, they are separated by using the separation funnel. After that, three-time washing of biodiesel with distilled water was done to remove the KOH catalyst and traces of unreacted oil. Sample is then dried to eliminate water traces to obtain the pure biodiesel.

The percentage biodiesel yield was determined by utilizing the equation (2) .

$$\%Yield = \frac{(Weight\ of\ Biodiesel\ Produced, g) \times (\%FAME\ from\ GC)}{Weight\ of\ Oil, g} \times 100 \quad (2)$$

for each run with methanol and KOH catalyst as per DOE runs

(refer eq no.3)

$$Triglyceride + 3Methanol \overset{KOH}{\rightleftarrows} Glycerol + 3FAME \qquad (3)$$

Figure 2 Linseed raw oil

Figure3 Transesterificati process

Table 3. List of observations considered in DOE for BBD. (Bold term is maximum yield value)

	Molar ratio(A)	KOH (wt%)(B)	Temp c (C)	Yield %
1	6.00	0.50	60.00	89.75
2	12.00	0.50	60.00	88.34
3	6.00	1.50	60.00	82.35
4	12.00	1.50	60.00	84.64
5	6.00	1.00	55.00	91.98
6	12.00	1.00	55.00	87.55
7	6.00	1.00	65.00	91.053
8	12.00	1.00	65.00	88.976
9	9.00	0.50	55.00	89.75
10	9.00	1.50	55.00	90.7407
11	9.00	0.50	65.00	89.978
12	9.00	1.50	65.00	90.5229
13	9.00	1.00	60.00	93.873
14	9.00	1.00	60.00	93.95
15	9.00	1.00	60.00	94.12

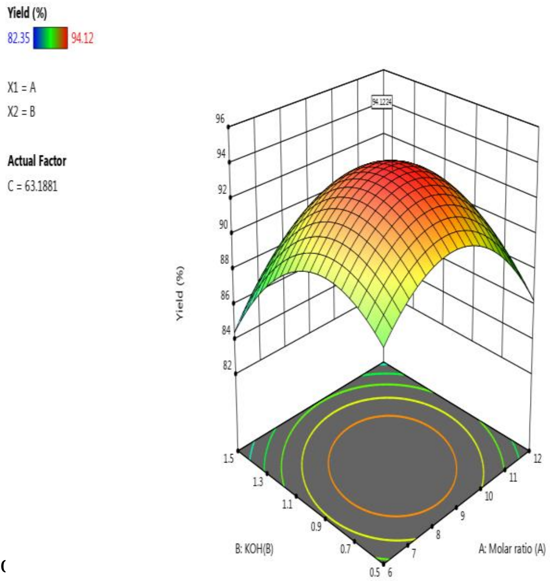


Figure 4 response surface plot and their relative 3-D for second order model.

2.5. Characterization and analytical method

(TGA) analysis of Linseed raw oil, Biodiesel oil and Diesel which *The optimal pyrolysis temperature of linseed raw and Biodiesel oil were determined using TGA at Biofuel lab, Benha faculty of engineering. TGA analysis was performed in a nitrogen atmosphere at temperatures ranging from 30 C to 700 C at a heating rate of 10 C/min, as shown in Fig.7.*

Table 4. Properties of linseed raw oil, Biodiesel oil and Diesel

Properties	Unit	Linseed oil	Linseed Biodiesel	Diesel
Density (15 C)	gm/cm^3	0.893	0.852	0.82-0.86
Kinematic viscosity (40 C)	mm^2/sec	26.24	3.95	1.9-4.1
Flash point	(C)	265	151	>52
Cloud point	(C)	3.5	3.17	_
Pour point	(C)	14.65	6.25	_
Carbon residue	%mass	0.440	0.018	0.15-

				0.35

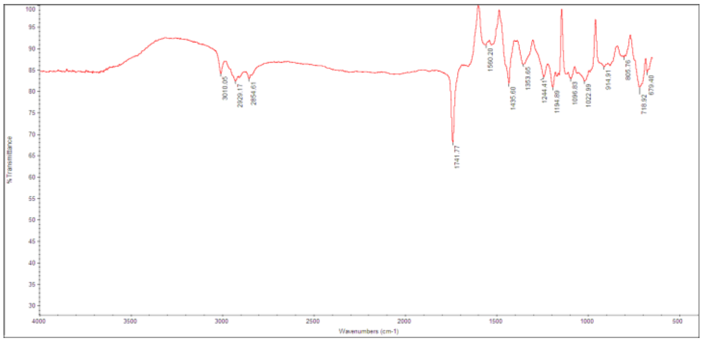


Fig.5.FTIR band of Linseed Biodiesel Oil (optimum condition)

3.DIESEL ENGINE TEST RIG

A diesel engine facility, cylinder pressure measuring system, engine performance assessment system, and other components comprised the experimental system. as well as exhaust analysis devices Figure 6 depicts the arrangement. Table 5 summaries the technical characteristics of the CI engine plant. Details engine performance, combustion pressure measuring system. Table 6 shows the assessment system and the exhaust analysis system. A Kistler piezoelectric pressure sensor was used to detect the cylinder pressure. water-cooled pressure sensor (model 606; pressure range) up to 25 MPa with a sensitivity of 2.75 pc/MPa) linked to a Kistler charge amplifier (type 5018A, 10 MPa, Engine Draft). Compensation measurement mode (DrCo). Compensation measurement mode (DrCo). The crank angle encoder type LM12-3004NA, with a detection distance of 4 mm and a DC voltage range of up to 36 V, was calibrated to perform well at the piston top dead centre (TDC). A digital linear displacement was used to identify the location of the TDC in relation to the position of the proximity (Sony-Magnescale LY-1115). The injector was removed during this procedure, and the linear displacement sensor was attached to the piston head. The flywheel was slowly turned higher until the device reading became inflected (the digital liner displacement had a sensitivity of 5µm). The proximity sensor was tuned to be sensitive solely to this area, which was designated as the TDC. This technique was carried out three times in order to confirm the proximity measurement at the TDC.

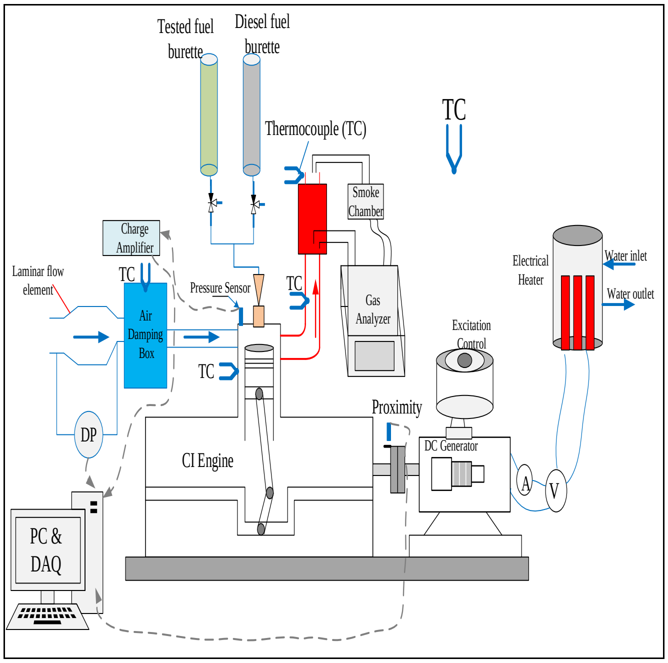


Fig.6. Diagram of the test engine facility layout.

Table 5 Test rig specs

Engine model	Deutz F1L511, single-cylinder
Aspiration	Naturally aspirated
Capacity	824 cm^3
Bore × stroke	100 mm × 105 mm
Cooling type	Air-cooled
Geometric compression ratio	17:1
Fuel injection timing	24 °CA bTDC
Injection pressure	175 bar
Pump type	Diaphragm feed pump
Maximum torque	44 Nm @ 900 rpm
Rated power × speed	5.7 kW × 1,500 rpm

Table 6. Descriptions of the used instruments

Parameter	Instrument/sensor	Scale
Data sampling, processing, and storage	NI-PCI-6251 and LabView	
Engine speed	Digital stroboscope (DS-303)	250–8,000 rpm
Air volume flow rate	Differential pressure transducer (Setra 239)	0–1,245 Pa
Fuel volume	Cylinder burette	0–50 mL

flow rate		
Temperature	Type K thermocouple	-200–1,370 °C
O_2	Emissions analyzer (Ecom J2KNPro) NDIR / Electrochemical cells	0–21 vol%
CO		0–6.3 vol%
HC		0–4 vol%
NO_x		0–5,000 ppm
CO_2		0–20 vol%
SO_2		0–5,000 ppm
Smoke opacity	Smoke chamber (AVL Di Smoke 4000)	0%–100%

Shape grows from zero, indicating the beginning of burning, to unity, indicating the conclusion of combustion.

The difference in these two ends is known as the combustion duration.

The Wiebe function is given by:

$$X_b(\theta) = 1 - \exp\left(-a * \left(\frac{\theta - \theta_0}{\theta_d}\right)^{m+1}\right)$$

Xb () is the burned fuel fraction at the immediate crank angle (CA); an is a constant for a combustion duration corresponding to 0 percent -99.9 percent mass fuel burned, which is is the the same to 6.908; and 0 is the crank viewpoint the start of combustion (SOC) d is the combustion time; and m is a speed of combustion parameter that may be determined using the equation [84]:

$$\tau_{max} = \frac{\theta_{max}}{\theta_d} = \left[\left(\frac{1}{6.908}\right) * \left(\frac{m}{m+1}\right)\right]^{\frac{1}{m+1}}$$

where θ_{max} max is the CA duration from the SOC to the site of the Qgross maxima.

4.RESULT AND DISCUSSION

4.1. RSM statistical analysis

The design expert software (edition 11; Stat-Ease, Inc., USA) was used to optimize statistical process parameters to get maximize the biodiesel yield as per the process mentioned in section 2.3. The results of regression and analysis of variance (ANOVA) of biodiesel yield were dissected by selecting the best possible model either linear or quadratic. Second-order quadratic regression model was obtained to be the best fit for both RSM methods. As mentioned earlier, for three factors, fifteen factorial point experimental set was generated for the BBD model (refer to Table 3)

The technique utilized the regression condition regarding uncoded factors created through the curve fitting utilizing the least square method to generate the predicated regression equation for BBD (refer to Eq.(4))which are mentions below,

The regression equation for the BBD method:

$$R_{1}=92.04-0.56A+0.5187B+1.34C-0.6825AB+0.5775AC+0.77BC-0.5825A^2-1.19B^2-2.14C^2 \quad (4)$$

where A, B, and C are encoded forms of independent variables of methyl alcohol: oil molar ratio, KOH wt%, and temperature respectively. In both methods, over-all nine terms are generated in regression equation (refer to Eq.4), out of them, three liner term of A, B, C represents main effects; next three terms AB, BC, AC represents interaction effect among process variables, and remaining three terms A^2, B^2, C^2 represents quadratic effects of the factors. By utilizing the above equations Eq. (4) the predicted yield values for both models were obtained (refer to Tables 4). The maximum experimental yield of 94.12% was obtained (refer to Table 4) for the BBD method . The details of ANOVA parameters for BBD is listed in Table 7.

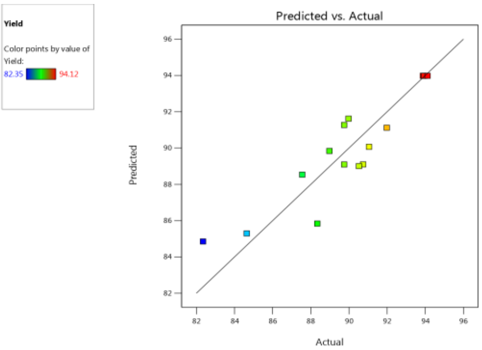
As per Table 7 the F-value of 559.45 for the BBD model was obtained with a corresponding p-value less than0.05 indicating it is significant. The F- values can be higher, it indicate the model is significant. So, for the significance. The probability of F-value due to noise is 0.0018 (for BBD) found to be less than 0.05. This observation overall designates that the investigational data fitted satisfactorily with the proposed quadratic model.

Table 7 Result of the ANOVA for the biodiesel production using BBD. terms are significant)

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	123.38	9	13.71	2.55	0.1572	
A-Molar ratio	3.96	1	3.96	0.7373	0.4298	
B-KOH	11.43	1	11.43	2.13	0.2042	
C-Temp	0.0324	1	0.0324	0.0060	0.9411	
AB	3.42	1	3.42	0.6376	0.4608	
AC	1.38	1	1.38	0.2579	0.6332	
BC	0.0497	1	0.0497	0.0093	0.9271	
A^2	60.10	1	60.10	11.20	0.0204	
B^2	49.91	1	49.91	9.30	0.0285	

C^2	0.0119	1	0.0119	0.0022	0.9643	
Residual	26.84	5	5.37			
Lack of Fit	26.81	3	8.94	559.45	0.0018	Significant
Pure Error	0.0319	2	0.0160			
Cor Total	150.22	14				

The higher value of the coefficient of determination (R^2) indicate the accuracy and developed the model is the best fit with the predicted model data. The coefficient of determination (R^2) values of 94.1214% for BBD model was observed for KOH catalyzed US process.As per the analysis of the developed quadratic model, as seen in Table 6(a) the significant model terms found in the BBD model were B, AB, AC, BC, A^2, B^2, C^2. Fig.10(a) depicts distribution of experimental and model predicted yield data for BBD . The biodiesel yield data are regularly distributed along the straight line of 45^0 in BBD as seen in Fig.10(a). The predicted yield values were dispersed reliably close to the real response and this verifies that developed regression models are best fit between the process variables and biodiesel yield. In both models the all the data points were distributed near the reference line, which indicate a good fit with the response. Fig.10(b) shows the plots of the normal percentage probability versus residual data of biodiesel yield for the BBD model respectively. It shows a respectable connection between externally studentized residuals and their normal percentage probability rank position data In



(a)

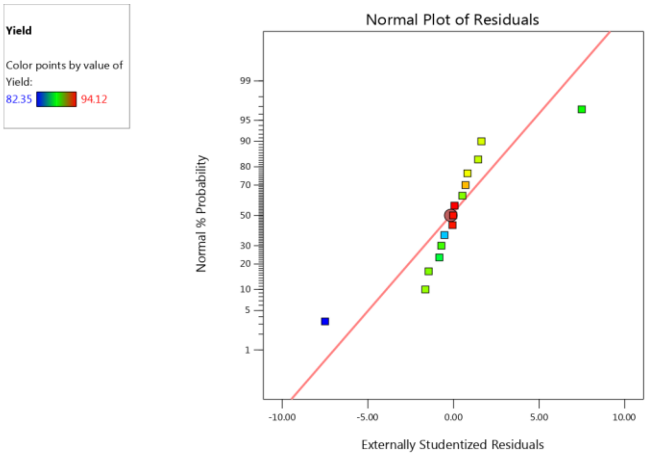


Fig. 7. (a) predicted vs. actual linseed biodiesel yield conversion in percentage; (b) Normal probability plot of residuals for model of BBD.

Fig.7 shown the plot of externally studentized residual vs. run number of experiments. Use the residuals versus run order plot to check the presumption that the residuals are liberated from one another. Patterns in the points may demonstrate that residuals close to one another might be related, and thus, not independent. In the graph, all the data points are falling randomly near the centerline in method of BBD (refer to Fig.8). In model in the few points are given the higher response compared to the other point due to the residual value is very less and it's shown near to the centerline. Thus in the BBD method run numbers of 5, 6, 8,10,11, (refer to Fig. 11).

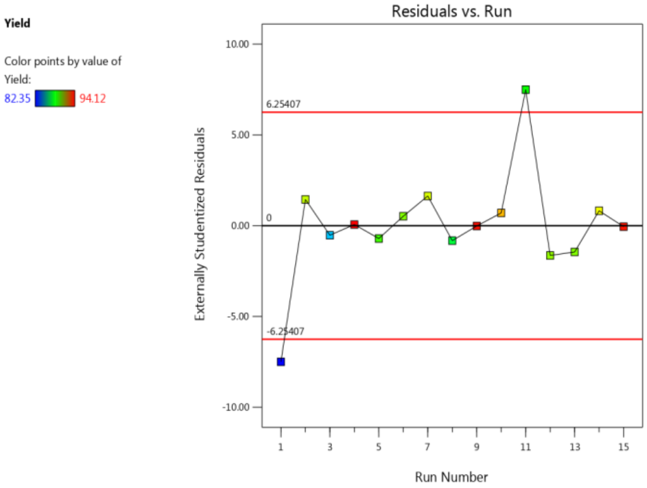


Fig 8. The graphs of the externally studentized residual vs. run number of experiments for the BBD.

4.3. Optimization of the process parameters

The RSM mathematical optimization procedure was used for investigating the ideal response conditions within the scope of the control factors by contemplating the standard blunder (Std Err) that occurred in the model. Fig15 shows that the lowest and higher limits of the range for all the parameters which are included in this optimization process. As indicated by the breaking point basis for biodiesel yield optimization, the second-order polynomial equation was applied to optimize the operating process conditions by utilizing mathematical RSM optimization in BBD approaches. By utilizing the design-expert software, various arrangements of various optimal operating factors and corresponding biodiesel yields were created. In the BBD model, the optimal solution of parameters found to be 8.68, 0.92%, 61.57 C respectively for molar ratio (A), KOH wt% (B), temperature (C), and at this optimal condition, the predicted yield is 94.1241% as shown in Fig9. 15.

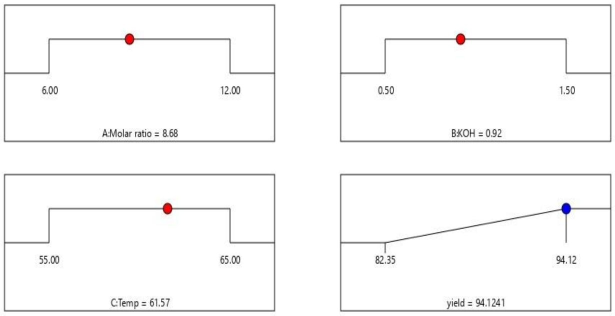


Fig.9.Optimum condition.

4.4. Engine combustion and emission parameters

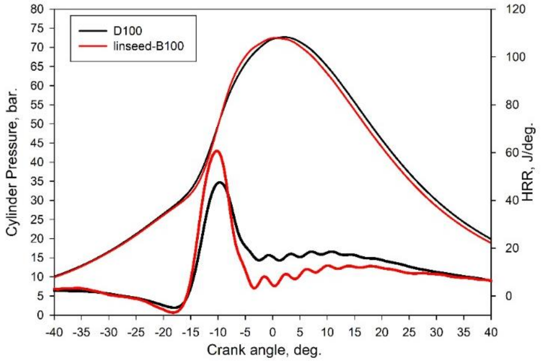


Fig. 10. cylinder Pressure and HRR for Diesel, Linseed Biodiesel.

The in-cylinder pressure and HRR were lower for linseed biodiesel compared with diesel fuel. This is ascribed to the low energy content and high latent heat of vaporization that cause a deterioration in the combustion process

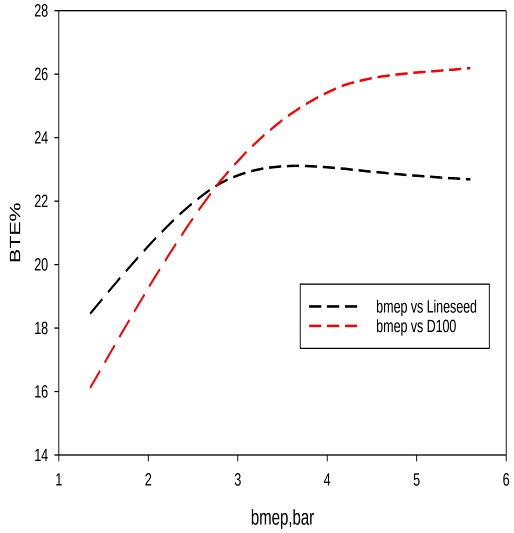


Fig.11.BTE for Diesel, Linseed Biodiesel oil.

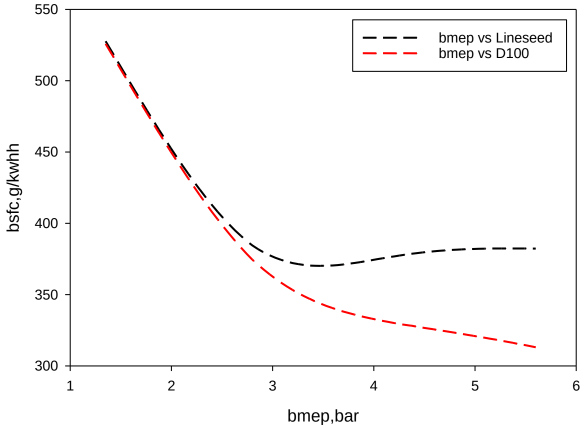


Fig .12. BSFC for Diesel, Linseed Biodiesel.

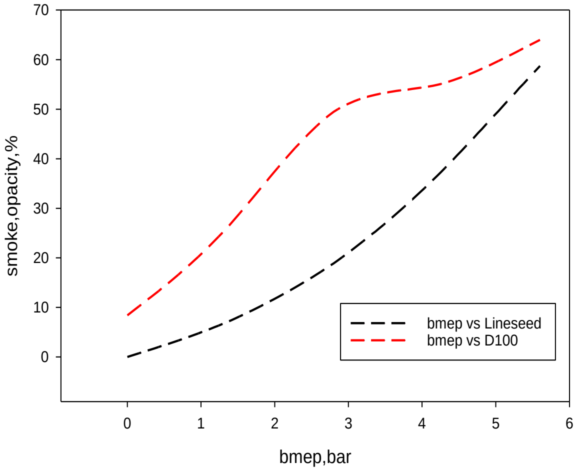


Fig .13. Smoke for Diesel, Linseed Biodiesel oil.

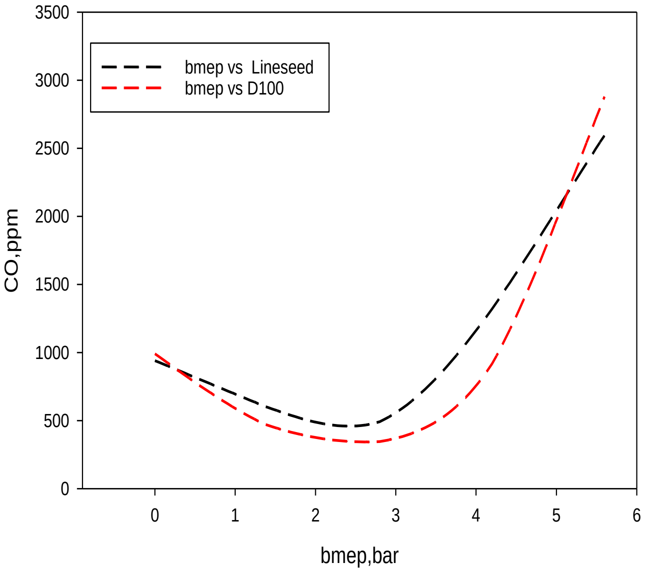


Fig.14.CO for Diesel, Linseed Biodiesel oil.

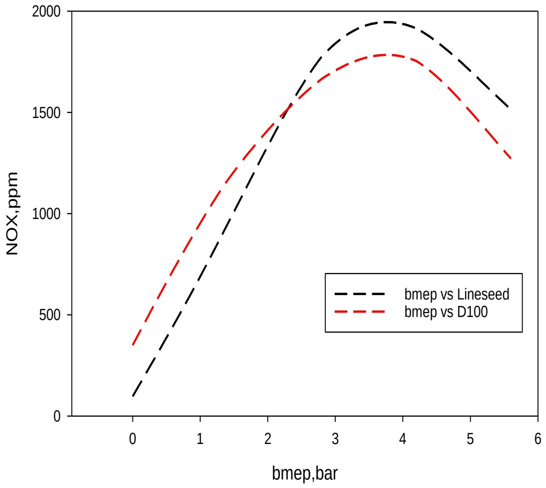


Fig.15. NOX for Diesel, Linseed Biodiesel oil.

-The in-cylinder pressure and HRR were lower for linseed biodiesel compared with diesel fuel. This is ascribed to the low energy content and high latent heat of vaporization that cause a deterioration in the combustion process.

-The BTE reduced while the BSFC increased for the linseed biodiesel compared with the diesel fuel.

-The smoke opacity, UHC, and CO levels were lower for linseed biodiesel compared with diesel oil.

-The NO_x level increased for the linseed biodiesel compared with diesel oil.

5. CONCLUSIONS

This study aimed to optimize the biodiesels production from linseed oil using raped response method (RSM) to get the optimum conditions. The experiments were also extended to assess the combustion and emission parameters of a diesel engine fueled by diesel fuel and linseed biodiesel blends. The following main findings were identified from this research.

-The optimum operating condition is to be methyl alcohol: oil molar ratio: 8.68:1, KOH wt %: 0.92% reaction temperature: 61.57 C.

-The use of RSM demonstrated a substantial potential for getting the optimum conditions for biodiesel production.

-The in-cylinder pressure and HRR were lower for linseed biodiesel compared with diesel fuel. This is ascribed to the low energy content and high latent heat of vaporization that cause a deterioration in the combustion process.

-The BTE reduced while the BSFC increased for the linseed biodiesel compared with the diesel fuel.

-The smoke opacity, UHC, and CO levels were lower for linseed biodiesel compared with diesel oil.

-The NO_x level increased for the linseed biodiesel compared with diesel oil.

Additionally, further examinations are also essential to evaluate the influence of diesel/ linseed biodiesel blends on the diesel engine performance and underline its commercial application.

Achievements

-1st and 2nd places in1st Annual Conference of Post Graduate Studies for Applied Science in Benha university.

-Obtaining financial support from the Academy of Scientific Research and Technology to apply a project (Optimization of transesterification process for Jatropha oil applying response surface method (RSM) and its application in diesel engines) with a value of 66540 pound.

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