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# THE ROLE OF TRANSESTERIFICATION PERIOD ON THE EFFECT OF ENGINE PERFORMANCE PARAMETERS USING SOYBEAN BIODIESEL AND DIESEL BLENDS

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## ABSTRACT

Gradual depletion of fossil fuel and their harmful combustion effects are compelling to use now-a-days Biodiesel in engines. Transesterification is a method which is used for production of Biodiesel through removal of fatty acid vegetable oil. This Biodiesel can be used as engine fuel mixing with pure diesel with various proportions. In the present work, four types of Soybean Biodiesel have been made just by varying transesterification period. The transesterification periods are 30mins, 60 mins, 90mins and 120 mins respectively. Twenty percent of each type of Soybean Biodiesel is mixed with eighty percent mineral diesel to make B20 fuel. Now these four types of B20 fuels have been used to run the engine. The engine performance parameters viz. Brake power (BP), Specific fuel consumption (SFC) and RPM is tabulated against various load conditions of engine like 0%, 20%, 40%, 50% 80% and 100%. From the experimental observations, nature of each parameter is represented graphically to show which B20 fuel gives the best result. The statistical Analysis by two-way classification (Randomized Block Design) is done to determine whether Variation of Transesterification period is significant on the engine performance parameters.

**Keywords :** Transesterification, Biodiesel, Engine Performance, Randomized Block Design.

## 1. INTRODUCTION

Biodiesel is an alternative fuel for Internal combustion engines that is gaining attraction in terms of the reducing fossil fuel resources of the world and the mitigating of Greenhouse effects due to carbon dioxide. The main advantages of using a biodiesel are that it is one of the most renewable fuels available and it also non-toxic and biodegradable (1). In addition, this fuel can be used directly or mixed with conventional fuel for most Internal Combustion engines without requiring engine modifications to a great extent (2).

Biodiesel is produced from vegetable oils. The major components of vegetable oils are triglycerides. Triglycerides are esters of glycerol with long chain acids, commonly called fatty acids. Problems associated with vegetable oils during engine tests can be classified into two broad groups, viz, operational and durability problems. Operational problems are related to starting ability, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injection tip, ring sticking and lubricating oil dilution. It has been observed that the straight vegetable-oils when used for long hours tend to choke the fuel filter because of high viscosity and insoluble present in the straight vegetable oils. The high viscosity, polyunsaturated character and extremely low volatility of vegetable oils are responsible for the operational and durability problems associated with its utilization as fuels in diesel engines. High viscosity of vegetable oils causes poor fuel atomization, large droplet size and thus high spray jet penetration. The jet tends to be a solid stream instead of a spray of small droplets. As a result, the fuel is not distributed or mixed with the air required for burning in the combustion chamber. This result in poor combustion accompanied by loss of power and economy.

Blending, cracking/ pyrolysis, emulsification or transesterification of vegetable oils may over come these problems. Heating and blending of vegetable oils reduce the viscosity and improve volatility of vegetable oils but its molecular structure remains unchanged hence polyunsaturated character remains. Blending of vegetable oils with diesel, however, reduces the viscosity drastically and the fuel handling system of engine can handle the vegetable oil diesel blends without any problems. On the basis of experimental investigations, it is found that converting vegetable oils into simple esters is an effective way to overcome all the problems associated with the vegetable oils. Most of the conventional production methods for bio diesel use basic or acidic catalyst. A reaction time of 45 min to 1 hour and reaction temperature of 55-65$^{0}$C are required for completion of reaction and formation of respective esters[3,4,5,6,7,8,9,11, and 12]

But no such exact study related to effectiveness of transesterification time on the engine performance parameters have been made. In this present study, the authors have tried to find out the effectiveness of tranesterification period on engine performance parameters viz. specific fuel consumption, brake power and r.p.m. Four types of soybean biodiesel have been prepared just by varying transesterification period which are 30mins, 60mins, 90mins and 120mins respectively. Then 20% of each type of soybean biodiesel is mixed by volume with 80 percent of mineral diesel to make four types of B20 fuel. The performance parameters of engine run by these four types of B20 fuel is recorded and a statistical model by Randomized Block Design is developed to show significance of transesterfication period.

## 2. METHODOLOGY

### 2.1 Randomized Block Design

The essence of this design is that the experimental material is divided into groups, each of which constitutes a single trial or replication. At all stages of the experiment the object is to keep as small as in practicable. Thus, when the units are assigned to the successive groups, all units which go in the same group should be closely comparable. Similarly, during the course of the experiment, a uniform technique should be employed for all units in the same group. Any changes in technique or in other conditions that may affect the results should be made between groups. This division into replications need be recognized only at those stages in the conduct of the experiment where the division may help to reduce experimental errors.

### 2.2 Procedure for Two Way Classification

**Step 1**: To find the treatment totals ($T_i$), the Replicate totals ($R_j$) and the grand total (G)

**Step 2**: The sums of squares (SS) are obtained as follows :-

Correction factor $C = \frac{G^2}{t_r}$

($t_r$ = no of observations)

Total : $\sum y^2 - C$

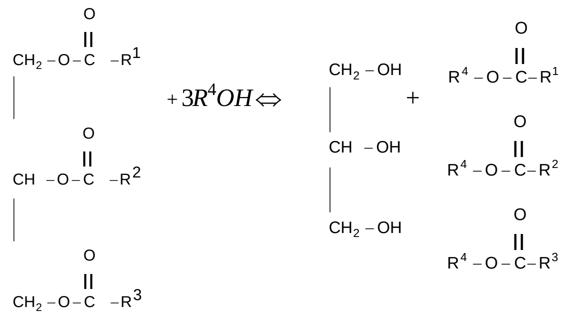
Replications : $\sum \frac{R_j^2}{t} - C$ (t = no of treatments)

Treatments : $\sum \frac{T_i^2}{r} - C$ (r = no of replications)

Error : (total SS)-(Replications S.S) – (treatments S.S.)

### 2.3 Transesterification

The formation of methyl esters by transesterification of vegetable oils requires 3 moles of alcohol stoichiometrically. However, transestrification is an equilibrium reaction in which excess alcohol is required to drive the reaction close to completion. The vegetable oil is chemically reacted with an alcohol in presence of a catalyst to produce vegetable oil esters. Glycerol is produced as a by-product of transesterification reaction. The chemical reaction of the transesterification process is shown below :



Triglyceride Alcohol Glycerol Esters

The mixture is stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24hours. The upper layer is of ester and lower layer is of glycerol. The lower layer is separated out. The separated ester is mixed with some worm water (around 10% volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24h. the catalyst gets dissolved in water, which is separated. Moisture is removed from this purified ester using silica gel crystals. The ester is then blended with mineral diesel in various concentrations for preparing bio diesel blends to be used in CI engine for conducting various engine tests. The process of transesterification brings about a drastic change in the density of linseed oil and the linseed oil methyl ester (LOME) has almost similar density as that of mineral diesel.

## 3. EXPERIMENTAL RESULTS AND DISCUSSION

Table 1: Four levels of two factors

| **% of Load (Nm)** | **20 ($L_1$)** | **40 ($L_2$)** | **60 ($L_3$)** | **80 ($L_4$)** |
|---|---|---|---|---|
| Transesterification period (min) | 30 ($P_1$) | 60 ($P_2$) | 90 ($P_3$) | 120 ($P_4$) |

Table 2 : Performance parameters of Engine run by B20 fuel (Transesterification period : 30mins)

| **Percentage of Load** | **SFC (Kg/kwh)** | **BP (kw)** | **RPM** |
|---|---|---|---|
| $L_1$ | 0.432 | 1.0 | 1470 |
| $L_2$ | 0.309 | 2.1 | 1440 |
| $L_3$ | 0.324 | 3.0 | 1405 |
| $L_4$ | 0.443 | 3.9 | 1340 |

Table 3: Performance parameters of Engine run by B20 fuel (Transesterification period : 60mins)

| Percentage of Load | SFC (Kg/kwh) | BP (kw) | RPM |
|---|---|---|---|
| $L_1$ | 0.594 | 1.0 | 1470 |
| $L_2$ | 0.334 | 2.1 | 1445 |
| $L_3$ | 0.324 | 3.0 | 1420 |
| $L_4$ | 0.385 | 3.5 | 1270 |

Table 4: Performance parameters of Engine run by B20 fuel (Transesterification period : 90mins)

| Percentage of Load | SFC (Kg/kwh) | BP (kw) | RPM |
|---|---|---|---|
| $L_1$ | 0.486 | 1.0 | 1460 |
| $L_2$ | 0.324 | 2.0 | 1430 |
| $L_3$ | 0.278 | 3.1 | 1405 |
| $L_4$ | 0.496 | 3.7 | 1270 |

Table 5: Performance parameters of Engine run by B20 fuel (Transesterification period : 120mins)

| Percentage of Load | SFC (Kg/kwh) | BP (kw) | RPM |
|---|---|---|---|
| $L_1$ | 0.489 | 1.0 | 1465 |
| $L_2$ | 0.328 | 2.0 | 1430 |
| $L_3$ | 0.296 | 3.1 | 1410 |
| $L_4$ | 0.429 | 3.9 | 1280 |

Taking data from table 2,3,4 and 5 graphs have been plotted of specific fuel consumption, Brake power and RPM with percentage of load with increasing rate of transesterification period.

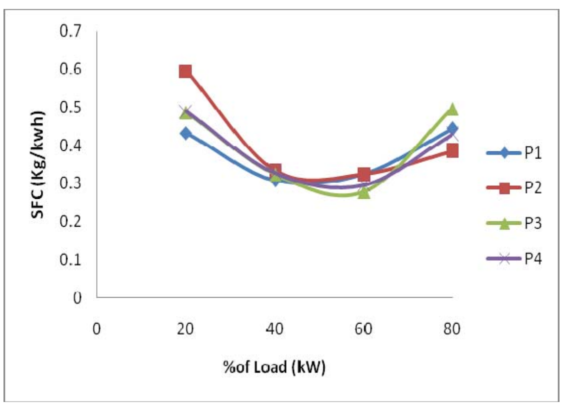



Fig 1. Variation of specific fuel consumption with percentage of load.

Figure-1 shows that specific fuel consumptions are higher for all B20 blends at 20% load of the engine. This is decreasing in nature up to 60% load and then increasing characteristics. At 40% load, specific fuel consumptions are almost same for all the blends. So transesterification period has no effect at this load condition. The B20 fuel for which transesterification is 60 minutes shows maximum variation of specific fuel consumption.

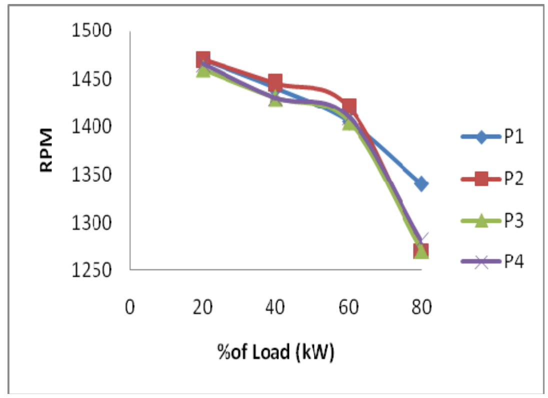



Fig 2. Variation of Brake power with percentage of load.

From figure-2, it can be concluded that Brake power is gradually increasing with higher percentage of loads for all the blends. And for any particular load of the engine, there is negligible variation of Brake power. So transesterification period has no such effect on the Brake power parameter of the engine.

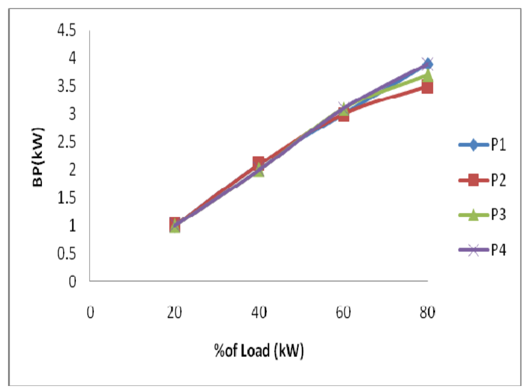



Fig 3. Variation of engine RPM with percentage of load.

From figure 3 – it is seen that at 20% load, RPM of the engine run by all the B20 fuels are almost same which is not true for higher percentage of loads. Maximum variation of RPM for all the B20 fuels occur at 80% load of the engine. And maximum variation of RPM for a particular fuel occurs for the B20 fuel for which transesterification is 60 minute.

From the experimental observations (table 2,3,4 and 5) analysis by Tow way classification has been done and significance of transesterification period on engine performance parameters in shown.

Table 6 : Two-way classification on Specific fuel consumptions .

**Percentage of Load**

| Transesterification Period | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Total |
|---|---|---|---|---|---|
| $P_1$ | 0.432 | 0.309 | 0.324 | 0.443 | 1.508 |
| $P_2$ | 0.594 | 0.334 | 0.324 | 0.385 | 1.637 |
| $P_3$ | 0.486 | 0.324 | 0.278 | 0.496 | 1.584 |
| $P_4$ | 0.489 | 0.328 | 0.296 | 0.429 | 1.542 |
| Total | 2.001 | 1.295 | 1.222 | 1.753 | 6.271 / 6.271 |

$$C = \text{Correction factor} = \frac{(\text{Grand Total})^2}{\text{Number of observations}}$$

$$= \frac{(6.271)^2}{16} = 2.458$$

Total sum of squares,

$$SST = [(0.432)^2 + (0.594)^2 + (0.486)^2 + (0.489)^2$$
$$+ (0.309)^2 + (0.334)^2 + (0.324)^2 + (0.328)^2$$
$$+ (0.324)^2 + (0.324)^2 + (0.278)^2 + (0.296)^2$$
$$+ (0.443)^2 + (0.385)^2 + (0.496)^2 + (0.429)^2 \;] - C$$

= 2.584 - 2.458
= 0.126

Treatment sum of squares,
SSA=

$$\frac{1}{4}\left[(1.508)^2 + (1.637)^2 + (1.584)^2 + (1.542)^2\right] - C$$

= 2.460-2.458 = 0.002

Block sum of squares**,**
SSB =

$$\frac{1}{4}\left[(2.001)^2 + (1.295)^2 + (1.222)^2 + (1.753)^2\right] - C$$

= 2.460-2.458 = 0.104

Error sum of squares,
SSE = SST-SSA-SSB
= 0.126 – 0.002 – 0.104
= 0.02

Table 7 : Analysis of Variance

| **Source** | **Degree of Freedom** | **Sum of Square** | **Mean Square** | **Computed f** |
|---|---|---|---|---|
| Factor A | 3 | 0.002 | 0.00067 | 0.305 (<1)* |
| Factor B | 3 | 0.104 | 0.0347 | 15.77** |
| Error | 9 | 0.02 | 0.0022 | |
| Total | 15 | | | |

** Significant
* insignificant

Table 8 : Two-way classification on Brake Power : Percentage of Load

| Transesterification Period | $L_1$ | $L_2$ | $L_3$ | $L_4$ | Total |
|---|---|---|---|---|---|
| $P_1$ | 1 | 2.1 | 3 | 3.9 | 10 |
| $P_2$ | 1 | 2.1 | 3 | 3.5 | 9.6 |
| $P_3$ | 1 | 2 | 3.1 | 3.7 | 9.8 |
| $P_4$ | 1 | 2 | 3.1 | 3.9 | 10 |
| Total | 4.0 | 8.2 | 12.2 | 15 | 39.4 / 39.4 |

C= Correction factor

$$= \frac{(\text{Grand Total})^2}{\text{Number of observations}}$$

$$= \frac{(39.4)^2}{16} = 97.02$$

Total sum of squares,

$$SST = [1^2 + 1^2 + 1^2 + 1^2$$
$$+ (2.1)^2 + (2.1)^2 + 2^2 + 2^2$$
$$+ 3^2 + 3^2 + (3.1)^2 + (3.1)^2$$
$$+ (3.9)^2 + (3.5)^2 + (3.7)^2 + (3.9)^2 \;] - C$$

= 114.4 – 97.02
= 17.38

Treatment sum of squares,

SSA = $\frac{1}{4}\left[10^2 + 9.6^2 + 9.8^2 + 10^2\right] - C$

= 97.05 – 97.02 = 0.03

Block sum of squares,

SSB = $\frac{1}{4}\left[4^2 + 8.2^2 + 12.2^2 + 15^2\right] - C$

= 114.27 -97.02
= 17.25

**Error sum of squares,**

SSE = SST-SSA-SSB

= 17.38 – 0.03 – 17.25

= 0.10

Table 9 : Analysis of Variance

| Source | Degree of Freedom | Sum of Square | Mean Square | Computed f |
|---|---|---|---|---|
| Factor A | 3 | 0.03 | 0.01 | 0.909 (<1)* |
| Factor B | 3 | 17.25 | 5.75 | 522.72** |
| Error | 9 | 0.10 | 0.011 | |
| Total | 15 | | | |

** Significant
* Insignificant

Table : 10 : Two-way classification on RPM :

Percentage of Load

Transesterification Period

| | **$L_1$** | **$L_2$** | **$L_3$** | **$L_4$** | **Total** |
|---|---|---|---|---|---|
| $P_1$ | 1470 | 1440 | 1405 | 1340 | 5655 |
| $P_2$ | 1470 | 1445 | 1420 | 1270 | 5605 |
| $P_3$ | 1460 | 1430 | 1405 | 1270 | 5565 |
| $P_4$ | 1465 | 1430 | 1410 | 1280 | 5585 |
| Total | 5865 | 5745 | 5640 | 5160 | 22410 / 22410 |

$$\text{C=Correction factor} = \frac{(\text{Grand Total})^2}{\text{Number of observations}}$$

$$= \frac{(22410)^2}{16} = 31388006.25$$

Total sum of squares,

$$SST = [1470^2 + 1470^2 + 1460^2 + 1465^2 + 1440^2 + 1445^2 + 1430^2 + 1430^2 + 1405^2 + 1420^2 + 1405^2 + 1410^2 + 1340^2 + 1270^2 + 1270^2 + 1280^2 ] - C$$

= 31463400 – 31388006.25
= 75393.75

Treatment sum of squares,

$$\text{SSA} = \frac{1}{4}\left[5655^2 + 5605^2 + 5565^2 + 5585^2\right] - C$$

= 31389125 – 31388006.25 = 1118.75

Block sum of squares,

$$\text{SSB} = \frac{1}{4}\left[5865^2 + 5745^2 + 5640^2 + 5160^2\right] - C$$

= 31459612.5 -31388006.25 = 2668.75

Error sum of squares,

SSE = SST-SSA-SSB
= 075393.75 – 1118.75 – 71606.25
= 2668.75

Table 11: Analysis of Variance

| Source | Degree of Freedom | Sum of Square | Mean Square | Computed f |
|---|---|---|---|---|
| Factor A | 3 | 1118.75 | 372.92 | 1.25* |
| Factor B | 3 | 71606.25 | 23868.75 | 80.49** |
| Error | 9 | 2668.75 | 296.53 | |
| Total | 15 | | | |

** Significant
* Insignificant

## 4. CONCLUSION

It is evident from the tables 7, 9 and 11 that transesterification period is insignificant where as percentage of load in highly significant. So we must take care of percentage of load. It can be concluded that transesterification period upto 45 minutes to 60 minutes is sufficient to set desirable results using soybeen Biodisel and Diesel blends as Internal Combustion Engine fuels. However, lots of R&D work essential for this.

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## 6. MAILING ADDRESS

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