

# EFFECT OF INDIVIDUAL PHYSIO – CHEMICAL PROPERTIES OF KARANJA OIL METHYL ESTER (KOME) & ITS STATISTICAL CORRELATION WITH GROSS CALORIFIC VALUE

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## Abstract

*Biodiesel is double sided sword. Due to depletion of fossil diesel, the Biodiesel have taken same position in the fossil fuel category. That's why now a day the world is taking step towards the biodiesel because the depletion of fossil diesel. Biodiesel is basically Fatty Acid methyl ester based fuel, a long chain of triglycerides and the alcohol in the presence of catalyst forms ethyl esters and the glycerol that process is known as Transesterification, if the free fatty acid content percentage in the oil is more than 2.5 % then the process by which the oil is converted to ethyl esters is known as Esterification followed by Transesterification. In this study we mostly concentrate on the physio – chemical properties; The Physio – chemical properties like Density, Kinematic Viscosity, Flash Point, Cetane Number, are having statistical correlations with the Gross Calorific Value of Karanja Oil Methyl Ester (KOME). We have also shown in the paper, the individual properties how much percent statistical correlation have with the gross calorific value, we have calculated it by Least square Approximation of Linear Regression.*

**Keywords:** Biodiesel, Transesterification, Esterification, Characterization of Biodiesel.

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## 1. INTRODUCTION:

Now a days Energy crises is one of the important issue for us, fossil diesel has utilized everywhere in the world for the production process of the industry, Transportation sectors and also used in ships, motor vehicles, Etc. but the emission produced by that fossil diesel after burning is very ineffective for our health and also for climate, it increases air pollution and the global warming. Fossil diesel contributes almost 80 % of the world's energy needs [1, 2, 3].

Most of the country in the world that are agricultural, due to fluctuating global prices of the crude oil has an adverse impact on economy of many nations especially oil importing countries, apart from the fossil diesel is non – renewable source of energy, due to the depletion of fossil diesel fuels, the prices are also increasing day by day ultimately it leads to the economic recession in the various developing countries. If we see the previous data the diesel consumption itself in India 2008 – 2009 was 51.7 million Tons and 159.7 million Tons of CO<sub>2</sub> was likely to be generated by such usage of fossil diesel [4].

Basically, Karanja is a medium sized fast – growing evergreen tree, which reaches 40 feet in height and spread, forming a broad, spreading canopy casting moderate shade showing in Photo 1. The time needed by the tree to mature

ranges from 4 to 7 years and depending on the size of the tree the yield of kernels per tree is between 8 to 24 kg and the yield of potential per hectare is 900 to 9000 kg/hectare [4].

The plant is also said to be highly tolerant and salinity and can be grown in various soil textures viz. stony, sandy and clayey, it can also grow in humid as well as subtropical environments with annual rainfall ranging between 500 to 2500 mm [2, 4]. Most of the researchers have put the statement this tree is having oil content 30 to 33% or 30 to 40 %. It is one of the few nitrogen fixing tree. This spice is commonly called Pongam, Karanja, pongamia, or a derivation of these names. Flowers are pink, light purple or white showing in photo 3. Pods are elliptical, 3 to 6 cm long and 2 to 3 cm wide, thick walled and usually contain a single seed. Seeds are 10 to 20 mm long, fig oblong and light brown colour showing in photo 2 [4].

In its natural habitat, the maximum temperature ranges of maximum from 27 – 38 °C and minimum 1 – 16 °C. Mature trees can withstand water logging and slight forest. Air – dried karanja kernels have typically 19% Moisture, 27.5% Fatty Oil, 17.4% Protein, 6.6% Starch, 7.3% Crude Fiber and 2.4% Ash. The oil is used by common people due to its low cost and easy availability [2, 4]. The fatty acids composition of karanja oil has been reported in Table 1:

**Table 1:** Fatty Acid Composition of Karanja Oil [4].

Fatty Acids	Formula	Structure	Weight in %
Palmitic	C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>	16:0	3.7 – 7.9
Stearic	C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>	18:0	2.4 – 8.9
Lignoceric	C <sub>20</sub> H <sub>40</sub> O <sub>2</sub>	24:0	1.1 – 3.5
Oleic	C <sub>18</sub> H <sub>34</sub> O <sub>2</sub>	18:1	44.5 – 71.3
Linoleic	C <sub>18</sub> H <sub>32</sub> O <sub>2</sub>	18:2	10.8 – 18.3



**Photo 1:** Karanja Tree **Photo 2:** Karanja Seeds



**Photo 3:** Flowers of Karanja

The Equations were developed for the calculations of the Gross Calorific Value of Karanja Oil Methyl Esters from Density, Kinematic Viscosity, Flash Point, and Cetane Number.

The Equations between Density and the Gross Calorific Values are for Karanja Oil Methyl Esters.

$$\text{Gross Calorific Value (kJ/kg)} = 95.5058 - 0.0661777 \times \text{Density (kg/m}^3\text{)} \dots \text{(Equation 1)}$$

Then after that, we were developed the Equations between Kinematic Viscosity and Gross Calorific Value are for Karanja Oil Methyl Esters.

$$\text{Gross Calorific Value (kJ/kg)} = 45.8031 - 0.599455 \times \text{Kinematic Viscosity (mm}^2\text{/s)} \dots \text{(Equation 2)}$$

Then after that, we were developed the Equations between Flash Point and Gross Calorific Value are for Karanja Oil Methyl Esters.

$$\text{Gross Calorific Value (kJ/kg)} = 45.2092 - 0.0663784 \times \text{Flash Point (Degree)} \dots \text{(Equation 3)}$$

Then after that, we were developed the Equations between Cetane Number and Gross Calorific Value are for Karanja Oil Methyl Esters.

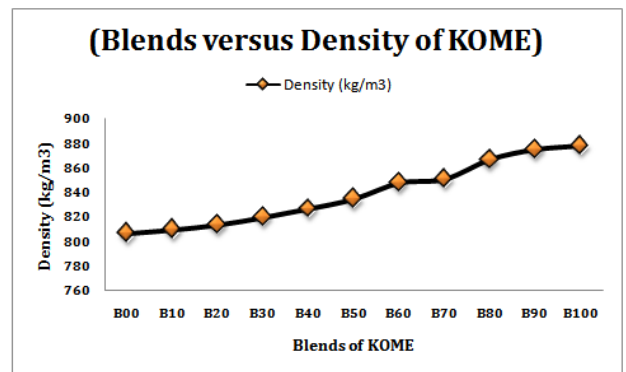
$$\text{Gross Calorific Value (kJ/kg)} = 46.3868 - 0.147154 \times \text{Cetane Number (No.)} \dots \text{(Equation 4)}$$

## 2. MATERIAL & METHODS:

### 2.1 Density:

The term density of liquid is defined as the ratio of mass per unit volume, and the unit for density is kg/m<sup>3</sup>. Most of the researchers have preferred dimensionless number specific gravity. As per the ASTM D6751 standards the density of liquid can be measured by D 941 standard and as per European Standards the density of liquid can be measured by EN ISO 3675 and EN ISO 12185 [4, 5]. But we have calculated the density as a derived quantity. The Karanja biodiesel blends density increases as the fossil diesel percentage decreases or the biodiesel percentage increases in the blends. For Density we have taken here blends in the step of 10, like B00 (Neat Fossil Diesel), B10, B20, B30, B40, B50, B60, B70, B80, B90, B100 (Neat Biodiesel).

The below graph is showing how the density of Karanja oil Methyl Ester blends increases as the percentage of fossil diesel decreases or the percentage of biodiesel increases in the blends.



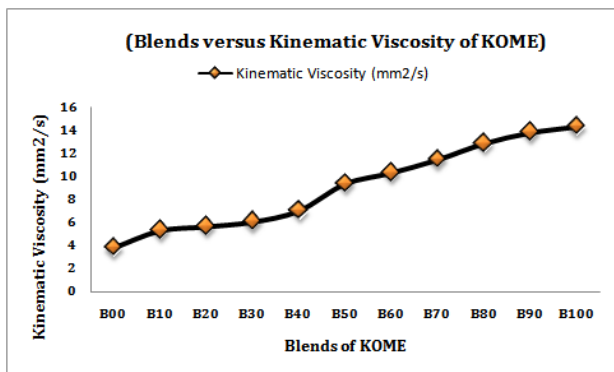
**Graph1**

### 2.2 Kinematic Viscosity:

Kinematic viscosity is the primary reason why biodiesel is used as an alternative fuel instead of neat vegetable oils or animal fats. Viscosity is a measure of the internal fluid friction or resistance of oil to flow, which tends to oppose any dynamic change in the fluid motion. Kinematic Viscosity of the biodiesel, diesel fuel and their blends can be measure by

ASTM Standard D 445 or as per European Standard of EN ISO 3104 and EN ISO 3105 test methods. The Viscosity ranges have given as per the ASTM D445 standard 3.5 to 5.0 mm<sup>2</sup>/s and as per the EN ISO 3104, 05 standards 1.9 to 6.0 mm<sup>2</sup>/s [3, 5]. Here we have measured the kinematic viscosity in mm<sup>2</sup>/s by Finoke tube used in kinematic viscometer bath tub. We have used this formula while calculating the kinematic viscosity of karanja oil methyl ester: **Kinematic viscosity = Calibration constant (mm<sup>2</sup>/s<sup>2</sup>) x mean time of flow (s) in mm<sup>2</sup>/s**. The Karanja biodiesel blends kinematic viscosity increases as the fossil diesel percentage decreases or the biodiesel percentage increases in the blends. For Kinematic Viscosity we have taken here blends in the step of 10, like B00 (Neat Fossil Diesel), B10, B20, B30, B40, B50, B60, B70, B80, B90, B100 (Neat Biodiesel).

The below graph is showing how the kinematic viscosity of Karanja oil Methyl Ester blends increases as the percentage of fossil diesel decreases or the percentage of biodiesel increases in the blends.



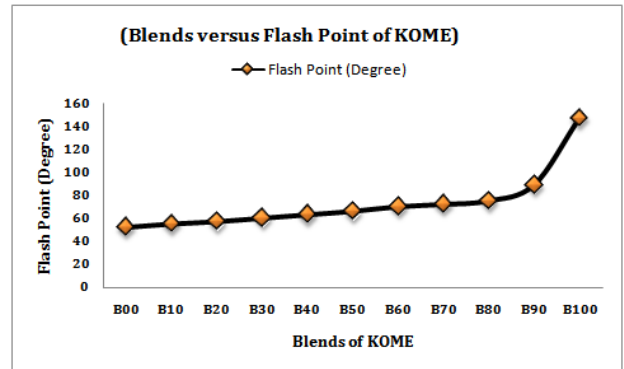
Graph2

### 2.3 Flash Point:

Biodiesel and diesel have a common boiling point, but biodiesel has higher flash point – the temperature at which a fuel will catch fire – because biodiesel has higher number of FAMES which are generally not volatile. Flash point varies inversely with the fuel’s volatility. Thus, biodiesel is safer to handle at higher temperature than fossil diesel. Flash Point of the biodiesel, diesel fuel and their blends can be measure by ASTM Standard D 93 or as per European Standard of EN ISO 3679 and IP 523 & IP 524 test methods [3, 5]. We have used Pensky Marten Closed cup apparatus in the testing purpose. While calculating the flash point we have taken the temperature of thermometer which we have used in the apparatus. The Karanja biodiesel blends flash point increases as the fossil diesel percentage decreases or the biodiesel percentage increases in the blends. For Flash Point we have taken here blends in the step of 10, like B00 (Neat Fossil Diesel), B10, B20, B30, B40, B50, B60, B70, B80, B90, B100

(Neat Biodiesel).

The below graph is showing how the flash point of Karanja oil Methyl Ester blends increases as the percentage of fossil diesel decreases or the percentage of biodiesel increases in the blends.



Graph3

### 2.4 Copper Strip Corrosion:

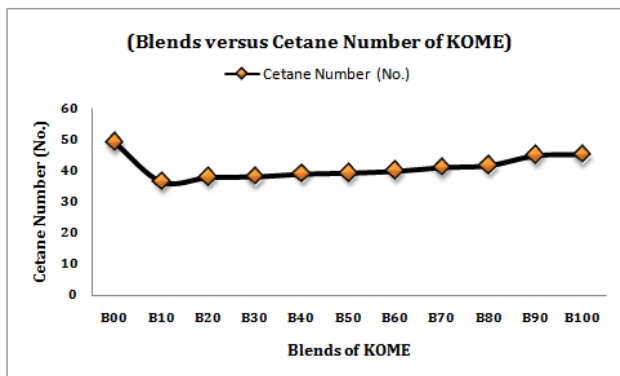
The Copper Strip Corrosion is one the important Physio – chemical property of diesel fuel. For biodiesel it is necessary to test the effect of copper strip corrosion. For copper strip corrosion as per the ASTM standard D130 test method is used. It has no unit but the limit No. 3 Max. is given for this. If copper strip corrosion exceeds from this limit then the fuel have corrosion. During experimentation it is observed that Karanja oil methyl ester and its blends don’t have more than 1 Unit [4, 5].

### 2.5 Cetane Number:

One of the most influential properties of the diesel fuel is the dimensionless Cetane number (CN), which represents the ignitability of the fuel, particularly critical during cold starting conditions. Cetane number of the fuel is defined as the percentage by volume of the normal Cetane in a mixture of normal Cetane and  $\alpha$  – methyl naphthalene which has the same ignition characteristics (ignition delay) as the test fuel, when combustion has carried out in a standard engine under specified operating conditions. The Cetane number of the Biodiesel and fossil diesel can be measured by D 613 as per the ASTM D6751 standard and EN ISO 5165 as per the EN 14214 standard. The limit is given for Cetane Number as per the ASTM D6751 standard 47 minimum and as per EN 14214 standard 51 minimum for Biodiesel and Cetane number limit is given for fossil diesel 40 minimum as per ASTM D975 standard [3, 5]. The physical and chemical properties of the fuel play very important role in the delay period. The Cetane number (CN) of the fuel is one such important parameter which is responsible for the delay period. The ignition quality

of the fuel is measured by Cetane number (CN) and it measures how easily ignition occurs. A fuel with good ignition quality has higher Cetane Number, where the ignition delay period between the start of the fuel injection and the onset of auto ignition is short. The higher Cetane Number, Shorter the Ignition delay time and vice versa. While testing the Cetane number we have used Ignition Quality Tester and the standard method we have adopted i.e. ASTM D613 Norms for Cetane Number. The Karanja biodiesel blends Cetane Number decreases as the fossil diesel percentage decreases or the biodiesel percentage increases in the blends. For Cetane Number we have taken here blends in the step of 10, like B00 (Neat Fossil Diesel), B10, B20, B30, B40, B50, B60, B70, B80, B90, B100 (Neat Biodiesel).

The below graph is showing how the Cetane Number of Karanja oil Methyl Ester blends decreases as the percentage of fossil diesel decreases or the percentage of biodiesel increases in the blends.



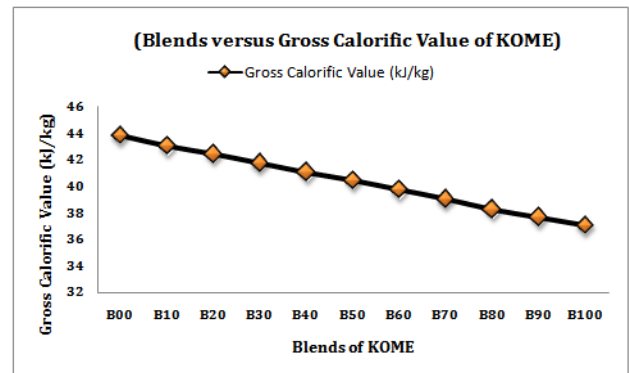
Graph4

**2.6 Gross Calorific Value:**

The lower (LHV) and the higher (HHV) heating values are measures of a fuel’s heat of combustion, with the difference between them being the water’s heat of vaporization. Biodiesel contains on average 10 – 12% w/w oxygen, which leads to proportionally lower energy density and heating value, thus more fuel needs to be injected in order to achieve the same engine power output. Some of the Researchers have measured the Heating Value of the biodiesel, and their blends can be measure by ASTM Standard D 240 or as per DIN Standard of DIN 51900, DIN 51900-1, and DIN 51900-2, DIN 51900-3test methods [3 ,5]. We have used Bomb Calorimeter Apparatus in the measurement of Heating Value but there is no specification as regards the biodiesel heating value, neither in the EU nor in the US. The Karanja biodiesel blends Gross Heating Value decreases as the fossil diesel percentage decreases or the biodiesel percentage increases in the blends. For Gross Calorific Value we have taken here blends in the step of 10, like B00 (Neat Fossil Diesel), B10, B20, B30, B40,

B50, B60, B70, B80, B90, B100 (Neat Biodiesel).

The below graph is showing how the Gross Calorific Value of Karanja oil Methyl Ester blends decreases as the percentage of fossil diesel decreases or the percentage of biodiesel increases in the blends.

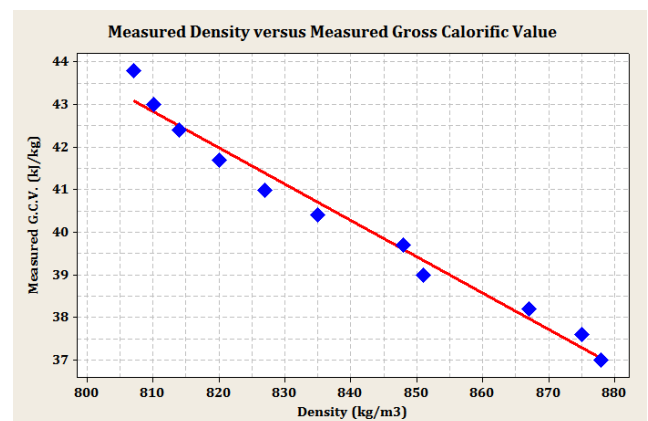


Graph5

**3. RESULT & DISCUSSIONS:**

**3.1 Density versus Gross Calorific Value:**

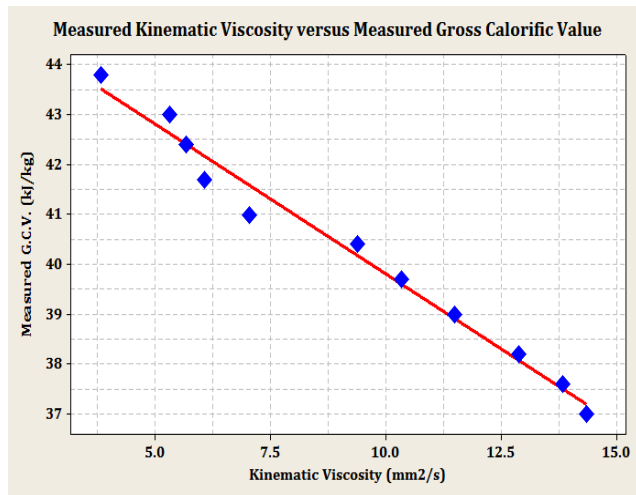
Density versus Gross Calorific Value graph is showing below; In this graph we have seen as that as the density of Karanja Oil Methyl Ester Increases simultaneously the Gross Calorific Value of Karanja Oil Methyl Ester Decreases, from this graph we can conclude that as the temperature increases the Density of Biodiesel decreases and as the density of biodiesel increases or the proportion of biodiesel increases in the fossil diesel the density increases and the Gross Calorific Value of Blends Decreases. The density must be equal to the fossil diesel; if density is less than the fossil diesel then more fuel will be supplied to the combustion chamber and vice – versa. It ultimately leads to the cost of the fuel.



Graph6

### 3.2 Kinematic Viscosity versus Gross Calorific Value:

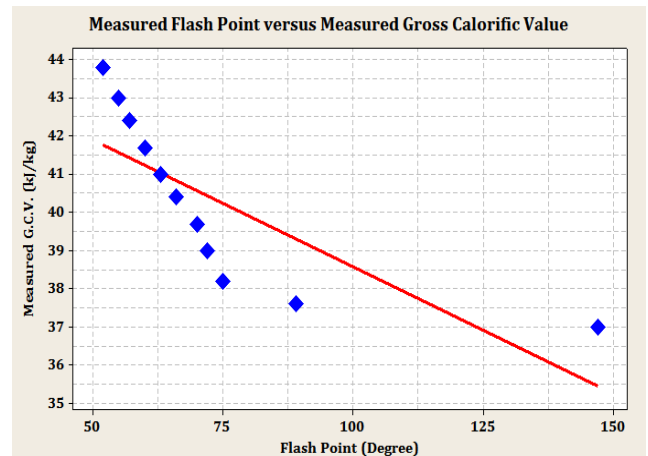
Kinematic Viscosity versus Gross Calorific Value graph is showing below; In this graph we have seen as that as the Kinematic Viscosity of Karanja Oil Methyl Ester Increases simultaneously the Gross Calorific Value of Karanja Oil Methyl Ester Decreases, from this graph we can conclude that as the temperature increases the Kinematic Viscosity of Biodiesel decreases and as the Kinematic Viscosity of biodiesel increases or the proportion of biodiesel increases in the fossil diesel the Kinematic Viscosity increases and the Gross Calorific Value of Blends Decreases. The Kinematic Viscosity must be equal to the fossil diesel; if Kinematic Viscosity is less than the fossil diesel then more fuel will be supplied to the combustion chamber and vice – versa, proper Kinematic viscosity will increase the life of the engine. If the biodiesel is having high kinematic viscosity then it ultimately leads to the cost of the fuel.



Graph7

### 3.3 Flash Point versus Gross Calorific Value:

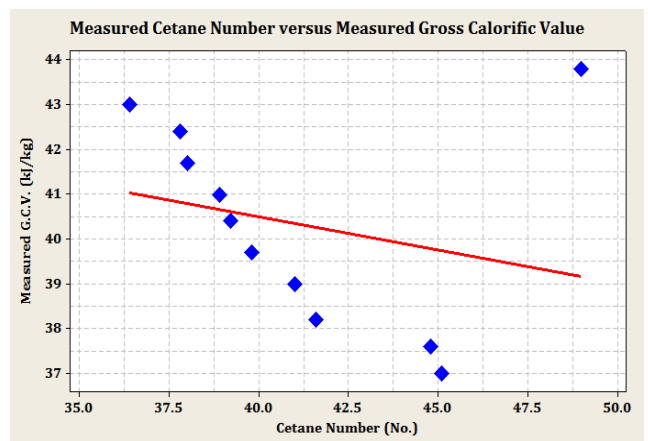
Flash Point versus Gross Calorific Value graph is showing below; In this graph we have seen as that as the Flash Point of Karanja Oil Methyl Ester Increases simultaneously the Gross Calorific Value of Karanja Oil Methyl Ester Decreases, from this graph we can conclude that as the Biodiesel is having higher Flash point temperature than the fossil diesel, as the Biodiesel percentage increases in the blends simultaneously the flash point of blends also increases and vice – versa. The flash point must be higher than the fossil diesel; if flash point of biodiesel is less than the fossil diesel then it ignites rapidly at the atmospheric temperature so the flash point must have high temperature, it ultimately help more safety in the transportation.



Graph 8

### 3.4 Cetane Number versus Gross Calorific Value:

versus Gross Calorific Value graph is showing below; In this graph we have seen as that as the Flash Point of Karanja Oil Methyl Ester Increases simultaneously the Gross Calorific Value of Karanja Oil Methyl Ester Decreases, from this graph we can conclude that as the Biodiesel is having higher Flash point temperature than the fossil diesel, as the Biodiesel percentage increases in the blends simultaneously the flash point of blends also increases and vice – versa. The flash point must be higher than the fossil diesel; if flash point of biodiesel is less than the fossil diesel then it ignites rapidly at the atmospheric temperature so the flash point must have high temperature, it ultimately help more safety in the transportation.



Graph 9

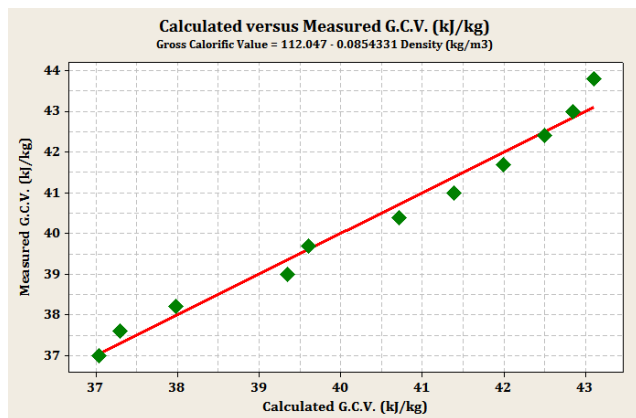
## 4. CONCLUSIONS

### 4.1 Statistical Correlation between Density & Gross Calorific Value:

The below given equation gives the statistical correlation between the density & the gross calorific value of Karanja Oil Methyl Ester,

$$\text{Gross Calorific Value (kJ/kg)} = 95.5058 - 0.0661777x \text{ Density (kg/m}^3\text{)} \dots \text{(Equation 1)}$$

There is a strong statistical correlation between Density & the Gross Calorific Value because after the statistical analysis  $R^2$  shows the value 97.78% only, it means that the Density & Gross Calorific Value have 97.78% Correlation between them. This correlation we have shown the Calculated Gross Calorific Value versus Measured Gross Calorific values on the graph.



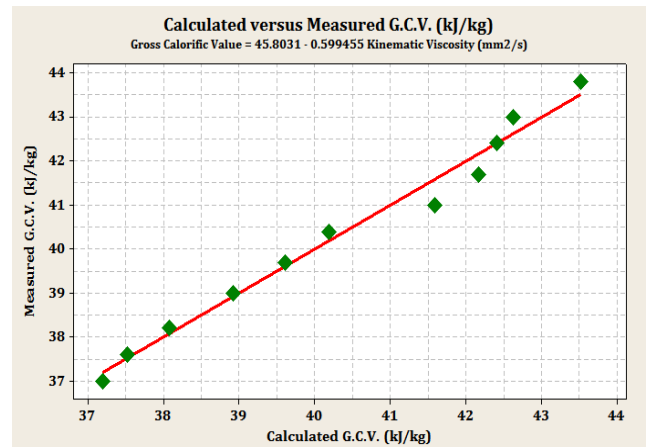
Graph 10

### 4.2 Statistical Correlation between Kinematic Viscosity & Gross Calorific Value:

The below given equation gives the statistical correlation between the Kinematic Viscosity & the gross calorific value of Karanja Oil Methyl Ester,

$$\text{Gross Calorific Value (kJ/kg)} = 45.8031 - 0.599455x \text{ Kinematic Viscosity (mm}^2\text{/s)} \dots \text{(Equation 2)}$$

There is a strong statistical correlation between Kinematic Viscosity & the Gross Calorific Value because after the statistical analysis  $R^2$  shows the value 98.22% only, it means that the Kinematic Viscosity & Gross Calorific Value have 98.22% Correlation between them. This correlation we have shown the Calculated Gross Calorific Value versus Measured Gross Calorific values on the graph.



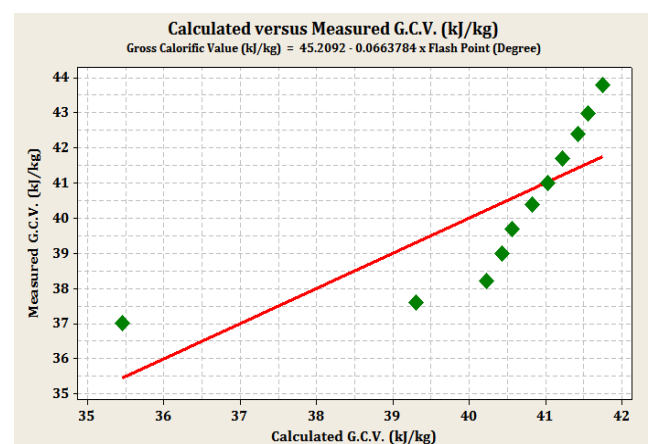
Graph 11

### 4.3 Statistical Correlation between Flash Point & Gross Calorific Value:

The below given equation gives the statistical correlation between the Flash Point & the gross calorific value of Karanja Oil Methyl Ester,

$$\text{Gross Calorific Value (kJ/kg)} = 45.2092 - 0.0663784x \text{ Flash Point (Degree)} \dots \text{(Equation 3)}$$

There is no strong statistical correlation between Flash Point & the Gross Calorific Value because after the statistical analysis  $R^2$  shows the value 61.17% only, it means that the Flash Point & Gross Calorific Value have 61.17% Correlation between them. This correlation we have shown the Calculated Gross Calorific Value versus Measured Gross Calorific values on the graph.



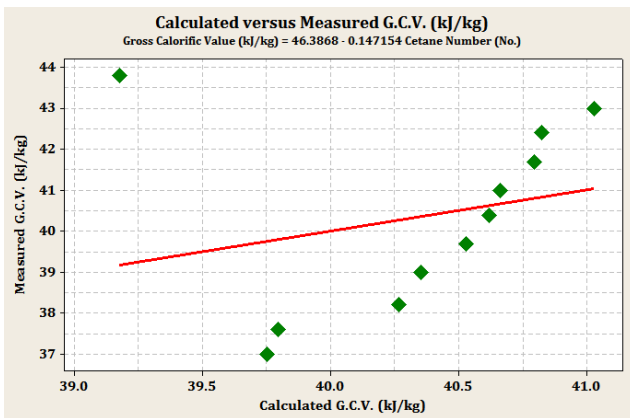
Graph 12

#### 4.4 Statistical Correlation between Cetane Number & Gross Calorific Value:

The below given equation gives the statistical correlation between the Cetane Number & the gross calorific Value of Karanja Oil Methyl Ester,

$$\text{Gross Calorific Value (kJ/kg)} = 46.3868 - 0.147154x \text{ Cetane Number (No.)} \dots \text{(Equation 4)}$$

There is no strong statistical correlation between Cetane Number & the Gross Calorific Value because after the statistical analysis  $R^2$  shows the value 6.16% only, it means that the Cetane number & Gross Calorific Value have 6.16% Correlation between them. This correlation we have shown the Calculated Gross Calorific Value versus Measured Gross Calorific values on the graph.



Graph 13

At last we can conclude that,

- i. The Density individually is having 97.78 % statistical correlation with the Gross Calorific Value, because of this accuracy we will get most accurate Gross Calorific Value of Karanja oil Methyl Ester from the given relation and it is the most important property in the calculation.
- ii. At the same time we have seen the relation between Kinematic Viscosity and the Gross Calorific Value; in this relation we got the individual property Kinematic Viscosity having 98.22 % statistical correlation with the Gross Calorific Value of Karanja Oil Methyl Ester. Because of this accuracy this property deserves its position in the calculation.
- iii. Flash point is not having that much of statistical correlation with the Gross Calorific Value. It has near about 61.17 % statistical correlation only. It means that flash point does not have most accurate correlation with the Gross Calorific value.

- iv. Cetane Number individual property does not have statistical correlation with the Gross Calorific Value because they are having 6.16 % correlation between them. The Cetane Number Individual property does not affect the Gross Calorific Value in any manner from the statistical analysis.
- v. As per the test analysis the copper strip corrosion is within the specific limits and it is accepted.
- vi. Future Scope of this study, at last if we considered the combination of physio – chemical property in the statistical analysis then and then only we will get most accurate results from the statistical Equations and it will definitely help in the calculation of engine combustion parameter designing in future.

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