CHARACTERIZATION AND DETERMINATION OF OPTIMUM BLENDING RATIO OF BLENDED WATERMELON SEED OIL METHYL ESTER

***Busari R. A; Adebayo K. R; & Alabi K. P.**
Food and Agricultural Engineering Department, Kwara State University Malete, Nigeria
E-mail: *rasheed.busari@kwasu.edu.ng

ABSTRACT

Watermelon fruit contains large amounts of seeds, which are underutilized in Nigeria. The seeds contain about 22% oil, which can be used as vegetable oil or as feedstock for biodiesel to power agricultural machineries. This study explored the physicochemical properties of watermelon biodiesel, crucial for understanding its suitability for various applications. The research demonstrated that watermelon biodiesel meets specified standards such as ASTM D-6751 and EN-14214, ensuring its viability for widespread use. Post-transesterification, the viscosity of raw watermelon oil decreases, though it remains notably higher than that of conventional diesel fuel. Moreover, watermelon biodiesel blends ranging from B5 to B25 comply with diverse specification standards, further validating its utility. Despite reductions in density, specific gravity, and flash point after transesterification, these values remain higher compared to diesel fuel. The study developed regression equations to forecast properties at varying blending ratios, indicating strong correlations between biodiesel properties and blending percentages. Notably, the derived equations exhibited high coefficient of regression values (0.8389 for density, 0.9317 for kinematic viscosity, 0.9669 for flash point, 0.9702 for specific gravity, and 0.9025 for calorific value), highlighting the reliability of predictions. Based on standard compliance considerations, a blending ratio of up to 25% was recommended as optimal for achieving desired properties in watermelon biodiesel blends.

Keywords: Blending ratio, Calorific value, Coefficient of regression, Kinematic viscosity, Watermelon biodiesel and Transesterification

INTRODUCTION

The primary liquid fuel is a mineral diesel, which is utilized in different industries which include transportation, energy, agriculture, etc. The transport sector accounts for more than 70% of all diesels use which is crucial to the economy of any nation. The fleet of transportation vehicles increases each year, and thus, fuel consumption rises as well. Mineral diesel is also used in the agricultural sectors for water pumps, generators or powering stationary machines. Diesel engines are preferred by both manufacturers and end users due to their excellent reliability, energy efficiency, durability, and cheap operating costs (Acharya *et. al*., 2016). Nevertheless, the supply of mineral diesel is running out just as the demand is rising. During burning, this non-renewable fuel releases pollutant substances such as smoke, nitrogen oxides, hydrocarbons, and carbon monoxide. These vehicle emissions are significant sources of air pollution, which is a leading factor in several respiratory illnesses and global warming (Acharya *et. al*., 2016).

Acid rain could be a result of sulphur being present in mineral diesel. The negative effects of pollution extend beyond just harming human existence; pollution also impacts other animals. The presence of these elements encouraged the use of alternative fuels such as biodiesel. Biodiesel is made from biomass, a naturally renewable resource that is environmentally friendly and biodegradable (Ashraful *et al*., 2014). Biodiesel significantly decreases pollutants such as Carbon Monoxide (CO), Particulate Matter (PM), and Hydrocarbon (HC). According to several studies on emission control of cars utilizing fuel, the United Environment Protection Agency performed research that found from their studies that the usage of 100% biodiesel can reduce CO and PM to

48% and HC to 68% (Acharya *et al*., 2016). Lower vapor pressure, a higher flash point, and cetane number are three other significant properties of biodiesel (Subramaniam *et al*., 2013). A higher cetane number suggests greater combustion and a shorter delay time. A higher flash point demonstrates that biodiesel is safer in terms of fire safety. Nevertheless, biodiesel also has several drawbacks, including poor oxidation stability, poor cold flow characteristics, and greater nitrogen oxide emission (Acharya *et al*., 2016). Biodiesel is now used in a blended form on a global scale. The blend of biodiesel is referred to as "Bn," where "n" is a number between 0 and 100, B0 being mineral diesel and B100 being biodiesel. For example, B40 stands for 40% biodiesel in a biodiesel-diesel blend. Non-edible oils are more suitable for biodiesel production because the oil do not compete with food materials.

The seeds of watermelon are underutilized presently in Nigeria. The juice from watermelon fruits is consumed on daily basis, while rind and seeds are major solid wastes. Watermelon fruit contains large quantities of seeds and an oil content of 22% as reported by Poornima *et al.* (2019). Presently, oil from watermelon seeds may be expressed utilizing a variety of techniques, including solvent oil extraction, conventional or local techniques, and mechanical extraction techniques (screw or hydraulic press). Although, current chemical methods of oil extraction (solvent) are characterized by high oil recovery yields, but associated with a number of drawbacks, including high cost, solvent retention in the oil, the need for skilled labour, and which may be a difficult task for local farmers in accessing these resources (Liauw *et al*., 2008). The ideal way of oil expression to address the aforementioned issues is mechanical expression, as this technique can be easily accessible and avoidable to local farmers. The quality of the oilseeds and the method of oil expression have a significant impact on the percentage of oil recovered from oil-bearing seeds in order to obtain the optimum oil out of the seeds. The expression process must be carefully controlled, and the number of factors may be manipulated to maximize oil yield. The moisture content of the seeds, particle size, applied pressure used, roasting times, and roasting temperature are some of the controllable variables (Olaoye and Busari, 2017). Raw watermelon oil and other vegetable oils have properties variation, such as a higher kinematic viscosity, poor cold flow characteristics, and poor spray characteristics, direct usage of these oils may not be feasible in compression ignition engines. Nevertheless, the kinematic viscosity may be decreased using a number of procedures such as blending, pyrolysis, and transesterification.

Shojaeefard *et al.* (2013) studied the effects of biodiesel blends on compression ignition engine performance and emissions. The study reported that blends with a lower biodiesel content might still deliver adequate engine performance and even enhanced the engine system but, 15% biodiesel blends was chosen as the ideal biodiesel-diesel ratio and lower blends are suitable substitute fuel for diesel engines. Also, Haiter *et al.* (2013) used methyl ester blends of 25% and 50% for performance testing under different loading situations. Tested parameters were brake thermal efficiency, brake-specific fuel, emissions of carbon dioxide, carbon monoxide, hydrocarbons, and nitrogen oxides. The properties of biodiesel developed were also compared with that of diesel fuel. The findings showed that diesel engines can run on B25 without the need for modification on the existing diesel engines. Properties and combustion characteristics of Jatropha biodiesel blends were examined; the relationship between different fuels established and a recommendation of up to 40% blends of biodiesel with conventional diesel was made (Chen *et al*., 2013). Dermibas (2008) computed the higher heating value of various vegetable oil and their corresponding biodiesel properties by developing mathematical equations. The literature mentioned above demonstrates that

mathematical equations can be created to forecast the fuel characteristics of blended biodiesel at different blending ratios and to suggest the ideal blending ratio for particular biodiesels.

In this study, biodiesel obtained from the seeds of watermelon was blended with diesel fuel at various ratios, and the physicochemical characteristics of each blend were examined using the accepted methodology. The mathematical equations for each property were developed by a simple regression model which can help to predict the properties of biodiesel at any blending percentage. An optimum blending ratio for blended watermelon biodiesel was proposed for various standards of biodiesel and diesel blends.

METHODOLOGY

Sample and Biodiesel Preparation

The seeds of watermelon were purchased from *Ipata* market in Ilorin metropolis, Nigeria and the oil was expelled from the seeds using a roaster expeller. The extracted oil was transformed into biodiesel using methanol as the solvent and potassium hydroxide as the catalyst in an alkaline transesterification process. For the experiment, 2% catalyst was dissolved in methanol, and the mixture was added to the measured watermelon oil. The prepared sample was then agitated at the set temperature and for the predetermined time. The reactant sample was kept in a transparent container and allowed to settle for about 6 hours at room temperature. Glycerine settled at the bottom of the container while methyl ester was on top; the sample was separated while the biodiesel was poured into the new vessel to remove fuel containments. The collected fuel was heated for about 10 minutes at a temperature of 110°C. The recovered fuel was allowed to cool under ambient temperature. The finished product (biodiesel fuel) was mixed with a prepared proportion of diesel fuel as follow: 5%, 10%, 15%, 20%, 25%, and 50%, and designated as B5, B10, B15, B20, B25, B50, and raw watermelon methyl ester (B100), respectively. The percentages of biodiesel blends were selected based on the trial experiments and the available literatures on the biodiesel blends. The methods reported by Busari and Olaoye (2017) and Busari *et al*. (2020) with some modifications were used for the determination of the physico-chemical properties.

Determination of Specific Gravity and Density

The ASTM D1298 standard was employed for measuring the density and specific gravity of the prepared watermelon biodiesel and its blends as reported by Busari *et al*. (2020). A Density Meter (Rudolph Research Analytical: DDM 2911 Automatic Density Meter), known for its precision (accuracy to 0.00005 g/cm^3) and manufactured in the United States of America, was utilized for this purpose.

Determination of Flash Point

The flash point was determined in accordance with ASTM-D93 standards following a specific procedure. About 70 ml of the oil sample was transferred to a test cup equipped with a thermocouple sensor. Subsequently, the sample was subjected to heating and agitation at intervals of 5–6 °C per minute and 90–120 rpm, respectively. An ignition source was periodically applied to the test cup, commencing from 23 to 28 °C below the anticipated flash point. Agitation ceased only upon the detection of a distinct flash. The recorded flash point was identified as the lowest corrected temperature under a barometric pressure of 101.3 kPa (ASTM, 2008).

Determination of Kinematic Viscosity

The viscosity of watermelon oil and biodiesel was determined according to the ASTM D445 standard procedure at a temperature of 40°C using a calibrated Viscometer (NDJ – IB Rotational Viscometer; Shanghai Chamgji). The sample was poured into the

beaker and placed directly onto the spindle of the machine, which was then activated to initiate the measurement. The displaced readings were noted and recorded.

Determination of Calorific Value/ Heat of Combustion

The calorific value was determined using a conventional bomb calorimeter (IKA Calorimeter, System C200 Basic Control) following the guidelines outlined in ASTM D240. A specimen of known mass was combusted under controlled conditions. Oxygen from a gas cylinder, pressurized between 20 – 35 Atm., was introduced to initiate combustion. The outcome was then observed and recorded on the bomb calorimeter's screen display (Busari *et al.*, 2020)

Characterization of watermelon oil and its biodiesel

Table 1 compares the various characteristics of watermelon oil, watermelon biodiesel, and conventional diesel to the following standards: ASTM-6751 and EN-14214. In comparison to mineral diesel, watermelon oil was found to have a higher density and kinematic viscosity. The higher molecular weight of triglyceride molecules is attributed to the higher density of biodiesel watermelon. Due to its different chemical makeup, biodiesel watermelon has a lower calorific value than that of diesel. These limitations prevent the direct use of raw watermelon oil in diesel engines. The kinematic viscosity value decreases significantly after transesterification, although it remains high but very close to that of mineral diesel. The prepared biodiesel meets ASTM D-6751 and EN-14214 criteria for properties such as density, kinematic viscosity, flash point, specific gravity, and calorific value, particularly in lower blends, B5 to B25. The Watermelon biodiesel has a higher flash point, reducing the risk of flammability hazards, and a lower calorific value, causing incomplete combustion and increased knocking characteristics when in use in existing diesel engines.

Analysis of properties of diesel-biodiesel blends

The Figs. 1 - 5 show variation of various properties of diesel-biodiesel blends. A regression coefficient (R^2) and mathematical equation have been developed for each property and the regression analysis tools of the Excel data analysis package was employed using the data presented in Table 2. This will help researchers and end users to estimate the value of properties at any blending ratio. The term "y" in all developed equations represents the blending ratio, which is defined as the percentage of biodiesel to mineral diesel in a blend of the mixture.

Table 1: Comparison of properties of watermelon oil, watermelon biodiesel, and conventional diesel.

Properties	**Unit**	**ASTM-D6751** (Atabani *et. al.,* 2013; Saravanan et. al., 2010)	**EN-14214** (Atabani *et. al.,* 2013; Saravanan et. al., 2010)	**Watermelon oil**	**Watermelon biodiesel**	**Diesel fuel**
Density at 15°C	g/cm^3		860–900	0.930	0.892	0.824
Kinematic viscosity at 40°C	mm^2/s	1.9–6	3.5–5	24.2	6.5	2.3
Flash point	ºC	>130	>101	270	180	53
Specific gravity		-	-	0.965	0.920	-
Calorific value	kJ/Kg	-	-	35,684	38,470	42,000

RESULTS AND DISCUSSION

Properties of watermelon biodiesel and diesel blend

Low calorific value, high specific gravity, and limited supply of biodiesel, it cannot be used in diesel engines at 100%, but can be blended with mineral diesel as a substitute. Blended biodiesel is now in use in some countries. Hence, research into the various properties of biodiesel-diesel blends to develop an effective fuel system that will work. Therefore, several of blends of watermelon biodiesel and mineral diesel were developed at different volume ratios ranging from 5 to 50%, and their characteristics, such as density, kinematic viscosity, flash point, calorific value, and specific gravity, were assessed. Table 2 displays these outcomes. In addition, different graphs for the variation of the mentioned properties with varying blending ratios have been plotted, and various mathematical equations have been established to account for the variation of various properties of watermelon biodiesel with different blends. These equations will enable the determination of the various properties at various blending ratios without the need for direct measurement, which saves both time and energy.

Mathematical relation between biodiesel properties and blending ratios.

The mathematical relationship between the characteristics of watermelon biodiesel and the blending ratio is shown in Table 3 and 4 present the recommended biodiesel standards for some physico-chemicals properties of biodiesel. The developed regression equations (Table 3) to forecast properties at varying blending ratios, indicating strong correlations between biodiesel properties and blending percentages. Notably, the derived equations exhibited high coefficient of regression values; 0.8389 for density, 0.9317 for kinematic viscosity, 0.9669 for flash point, 0.9702 for specific gravity, and 0.9025 for calorific value, highlighting the reliability of predictions. Based on standard compliance considerations, a blending ratio of up to 25% was recommended as optimal for achieving desired properties in watermelon biodiesel blends.

Table 2: Properties of blended watermelon biodiesel and diesel fuel.

Properties	Unit	Diesel	B5	B10	B15	B20	B25	B50	B100
Density at 15°C	kg/m^3	824	833	840	852	856	860	878	892
Kinematic viscosity at 40°C	mm^2/s	2.3	2.8	3.1	3.5	3.9	4.3	5.4	6.5
Flash point	ºC	53	88	102	110	115	122	135	180
Specific gravity	-	-	0.867	0.875	0.879	0.881	0.885	0.900	0.920
Calorific value	kJ/Kg	42,000	41,800	41,650	41,430	41,300	40,220	39,500	38,470

Table 3: Mathematical relation between watermelon biodiesel properties and blending ratios.

Properties	Unit	Regression coefficient (R^2)	Mathematical relation
Density at 15°C	g/cm^3	0.8389	0.0006x + 0.8416
Kinematic viscosity at 40°C	mm^2/s	0.9317	0.0384x + 2.9815
Flash point	ºC	0.9669	0.8768x + 93.532
Specific gravity	-	0.9702	0.0005x + 0.8698
Calorific value	kJ/Kg	0.9025	-36.131x + 41786

Table 4: Recommended biodiesel Standards for some Physico-chemicals Properties

Properties	Unit	ASTM D-975	EN-590	CNS-1471	ASTM D-7467	BIS
Density at 15°C	g/cm^3	-	820–845	-	-	820–860
Kinematic viscosity at 40°C	mm^2/s	1.9–4.1	2– 4.5	1.9 – 4.1	1.9 – 4.1	2 – 4.62
Flash point	ºC	52 min	52 min	52 min	52 min	35 min
Specific gravity	-	-	-	-	-	-
Calorific value	kJ/Kg	-	-	-	-	-

Acharya *et. al.* (2016).

Effects of Blends on Fuel Properties

The research delved into the impact of biodiesel/diesel blends on various fuel properties like kinematic viscosity, density, calorific value, specific gravity, and flash point, as illustrated in Figs. 1 to 5. With increasing concentrations of biodiesel in the blends, density exhibited an upward trend (Fig. 1). Notably, the densities of B5 to B25 fell within the acceptable range outlined by international standards while B50 and B100 fell out of range acceptable. Kinematic viscosity, a crucial indicator of fluid flow ability, rose with higher percentages of biodiesel in the blends (Fig. 2). However, high viscosity poses a significant challenge for the direct use of vegetable oils and animal fats in compression ignition engines due to its adverse effects on fuel flow and spray characteristics (Busari *et al.*, 2020). Despite this, the viscosities of B5 to B25 close to that of diesel fuel, making them viable for diesel engines without necessitating engine modifications. Higher viscosity in biodiesel can sometimes be attributed to unreacted triglycerides in the fuel. Modern diesel engines equipped with advanced injection pumps are intolerant to high-viscosity fluids, as they can cause fuel filter clogging (Igbokwe *et al.*, 2015. Biodiesel viscosity is influenced by its fatty acid profile, and blends from various feedstocks help mitigate viscosity to meet recommended standards. Comparatively, the viscosity of soybean reported by Knothe (2010) was slightly lower than the findings of this study. The calorific values of the blends decreased as the concentration of biodiesel increased (Fig. 3). This decline can be attributed to the higher oxygen content in biodiesel compared to diesel, leading to reduced hydrogen and carbon contents in the blend, which are essential for thermal energy generation (Acharya *et al.*, 2016).

Variation of density with the blending ratio

Density is a key fuel parameter that affects engine performance as the changes in fuel density will affect the amount of fuel injected into the combustion chamber of any engine. The volume of fuel is measured by the engine's fuel injection system. Without any doubt, any change in density will have an immediate impact on the engine's power. The relationship between density and blending ratio is shown in Fig. 1, which has a high coefficient of determination (R^2 =0.8389). It was observed that the density increases with an increase in the blending ratio due to an increase in the volumetric percentage of watermelon biodiesel blends. Hence, the density of methyl ester increases as the number of double bonds rises; the more unsaturated the originating vegetable oil, the higher the density of the resulting biodiesel, and the more fuel will be injected into the engine cylinder when the diesel engine is run on biodiesel (Giakoumis, 2013). The density of blended fuel was 833 kg/m^3, 840 kg/m^3, 852 kg/m^3, 856 kg/m^3, 860 kg/m^3, 878 $kg/m^3$and 892 kg/m^3 for B5, B10, B15, B20, B25, B50 and B100, respectively, whereas the density of mineral diesel was 824 kg/m^3. Furthermore, according to recommendation of biodiesel diesel blend standards by BIS, the density of methyl ester ranged between 820 to 860 kg/m^3. Therefore, only B5, B10, B15, B20, and B25 fall within the acceptable standard as shown in Table 4. The result obtained for this study was close to

the previous work carried out on mahua biodiesel by Acharya *et. al.* (2016) and blending ratio of 30% (B30) was recommended.

Variation of the kinematic viscosity with the blending ratio

One of the most crucial characteristics of liquid fuel is its kinematic viscosity since it affects how a fuel injection system functions, especially at low temperatures when an increase in viscosity reduces the fuel's fluidity. Higher fuel viscosity leads to delayed combustion, resulting in heightened levels of soot formation, carbon deposits, and challenges in fuel atomization. As depicted in Fig. 2, there is a clear correlation between kinematic viscosity and the rise in blending ratio. Similar to density, the kinematic viscosity of watermelon biodiesel shows a linear increase with higher volumetric percentages of biodiesel in a biodiesel-diesel blend. The kinematic viscosity of different biodiesel blends (50 %, 25 %, 20 %, 10 %, 5 %) and raw biodiesel was determined to be 5.4, 4.3, 3.9, 3.5, 3.1, 2.8, and 6.5 mm^2/s respectively, while the kinematic viscosity of mineral diesel was 2.3 mm^2/s. It was observed from the results obtained that the viscosities of blends of B5 – B25 were within the limits specified by BIS and EN-590 as reported in Table 4 which ranges from 2 - 4.62 mm^2/s. Research suggested that only biodiesel blends between B5 and B25 were within the recommended range, improved the fluidity of the fuel for diesel engines, would have a suitable spray pattern into the combustion chamber, and would allow for adequate mixing of air. Increased kinematic viscosity would result in ineffective fuel spray atomization and imprecise fuel injector performance (Giakoumis, 2013) and the coefficient of determination of the relationship between kinematic viscosity and blending ratio was 0.9317. The result obtained for this study was similar to the previous work carried out on castor Biodiesel by Olaoye and Busari (2018).

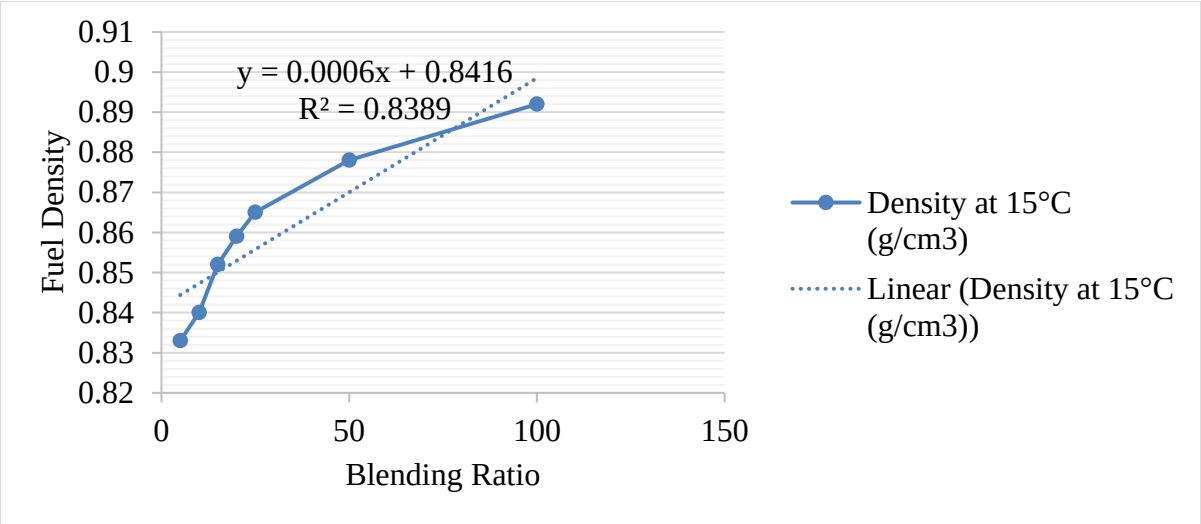

Fig. 1: Variation of watermelon biodiesel density

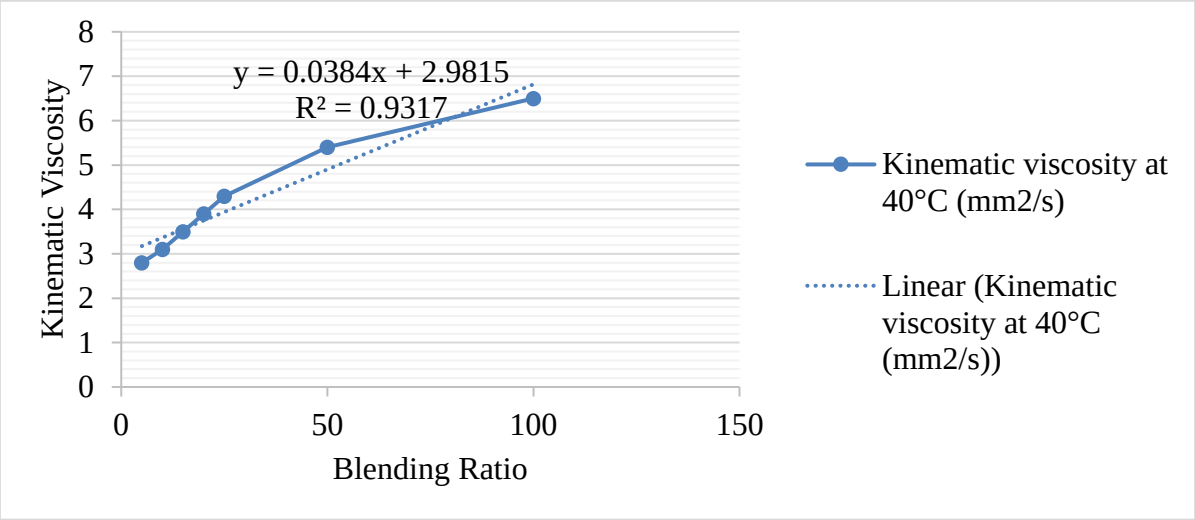

Fig. 2: Variation of watermelon biodiesel kinematic viscosity

Variation of the calorific value with the blending ratio

The calorific value, representing the amount of heat emitted per unit mass of fuel, stands as a critical factor in fuel selection for engines, influencing both fuel consumption and power output. Fig. 3 illustrates the variation in calorific value with the blending ratio. Interestingly, it reveals a decline in calorific value as the blending ratio increases, which contrasts with the trends observed in density and kinematic viscosity. This reduction in calorific value is attributed to the growing concentration of biodiesel in the biodiesel-diesel blend mixture, given that the calorific value of biodiesel is lower than that of diesel. A reduction in emissions of particulate matter and smoke has been confirmed when vegetable oil is used as the fuel source. A lower calorific value and greater possibility of particulate matter reduction result from a higher oxygen concentration (Agarwal, 2007; Giakoumis, 2013). Table 4 shows recommended standards for biodiesel-diesel blends, but no standard was mentioned for the calorific value of biodiesel According to Giakoumis (2013), biodiesel has a calorific value between 35,990 and 38,800 kJ/kg on average, which is 10–11% less than the mineral diesel fuel. The calorific value coefficient of determination (R^2) is 0. 9025.

Variation of a flash point with the blending ratio

The minimum temperature at which a fuel releases sufficient vapour to ignite is known as the flash point. From the perspective of safety, flash point is vital. A higher flash point is often recommended. Low fuel volatility is indicated by a higher flash point. The variation of flash point with the blending ratio is shown in Fig. 4. When the blending ratio increases and watermelon biodiesel has a higher flash point, it exhibits an increasing tendency. Despite this, none of the blends meet the suggested guidelines. Watermelon biodiesel has a higher flash point than conventional diesel (53°C), making it safer to transport and store than conventional diesel. The flash points of watermelon biodiesel and its blends were, 180°C, 135°C, 122°C, 115°C, 110°C, 102°C, and 88°C for B100, B50, B25, B20, B10, and B5, respectively. Giakoumis (2013) reported flash points of 26 feedstocks and found that the mean value for all the feedstocks investigated was 163.3°C. The results of both watermelon biodiesel and its blends are above the recommended value of flash point. The coefficient of regression value obtained for flash point of watermelon methyl ester at various blends is 0.9669,

which is relatively high and can be used to certain extent predict the flash point at any blending ratio.

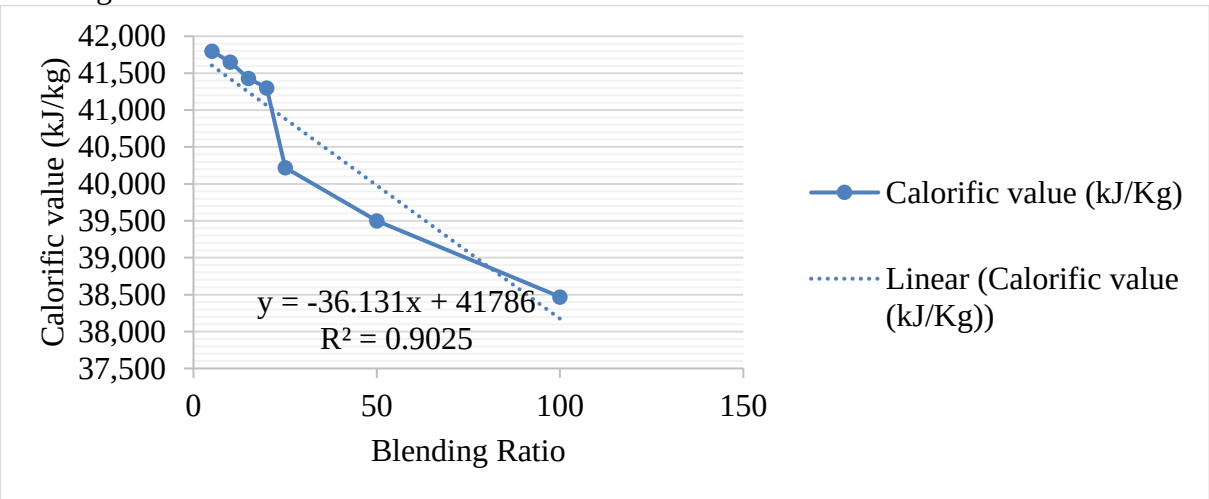

Fig. 3: Variation of watermelon biodiesel calorific value.

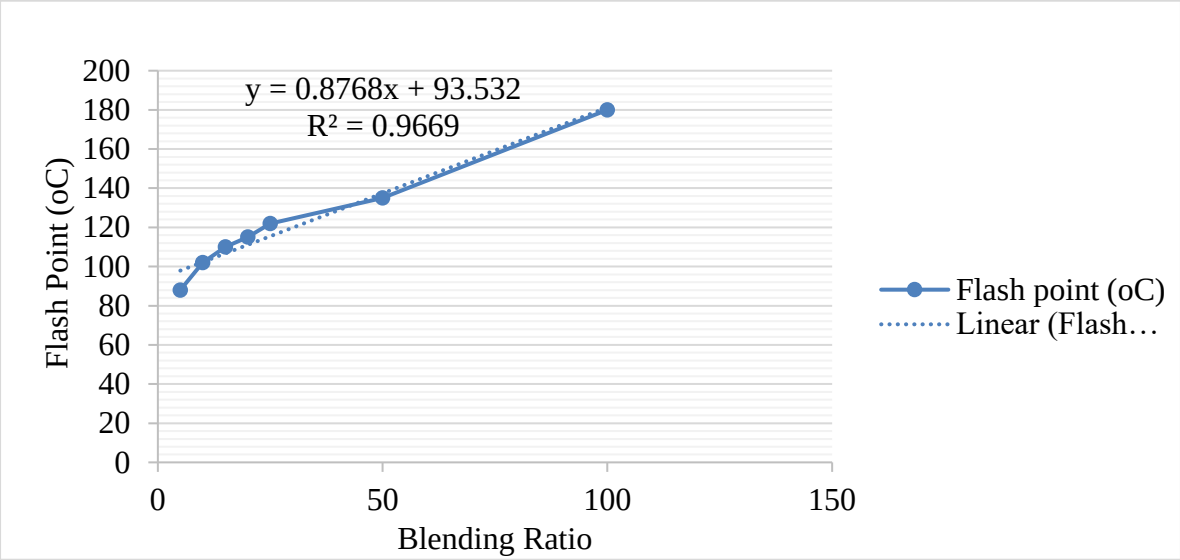

Fig. 4: Variation of watermelon biodiesel flash point.

Variation of Specific gravity with blending ratio

Specific gravity (a function of density) the property affects quantity of fuel is injected into an engine system, it has an impact on how well an engine performs (Acharya *et al*., 2016). The variation in specific gravity and biodiesel blending ratio are shown in Fig. 5.

It was observed that a linear relationship between the specific gravity and the blending ratio exists as the concentration of biodiesel in the blends increases. The coefficient of regression value obtained for specific gravityt of watermelon methyl ester at various blends is 0.9702, which is relatively high and can be used to certain extent estimate the specific gravity at any blending ratio.

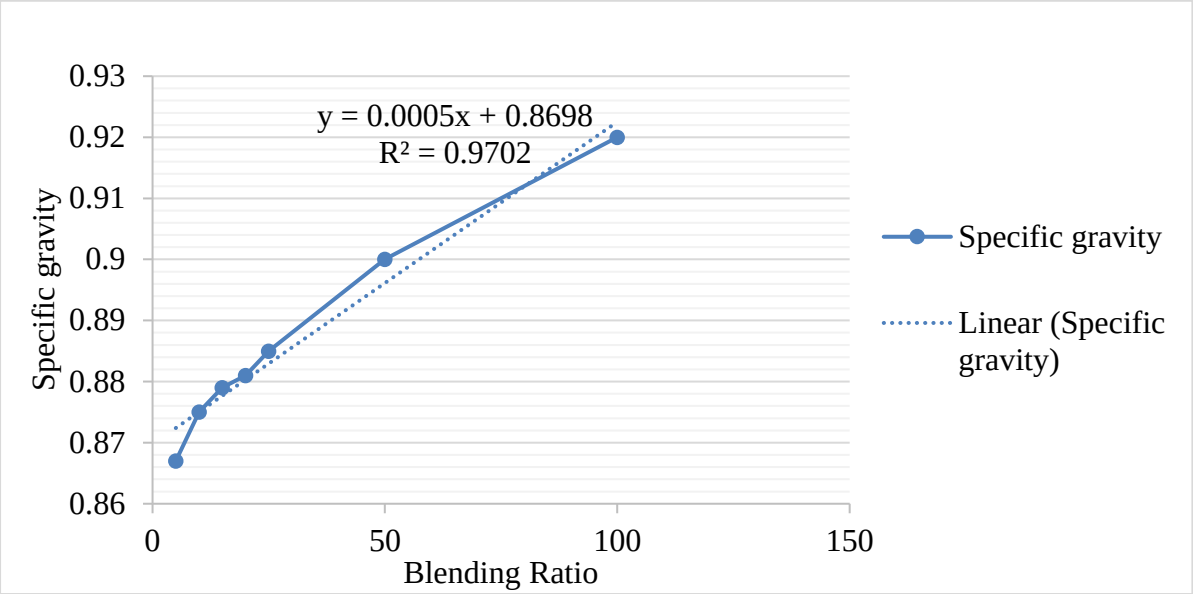

Fig. 5: Variation of Watermelon Biodiesel Specific gravity

Optimum blending ratio

When biodiesel and diesel fuel are mixed, the resultant fuel's properties are altered according to the volumetric percentage of biodiesel in the blend. The blending ratio will be optimum when the blended fuel satisfies the different standards as specified in Table 4. The blending ratio of 25% (B25), as reported in all biodiesel properties discussed complies with the requirements of the various standards listed in Table 4. Most properties above B25 are out of range. Moreover, blended biodiesel exhibits properties closer to those of diesel up to a 25% blending ratio. Specifically, the density is only 4.4% higher, the calorific value is merely 4.2% lower compared to mineral diesel, and the kinematic viscosity is 86.9% higher than that of diesel. Furthermore, the flash point value surpasses that of diesel. Consequently, the B25 blending ratio is suggested as the optimal blend for watermelon biodiesel with mineral diesel, suitable for use in unmodified diesel engines without significant power loss.

CONCLUSIONS

The suitability of watermelon oil as biodiesel for powering diesel engines was examined in this study, the various physicochemical characteristics of watermelon biodiesel meet the standards requirement such as ASTM D-6751 2017, EN-14214 2017, EN-590 2017, and BIS 2018. Nonetheless, watermelon biodiesel still has a higher viscosity than mineral diesel. In order to determine how the various properties of watermelon biodiesel vary with volumetric percentage, the watermelon biodiesel was blended with diesel fuel. Lower percentages of blended biodiesel exhibit characteristics more akin to those of diesel. To predict the properties of blended biodiesel across different blending ratios, several mathematical equations have been devised. These models demonstrate a higher coefficient of regression (R^2) between biodiesel characteristics and blending ratio. Adhering to standards and ensuring compliance with specifications, a recommended optimal blending ratio of 25% has been identified. Further research, on the engine performance and emission characteristics of the watermelon biodiesel-diesel blend at different. blending ratio to get

optimal engine performance and better emission characteristics is ongoing.

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