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A STUDIES ON PHYSICO-CHEMICAL PROPERTIES OF *JATHROPHA* BIODIESEL BLENDS

B. Anuraja* and D. Manohar Jesudas[1]

Department of Agricultural Engineering, Agriculture College, U.A.S., Dharwad (Karnataka), India.
[1]Department of Farm Power and Machinery, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India.

Abstract

A study was conducted at Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India. There are totally six fuel blends of *jatropha* biodiesel and petro diesel were made, *viz.*, D100, B20, B40, B60, B80 and B100 were taken up for physico-chemical studies. The fuel properties *viz.*, calorific value, kinematic viscosity, specific gravity, flash and fire point, cloud and pour point, carbon residue, ash content free fatty acid, acid value and saponification value were determined. The calorific value of diesel, raw *jatropha* oil and esterified oil were 43.67, 33.42 and 36.53 MJ/kg, respectively. The calorific value of biodiesel blends B20, B40, B60 and B80 were 41.51, 39.48, 38.85 and 37.98 MJ/kg, respectively. The kinematic viscosities of diesel, raw *jatropha* oil and esterified oil were 1.93, 25.28 and 3.84 cSt. The specific gravity of the raw *jatropha* oil and biodiesel blends varied from 0.824 to 0.91 g/cc. The flash and fire point of raw *jatropha* bio diesel was 143 ^{0}C and 161 ^{0}C respectively. The ash content, carbon residue and free fatty acid content of the biodiesel blends varied between 0.014 to 0.01, 0.28 to 0.35 and 0.26 to 0.53 per cent, respectively.

Key words : Bio diesel, physico chemical properties, biofuel, *Jathropa* oil, transisterification.

Introduction

The economy of a country is dedicated by its agricultural and industrial growth, which greatly depends on energy resources and their consumption. India is the world's sixth largest consumer of energy and fifth largest in diesel consumption (Joshi, 2005). By 2030 the demand for diesel of our country is projected to increase at an annual rate of 5.8 per cent which amounts to 65 million tons (Kumar *et al.*, 2003). The demand for refined product is forecasted to rise still at a higher rate. Out of the total consumption of petroleum products, the high speed of diesel oil consumption is alone about 40.124 MT and consumption of light diesel oil is about 8.83 MT (Joshi, 2005). The nation's energy bill amount to about 35 per cent of the union budget of Rs.10 29000 crores for the year 2009-10. In India the high speed diesel is used up to 56.75 and 18.86 per cent for transport and agricultural sector, respectively.

The energy demand for both industry and agriculture sector is economically increasing every year. The increase in energy demand for agricultural sector is mainly due to introduction of machineries like tractors, power tillers, combined harvesters, power sprayers, irrigation pumps and other power operated machineries. The share of mechanical and electrical power has increased from 40 per cent in 1971 to 84 per cent in 2004 (Anonymous, 2005). The agriculture sector of the country is completely depending on diesel for its motive power and to some extent for stationary power applications. Thus, the increased form mechanization in agriculture has future increased the requirement of this depleting fuel sources.

The alternative fuel technology usage will become more common in the coming decades for both automobile and stationary motive power applications in agriculture. The promising alternative is the usage of bio-diesel instead of fossil fuels. The main advantage of using of bio diesel is that its properties are similar to that of diesel fuel.

The advantage of using bio diesel as a fuel for diesel engines include better self ignition characteristics, better compatibility with fuel injection system used in the existing compression ignition engines, high energy content. Greater thermal efficiency than diesel fuel besides being eco friendly and non poisonous, Bio-diesel being a superior fuel compared to diesel fuel from environment point of view. The use of diesel makes net addition of carbon to

***Author for correspondence:** E-mail: anu_cae@rediffmail.com

the atmosphere when it is burnt. The use of bio-diesel also reduces our dependability in importing crude oil. As the flash point of the bio-diesel is higher than diesel it has no storage problems. Bio-diesel does not contain volatile organic compounds that give rise to poisonous and noxious fumes. It has no lead or sulphur to react and release of any harmful gases. Hence, an attempt has been made to determine the physic-chemical properties of bio-diesel derived from *jatropha* oil biodiesel blends and compared with petro-diesel.

Materials and Methods

High viscosity of *Jatropha* oil makes it unsuitable as complete replacement of diesel in CI engines. The biodiesel derived from *Jatropha* oil is designated as B100 (Biodiesel 100 per cent). Biodiesel always refers to the pure fuel. Biodiesel blend or BXX refers to a fuel that is composed of XX% of biodiesel and 100-XX% diesel fuel (Varma and Ajay Sharda, 2005). The blends were selected with an increment of 20% of XX value up to 100 percent blend level and designated as B20, B40, B60, B80 and B100 respectively. The nomenclature given for blends prepared is presented in table 1.

The selected fuels blended on volume basis are depicted in plate 1. These fuel blends were used for determining the physicochemical properties. Physico-Chemical properties of diesel and biodiesel blends that are critical for understanding their performance in engine were measured. The fuel properties, which were selected for this study are fallows (IS 1460:2000 and Pramanik, 2002). The properties of *Jatropha* oil and its blends were determined along with pure diesel. The chemical properties reflect the composition of biodiesel. The impurities like free fatty acid, water content, and acid value and Saphonification number were determined for standard diesel, raw *Jatropha curcas* oil and the blends. The nomenclature followed by Raheman and Phadatare, (2004) as D100, B20, B60, B80 and B100 for pure diesel and blend of esterified *jatropha* oil with diesel was adopted in this study. Physico-Chemical properties of diesel and biodiesel blends that are critical for understanding their performance in engine were measured. The fuel properties, *viz.*, i) calorific value, ii) kinematic viscosity, iii) specific gravity, iv) flash point, v) cloud point vi) pour point, vii) carbon residue, viii) ash content which were selected for this study are follows the IS 1460:2000 and Pramanik (2002) procedure.

The following chemical properties *viz.*, i) free fatty acid, ii) acid value, iii) saponificatio value of biodiesel blends were measured in this study as per procedure of Canacki and Van Gerpen (1999) and Tomasevic and Siler-Marinkovic (2003).

Results and Discussion

a. Physical properties

i. Calorific value : The calorific value is an important property of fuel, which directly relates to the fuel consumption. The calorific values of diesel and blends of biodiesel was determined using bomb calorimeter. The results are presented in table 2.

Goering *et al.* (1982) and Silvio *et al.* (2002) reported that the calorific value for vegetable oils and diesel blendes varied from 36.53 to 41.26 MJ/kg. The calorific value of diesel fuel is 43.67 MJ/kg. The calorific value of raw *Jatropha curcas* oil is 33.42 MJ/kg and esterified oil is 36.53 MJ/kg. From table 2, it is observed that the calorific value for blends B20, B40, B60 and B80 were 41.51, 39.48, 38.85 and 37.98 MJ/kg respectively and calorific value decreases as the per cent of fuel blend increases (Goering *et al.,* 1981). The same trends were observed for karanja oil (Raheman and Phadatare, 2004). The heating value decreases by 5.5 per cent to 16.30 per cent. These findings are similar to the findings of Yukitsugu and Takeuchi (1987). Hence, the addition of diesel increases the heating value of biodiesel blends. The comparison of theoretical and actual calorific values is shown in fig. 1 and it is observed that the theoretical value is more than actual findings which may due to experimental error.

ii. Kinematic viscosity : Bhasabutra and Sutiponpeibun (1982), Rao and Gopalakrishnan (1991); Foidl *et al.* (1996) and Srivastava and Prasad (2000) have reported based on experiment that higher viscosity levels (20 to 54 cSt) of oils are not suitable for running diesel engines.

The kinematic viscosity of standard diesel was 1.93 cSt and raw *Jatropha curcas* oil was 25.28 cSt. From experimental data, it was inferred that the kinematic viscosity of raw oil decreases during transesterification and for transesterified *jatropha* oil kinematic viscosity was 4.58 cSt. The results are in closer agreement with the findings of Sangha *et al*. (2000). From the table 2, it is observed that the viscosity of blends B20, B40, B60 and B80 were 2.43, 2.86, 3.15 and 3.43 cSt, respectively, as the biodiesel was added to the diesel, its kinematic viscosity increases. The comparison of actual to theoretical kinematic viscosities is shown in fig. 2. These findings were similar to the findings of Reheman and Phadatare (2004).

iii. Specific gravity : The specific gravity of the raw *jatropha* oil and its blends varied from 0.91 to 0.824

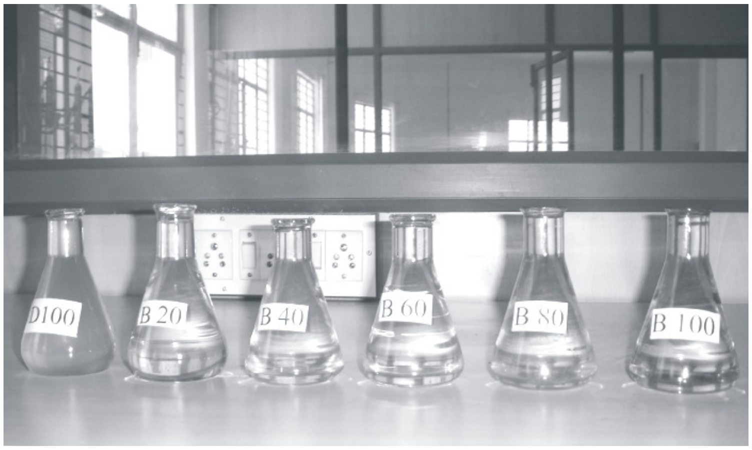

Plate 1 : Biodiesel blends.

Table 1: Details of biodiesel blends and nomenclature

S. no.	Fuel type	Nomenclature
1	0% Biodiesel +100% Diesel	D100
2	20% Biodiesel + 80% Diesel	B20
3	40% Biodiesel + 60% Diesel	B40
4	60% Biodiesel + 40% Diesel	B60
5	80% Biodiesel + 20% Diesel	B80
6	100% Biodiesel + 0% Diesel	B100

g/cc at 40^{0}C, which are comparable to the DIN standards (0.875 to 0.890).

The specific gravity of 0.910 g/cc for raw *jatropha* oil was on par with the value of 0.9098 g/cc at 40ºC as reported by Bringi (1987). After transesterification it was within the standard value of 0.9g/cc. From the table 2, it is observed that the specific gravity of the esterified *jatropha* oil decreases with the increase in the quantity of diesel in the blend. These values are in comparison with the findings of Raheman and Phadatare (2004) for esterified karanja oil.

iv. Flash point : The flash point of the raw *Jatropha curcas* oil was 188^{0}C and after transesterification, it reduced to 143^{0}C, which was lower than the value of 175^{0}C as reported by Kandapal and Mira (1995) and Foidl *et al.* (1996). This may be due to the composition of the volatile fractions in oil.

The flash point of diesel and its blends are shown in table 2. The flash point of blends B20, B40, B60 and B80 were 76, 87, 95, and 100^{0}C, respectively. The flash point was 2.13 times higher than that of diesel (67^{0}C). The flash point of esterified biodiesel decreases with addition of diesel. These values are in close agreement with the findings of Forson *et al.* (2004).

v. Fire point : The fire point of the raw *Jatropha curcas* oil was 203^{0}C, which is 2.7 times higher than the diesel (75^{0}C). This was reduced to 161^{0}C during esterification process.

The fire point of raw *Jatropha curcas* oil diesel and its blends are shown in table 2. The fire point of blends B20, B40, B60, B80 and B100 were 82, 94, 106 114 and 161^{0}C, respectively; it is observed that as the quantity of biodiesel in the blend increased the fire point also increased (Forson *et al*., 2004).

vi. Ash content : The maximum ash content was observed for diesel (0.021%). The ash content for *jatropha* oil was 0.00 per cent as it blends with diesel, it varies between 0.014 and 0.010 per cent. The addition of biodiesel to the diesel increases the carbon residue of the fuel as shown in table 2. It was reported that the ash content of ester and its blends with diesel was less than the ash content of diesel (0.01% at B80) as recommended by the ASTM.

vii. Carbon residue : The carbon residue is an important property for indicating the cooking characteristic of the fuel. The DIN standard of carbon residue is <0.50 per cent, Peterson *et al*. (1998) reported that the carbon residue of hydrogenated ethyl ester and its blends with diesel were less than the diesel fuel. The carbon residue in case of standard diesel was 0.26 per cent and for raw *jatropha* oil is 0.51 per cent which is 1.96 times higher than diesel. The addition of biodiesel to the diesel increases the carbon residue of the fuel as shown in table 2. The carbon residue for the selected blends were ranged from 0.28 -0.35 per cent, respectively.

Hence, it can be concluded that addition of biodiesel to the standard diesel increased the carbon residue of the blend. These trends were similar to the report of Foidl *et al.* (1996). The carbon residue could be reduced by further filtration of impurities.

viii. Cloud point : The cloud point of *jatropha* biodiesel was observed to be 3.5^{0}C, which is slightly lower than that of raw *Jatropha curcas* oil which may be due to change in composition of biodiesel during esterification. The addition of diesel in biodiesel decreases the cloud point and in case of 100 per cent standard diesel, it was –9.3^{0}C (table 2). This shows that cloud point of fuels with blend and additives was less than that of the diesel fuel (Clark *et al*., 1984).

ix. Pour point : The lowest pour point of -13.5^{0}C was observed in diesel (table 2) and addition of esterified *jatropha* oil increases the pour point and in case of 100 per cent esterified biodiesel it was –3.5^{0}C, which is slightly lower than that of raw *jatropha* oil (-1^{0}C). The same trend were observed and reported by Yukitsugu and

Table 2. Physico-Chemical properties of diesel and selected *Jatropha* biodiesel blends

Blends	Physical properties									Chemical properties			
	Calorific value MJ/Kg	Specific gravity g/cc	K. Visco-sities	Flash point ^{0}C	Fire point ^{0}C	Ash content %	Carbon residue %	Cloud point ^{0}C	Pour point ^{0}C	Free fatty acid %	Acid value %	Water content %	Saphoni -fication value
D100	43.67	0.824	1.93	67	75	0.021	0.26	-9.3	-13.5	-	-	0.10	-
B20	41.51	0.834	2.43	76	82	0.014	0.28	-8.0	-11.1	0.26	0.530	0.11	168.23
B40	39.49	0.841	2.86	87	94	0.010	0.30	-4.7	-7.4	0.30	0.597	0.11	170.1
B60	38.85	0.852	3.75	95	106	0.012	0.30	-2.2	-6.5	0.36	0.729	0.13	180.16
B80	37.98	0.865	3.43	100	114	0.010	0.34	-1.3	-4.0	0.53	0.895	0.17	187.66
B100	36.53	0.873	3.84	143	161	0.000	0.35	3.5	-3.5	0.66	1.326	0.19	192.16
Raw *jatropha* oil	33.42	0.910	25.28	188	203	0.000	0.51	5.5	-1	2.16	4.378	0.12	209.0

Takeuchi (1987).

b. Chemical properties

i. Free fatty acid : The fatty acid composition was used to predict the suitability of oil for use as biodiesel (Azam *et al.*, 2005). The free fatty acid of the esterified *Jatropha curcas* oil (0.66%) was lower than that of raw oil (2.16%). This may be due to neutralization of free fatty acid by excess amount of NaOH catalyst during esterification process.

The standard biodiesel has no free fatty acid as it is a mineral oil. The free fatty acid for standard diesel, its blends and raw *Jatropha curcas* oil are shown in table 2. It is observed that the increase in per cent of esterified oil in standard diesel increases the per cent free fatty acid.

ii. Acid value : The acid value of raw *Jatropha curcas* oil was 4.378 and reduced to 1.326 during esterification. In case of standard diesel, the acid value was zero. The acid value increases as per cent of biodiesel increase in the diesel blend as shown in table 2.

iii. Water content : The water content for raw *Jatropha curcas* oil was 0.12 per cent and in case of esterified *Jatropha curcas* oil, it was 0.19 per cent. This increase in water content in case of esterified *Jatropha curcas* oil is mainly due to the water retained in the oil during water washing in esterification process. In case of standard diesel, the water content was 0.10 per cent. The water content in case of diesel blends is shown in table 2. It is observed that addition of biodiesel increased the per cent of water content in the blend.

iv. Saponification value : Saponification value represents the amount of alkali required to saponify one gram of oil or fat. This value is useful for a comparative study of fatty acid bond length in oil. The saponification value in case of standard diesel was zero, as it has no fatty acid. The saponification value in case of raw *Jatropha curcas* oil was 209.0 and was reduced to 192.16 for esterified oil during esterification. The saponification values for biodiesel blends are shown in table 2. This indicates that the saponification value increases as the per cent biodiesel increases in the diesel. The same trends were observed and reported by Azam *et al.* (2005).

Conclusion

There are seven physical fuel properties were measured and four chemical properties were analyze using standard procedures. The calorific value of standard diesel fuel was 43.67 MJ/kg. The calorific value of raw *Jatropha curcas* oil was 33.42 MJ/kg and esterified oil was 36.53 MJ/kg and the calorific value for blends B20, B40, B60 and B80 were 41.51, 39.48, 38.85 and 37.98 MJ/kg respectively. The kinematic viscosity of standard diesel was 1.93 cSt. The kinematic viscosity of raw *Jatropha curcas* oil was 25.28 cSt and the esterified oil was 3.84 cSt. The viscosity of blends B20, B40, B60 and B80 were 2.43, 2.86, 3.15 and 3.43 cSt respectively. The specific gravity of the raw *Jatropha* oil and its blends varied from 0.91 to 0.824 g/cc at 40^{0}C. The flash point of the standard diesel was 67^{0}C. The flash point of raw *Jatropha curcas* oil was 188^{0}C and after transesterification, it reduced to 143^{0}C. This flash point was 2.13 times higher than that of diesel (67^{0}C). The flash point of blends B20, B40, B60 and B80 were 76, 87, 95 and 100^{0}C, respectively. The fire point of the raw *Jatropha curcas* oil was 203^{0}C, which is 2.7 times higher than standard diesel (75^{0}C). This was reduced to 161^{0}C during esterification process. The fire point of B20, B40, B60 and B80 were 82, 94, 106, 114 and 161^{0}C, respectively. The maximum ash content was observed for diesel (0.021%). The ash content for *Jatropha* oil was 0.00 per cent as it blends with diesel it varies between 0.014 and 0.010 per cent. The carbon residue in case of standard diesel was 0.26 per cent and for raw *Jatropha* oil it was 0.51 per cent, which is 1.96 times higher than diesel. The carbon residue for the selected blends ranged from 0.28 - 0.35 per cent, respectively. The cloud point of *Jatropha* biodiesel was observed to be 3.5^0C, which was slightly lower than that of raw *Jatropha curcas* oil. In case of 100 per cent standard diesel it was -9.3^0C. The lowest pour point of -13.5^0C was observed in diesel. In case of 100 per cent esterified biodiesel it was -3.5^0C, which was slightly lower than that of raw *Jatropha* oil. The free fatty acid of the esterified *Jatropha curcas* oil was 0.66 per cent and for raw oil it was 2.16 per cent. Free fatty acid for the other blends ranged from 0.26 to 0.53 per cent. The acid value of raw *Jatropha curcas* oil was 4.378 and reduced to 1.326 by esterification. In case of standard diesel, the acid value was zero. The water content for raw *Jatropha curcas* oil was 0.12 per cent and in case of esterified *Jatropha curcas* oil, it was 0.19 per cent. In case of standard diesel, the water content was 0.10 per cent. The saponification value in case of raw *Jatropha curcas* oil was 209.0 and was reduce to 192.16 during esterification.

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