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Research Article

Assessment of Chemical and biodiesel properties of seed oils of *Holoptelea integrifolia* and *Ichnocarpus frutescens*: Based on component fatty acids

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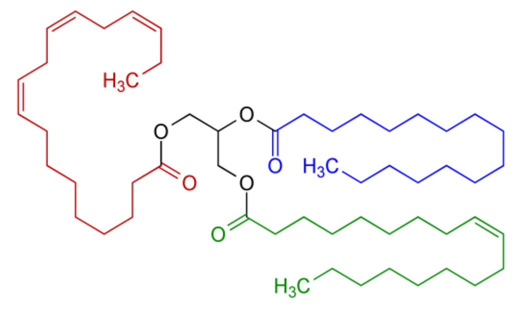
Abstract

Non edible seed oils like *Holoptelea integrifolia* seed oil (*HISO*) and *Ichnocarpus frutescensseed oil* (*IFSO*) yields 35% and 20.2% seed oil respectively. The molecular weight of oil is calculated based on the percentage component fatty acids. The important parameters of bio-diesel of these Fatty acid methyl esters (FAMEs) are empirically determined. The bio-diesel properties of FAMEs of these seed oils are compared with standard bio-diesels. The seed oils selected in this investigation convene the major specification of biodiesel standards. This work reports the suitability of *HISO* and *IFSO* candidates as new feedstock for the bio-diesel production.

Keywords: *Holoptelea integrifolia*, *Ichnocarpus frutescens*, fuel properties ,biodiesel



Triglyceride

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Introduction

Vegetable oils have constantly been vital parts of human foods and these being essential for healthiness as well as for preparations of various commodities. Industrially, they play an important role in pharmaceuticals, cosmetics, paints and foods. Commercially, use of plant seed oils in markets includes a range of products such as, surfactants, soaps, detergents, lubricants, solvents etc. The *unusual fatty acids* like *epoxy fatty acids*, *hydroxy fatty acids* and *cyclopropenoid fatty acids* have significance in synthesis of protective coatings, plastics, urethane derivatives, dispersants, lubricant additives, bio lubricants, textiles, synthetic intermediates, and stabilizers in plastic formulations etc, [1-3]. Generally, oils are composed of triacylglycerol molecules containing unsaturated fatty acids like oleic, linoleic, linolenic acids and saturated fatty acids like myristic, palmitic, stearic acids etc. [4].

Currently, energy sector needs alternative to fossil fuel. The widest practice of renewable raw materials significantly adds to sustainable advancement. Apart from various bio-based products from vegetable resources, plant seed oils largely contribute in various applications in oleo chemical industries [5]. The fast depleting fossil fuel tempted the researcher to focus towards bio based fuels [6]. At the moment worldwide, researchers are focused on non edible seed oils for the biodiesel production. This is to avoid competition of edible oil for food and fuel also possible escalation of prices [7-9]. If not, this lead to adverse effect on food insecurity worldwide. Biodiesel has dragged more allure due to its environmental benefits like renewability, non-toxicity, biodegradability, no particulate matter hence no emission etc. The technological aspects of biodiesel are; it can extend the life of diesel engines due to its inborn lubricating nature plus it releases competent energy output against fossil fuels. Wonderfully, its exhaust odour is with a more pleasant smell of popcorn or French fries [10]. A small percentage addition of biodiesel with fossil diesel increases flash point of fossil fuel which boost its safe handling and storage.

Literature reveals that 80% of the global fat production is plant oil and rest is of animal origin [11]. The methods of biodiesel production include dilution, microemulsions, thermal cracking and transesterifiication. Biodiesel is produced efficiently by transesterification. Developments in research triggered to work by adopting methods such as enzyme catalysed reaction, supercritical and ultrasound aided transesterification [12]. Seeds which yield more than 20% oil contribute significantly for biodiesel production. By deploying the mathematical models shown in Table-1 the biodiesel properties are assessed based on the component fatty acids in the respective seed oil.

Table 1 Mathematical models deployed for Screening of seed oil of *Holoptelea integrifolia* and *Ichnocarpus frutescens* for biodiesel properties [13-19]

Eqn No	Equation	Denominations	Ref.
(i)	***Molecular weight of oil:*** $\text{MW oil} = 3\,(MWi) + 3\,(MWglycerol) - 3(MWalcohol)$	where MWi = molecular weight of each fatty acid	[13]
(ii)	***Saponification value***: $SV = \sum \frac{561.06 \times A_i}{M_{wi}}$	where, Ai is the % of component fatty acids, Mwi is the molecular mass of each component	[14]
(iii)	***Iodine value:*** $IV = \sum \frac{253.81 \times N_{db} \times A_i}{M_{wi}}$	where, Ai is the % of component fatty acids, Ndb is the number of double bonds, Mwi is the molecular mass of each component	
(iv)	***Cetane Number:*** $CN = 46.3 + \frac{5458}{SV} - 0.225 \text{ x } IV$	where, SV is saponification value and IV is iodine value	[15]
(v)	***Higher heating value:*** $HHV = 49.43 - (0.015 \text{ x } IV) - (0.041 \text{ x } SV)$	where, SV is saponification value and IV is iodine value	[16]
(vi)	***Lower heating value*:** $LHV = 0.0109 \left(\frac{C}{O}\right)^3 - 0.3516 \left(\frac{C}{O}\right)^2 + 4.2000 \left(\frac{C}{O}\right) + 21.066 - 0.100\, Ndb$ $LHV = 0.0011 \left(\frac{H}{O}\right)^3 - 0.0785 \left(\frac{H}{O}\right)^2 + 2.0409 \left(\frac{H}{O}\right) + 20.992 - 0.100\, Ndb$	where, C is the number of carbon atoms, H is the number of hydrogen atoms, O is the number of oxygen atoms and Ndb is the number of double bonds.	[17]
(vii)	***Long chain saturated factor:*** $LCSF = (0.1 \times C16) + (0.5 \times C18) + (1\ C20) + (1.5 \times 22) + (2 \times C24)$	where, C16, C18, C20, C22 & C24 refer to the percentage composition of respective fatty acid component	[18]
(viii)	***Cold filter plugging point:*** $CFPP = -\ 0.561 \times UFAME + 43.967$	where, UFAME is % unsaturation of FAMEs	[16]
(ix)	***Cloud point:*** $CP = -\ 0.576 \times UFAME + 48.255$	where, UFAME is % unsaturation of FAMEs	

(x)	***Pour point:*** PP = $-\ 0.626 \times UFAME + 45.694$	where, UFAME is % unsaturation of FAMEs	
(xi)	***Degree of unsaturation:*** DU = $MUFA + (2 \times PUFA)$	where, MUFA is the amount of monounsaturated fatty acids PUFA is the amount of polyunsaturated fatty acids	[19]
(xii)	***Kinematic viscosity:*** KV = $0.235 \times Nc - 0.468 \times Ndbw$	where, Nc is the weighted average number of carbon atoms and Ndbw is the weighted average number of double bonds	
(xiii)	***Flash point:*** FP = $(23.362 \times Nc) + (4.854 \times Ndbw)$	where, Nc is the weighted average number of carbon atoms and Ndbw is the weighted average number of double bonds	

Experiment

Materials and Methods

Oil extraction

The seeds of *Holoptelea integrifolia* and *Ichnocarpus frutescens* were ground, powdered and the oil content extracted by extraction with light petroleum ether (B.P. 40-60 0C) in a Soxhelt extractor for 24 hrs. The organic extract has to be filtered and dried over anhydrous Na_2SO_4. The petroleum ether removed under vacuum. The % oil for each 100 grams of dry seeds is calculated [20,21].

Table 2 Fatty acid profile of *Holoptelea integrifolia* and *Ichnocarpus frutescens* Seed oils [20,21]
Where, Cs and Ndbs are number of carbons and number of double bonds respectively

Seed species	**% Oil**	**% Component Fatty Acids (CFAs)**									
		Saturated Fatty Acids (SFAs)					**Unsaturated Fatty Acids (USFAs)**			**Unusual fatty acids**	
		Myristic	**Palmitic**	**Stearic**	**Arachidic**	**Behenic**	**Oleic**	**Linoleic**	**Linolenic**	**Malvalic**	**Ricinoleic**
Holoptelea integrifolia	35.0	5.3	34.4	3.2	-	-	35.5	6.8	-	14.8	-
Ichnocarpus frutescens	20.2	-	25.9	3.8	2.2	7.1	30.2	25.3	1.7	-	3.8
No. of Cs and Ndbs		14:0	16:0	18:0	20:0	22:0	18:1	18:2	18:3	18:2	18:3
Molecular formula		$C_{14}H_{28}O_2$	$C_{16}H_{32}O_2$	$C_{18}H_{36}O_2$	$C_{20}H_{40}O_2$	$C_{22}H_{44}O_2$	$C_{18}H_{14}O_2$	$C_{18}H_{32}O_2$	$C_{18}H_{32}O_3$	$C_{18}H_{32}O_2$	$C_{18}H_{34}O_3$
Molecular weight		228.38	256.43	284.48	312.54	340.52	282.47	280.46	278.41	280.44	298.3

Transesterification or Alcoholysis

The first step is the conversion of triglycerides (Figure 1) to diglycerides followed by the conversion of diglycerides to monoglycerides and of monoglycerides to glycerol yielding one methyl ester molecule from each glyceride at each step.

$$\text{Triglycerides} + \text{ROH} \rightleftharpoons \text{Diglycerides} + \text{R}^1\text{COOR}$$

$$\text{Diglycerides} + \text{ROH} \rightleftharpoons \text{Monoglycerides} + \text{R}^2\text{COOR}$$

$$\text{Monoglycerides} + \text{ROH} \rightleftharpoons \text{Glycerol} + \text{R}^3\text{COOR}$$

Herein Oil is treated with a strong base / a strong acid as catalyst. Sodium or potassium methanoate can be used for efficient conversion of fatty acids present in oils to their corresponding FAMEs.

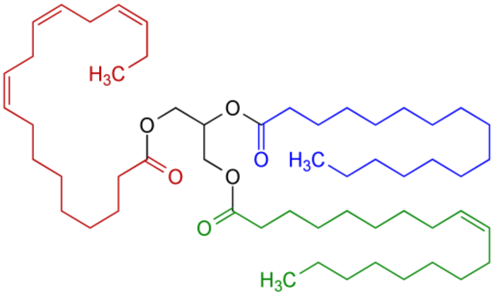
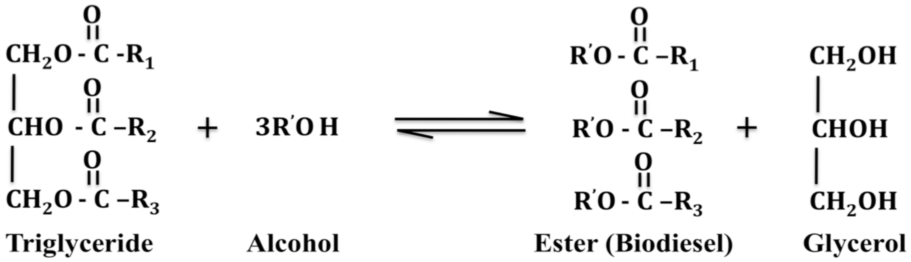


Figure 1 Chemical structure of Triglyceride



Procedure

The seed oil and the methanol or ethanol is taken in the ratio of 1:6 and refluxed for an hour in presence of acid / base as catalyst. Then the mixture is transferred to a separating funnel thereby two layers are formed. The methanol, glycerol is at lower layer, and most of the catalysts were drained out. The upper layer containing methyl esters along with traces of methanol and the catalyst are washed thoroughly by warm de-ionized water. Then, the residual methanol is removed by rotary evaporation at around 70 ^{0}C. Thus obtained product containing FAMEs or Fatty acid ethyl esters (FAEEs) is used as biodiesel [22].

Since the high demand of vegetable oils for edible purposes, the use of non edible seed oils are attaining much appreciation for biodiesel production.

Holoptelea integrifolia Roxb

It belongs to the family *Ulmaceae*. This family has 15 genera and about 200 species distributed over tropical and temperature regions of northern hemisphere. It is a large deciduous tree that grows up to 15 to 25 meters in height. The distribution of the plant can be seen in India, Nepal, Sri Lanka, Indo-Chaina, Cambodia, Myanmar, Vietnam, Burma and Chaina [23]. Various parts of the tree have been found to be useful in the treatment of bronchitis and obesity. Traditionally, the bark and leaves are used for the treatement of various ailments. Fruits are sub orbicular with membranous wings, and usually seen during month of April to May. Shape of fruit is notched at the top with 2 cm in diameter and 0.6 to 1 inch broad [24, 25].

Ichnocarpus frutescens

Ichnocarpus frutescens belongs to family *Appocyanaceae.* It is a species of flowering plant. English common name of this species is *black creeper*. It is native to much of Chaina, India, Southeast Asia, and northern Australia. It is a woody shrub. The bark produces a creamy white sap. The fruit is a follicle which may be over 14 centimetres long. The roots are either reddish or purple. The plant has various traditional medicinal applications. It is used in the treatment of rheumatism, asthma, cholera, and fever [26].

Figure 2 Fruits of *Holoptelea integrifolia*

Figure 3 Fruits of *Ichnocarpus frutescens*

Computational analysis of biodiesel properties of *Holoptelea integrifolia* and *Ichnocarpus frutescens* seed oils

The determination of biodiesel quality properties by always through the experimental procedures can be a costly and lengthy affair. The studies on non edible seed oils and screening of their biodiesel properties, by deploying well substantiated mathematical models is a useful method. This methodology reduces costs and analysis time of experimentation. Several research groups have tried and developed mathematical models as depicted in Table-1 (Equations (i) to (xiii) for assessment of biodiesel properties of seed oil based on the % CFAs. The results obtained are compared with those of existing biodiesels viz., *Soyabean* seed oil, *Rape* seed oil, *Sunflower* seed oil and Petro diesel.

In this study, the selected seed oils were assessed for their biodiesel properties by deploying the referred mathematical models. The SV and IV were evaluated empirically with the help of equations (ii) and (iii) respectively or referred from the literature. There is close correlation between SV, MW and the % CFAs present in seed oil. However, IV, according to equation (iii) depends upon three variables those are % CFAs, MW and the Ndbs (Number of double bonds) present in the corresponding fatty acids. The parameters like % SFAs, % USFAs, IV, SV, CN, LHV, HHV, LCSF, CFPP, CP, PP, DU, KV, and FP are deployed during assessment of seed oils under assessment.

Table 3 Analytical properties of seed oils of *Holoptelea integrifolia* and *Ichnocarpus frutescen*

Chemical and Fuel properties	***Holoptelea integrifolia* Seed oil (*HISO)***	***Ichnocarpus frutescens* Seed oil (*IFSO*)**
% Seed oil	35.0	20.2
Mol. Wt. of oil (g/mol)	902.9	925.9
SV (mg KOH/g oil)	206.5	201.0
IV (mg I_2/g oil)	56.8	80.8
% of TSFAs	42.9	39.0
% of TUSFAs	57.1	61.0
DU	63.9	89.7

CN	60.0	55.0
LHV (MJ/kg)	37.6	39.0
HHV (MJ/kg)	40.1	39.9
LCSF	5.0	17.3
CFPP (^{0}C)	11.9	9.8
CP (^{0}C)	15.4	13.1
PP (^{0}C)	9.9	7.4
KV (mm^2/s)	3.7	3.8
FP (K)	402.4	420.2

Where, SV = Saponofication value, IV = Iodine value, CN= Cetane number , LHV= Lower heating value, HHV= Higher heating value , LCSF= Long chain saturated factor , CFPP= Cold filter plugging point , CP= Cloud point , PP= Pour point, DU= Degree of unsaturation, KV= Kinematic viscosity, FP= Flash point

Table 4 Comparison of biodiesel properties of selected seed oils of *Holoptelea integrifolia* and *Ichnocarpus frutescens* with existing biodiesels and petro diesel

Biodiesel property	**Seed oil species under assessment**		**Existing biodiesel /diesel**			
	HISO	***IFSO***	***SBSO***[a]	**RSO**[a]	**SF*SO***[a]	***PD***[a]
% Seed oil	35.0	20.2	19.0	43.0	44.0	NA
Mol. Wt. of oil (g/mol)	902.9	925.9	920.6	926.7	924.9	NA
SV (mg KOH/g oil)	206.5	201.0	194.6	197.1	193.0	NA
IV (mg I_2/g oil)	56.8	80.8	120.5	108.1	132.1	NA
% of TSFAs	42.9	39.0	14.9	4.3	10.0	NA
% of TUSFAs	57.1	61.0	86.4	94.9	90.0	NA
DU	63.9	89.7	98.2	126.8	130.3	NA
Fuel Composition	C_{12}–C_{22} FAMEs or FAEEs					C_{10}–C_{21} HC[b]
CN	60.0	55.0	50.9	52.0	47.0	42.6
LHV (MJ/kg)	37.6	39.0	33.5	32.8	33.5	43.1
HHV (MJ/kg)	40.1	39.9	39.5	37.6	40.5	46.0
LCSF	5.0	17.3	4.3	4.6	3.1	NA
CFPP (^{0}C)	11.9	9.8	-3.0	-2.0	-6.6	NA
CP (^{0}C)	15.4	13.1	2.5	-3.6	-2.6	-15 to 5[b]
PP (^{0}C)	9.9	7.4	-4.1	-10.2	-9.2	-35 to -15[b]
KV (mm^2/s)	3.7	3.8	3.4	3.6	3.6	3.1
FP (K)	402.4	420.2	389.5	425.0	420.6	333 to 353[b]

Where, SBSO= Soyabean Seed Oil, RSO= Rape seed Oil, SFSO= Sunflower Seed Oil, PD= Petro diesel . * Indicates that the data obtained from Ref. ‘a’ [14, 27] and and ‘b’[28] HC= hydrocarbon

Result and Discussion

In the present work, non edible seeds which yield more than 20% seed oil and their acid profiles are utilized for the assessment of their biodiesel properties. After the meticulous survey, *Holoptelea integrifolia* seed oil and *Ichnocarpus frutescens* seed oil have been selected. The %CFAs profile is one of the key factors that resolve the suitability of feedstock for the biodiesel production. The details of %CFAs [20,21] of *HISO* and *IFSO* are shown in Table 2. After the analysis of seed oils / FAMEs by deploying the mathematical models the results obtained are shown in Table 3.

Fatty acid profile of seed oils of *Holoptelea integrifolia* and *Ichnocarpus frutescens*

The percentage of TSFAs are 42.9% and 39.0% in *HISO* and *IFSO* respectively. *S*imilarly, the percentage of TUSFAs is 57.1% and 61.0% in these seed oils respectively. The C16:0 (34.4%) and C18:1 (35.5%) are in *HISO*, C18:1 (30.2%) C18:2 (25.3%) are in *IFSO* and are the major contributors of CFAs in these seed oils. The *HISO* seed oil composed of 14.8% of *Malvalic acid* it is an industrially important unusual fatty acid.

Molecular Weight (MW)

Molecular Weight of individual seed oils are calculated based on the %CFAs using equation number (i) [13]. The molecular weight of *HISO* and *IFSO* is 902.9 g/mol and 925.9 g/mol respectively. *IFSO* contains the higher fatty acids like Arachidic acid and Behenic acid. The EN14214 specified percentage linolenic acid C 18:3 to be up to a limitation of 12% only. This is due to its high rate of oxidation and affecting in the biodiesel quality. Both seed oils under investigation are not exceeding mentioned limit of C 18:3 fatty acid. Beside, the concentration of linolenic acid and the acid containing four double bonds in FAMEs should not exceed the limit of 12% and 1%, respectively. This parameter gives an indication of the applicability of *HISO* and *IFSO* seed oils for biodiesel production [29,30].

Saponification Value (SV)

Saponification Value of seed oils are calculated using equation number (ii) [14] and the results are presented in Table 3. The SV depends upon the MW and the % CFAs. There is consistency in SV. As the molecular weight increases the SV decreases and vice versa. The *HISO* with a little lower molecular weight has relatively higher SV compare to *IFSO*.

Iodine Value (IV)

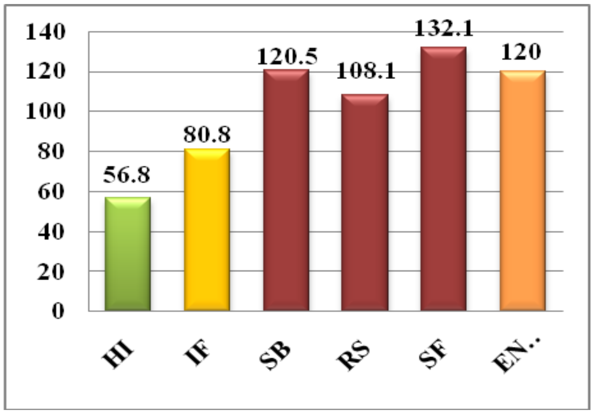


Figure 4 IVs of seed oils with existing biodiesel, EN14214 and petro diesel

Majority of the feedstock are difficult to satisfy the minimum requirements of biodiesel which could be attributed to the high unsaturated fatty acid in the feed stock [39]. IV refers to the amount of iodine required to iodize the double bonds of fatty acid molecule. It is calculated using equation number (iii) [14]. The IV of *HISO* is less than *IFSO* as is evident from % TUSFA and DU. As per limitation laid down in European standards EN 14214, the IV must not exceed 120 mg I_2/g. The calculated IVs of the species under investigation are 56.8 mg I_2 / g and 80.8 mg I_2 / g in *HISO* and IFSO respectively. Comparative results are shown in Figure 4 and Table 3. Poly-unsaturated fuels that contain high levels of mentioned components found in seed oil of *Soybean, Sunflower* and *Rape* seed oils showing high iodine values. This reflects that the seed species under investigation are comparable with existing biodiesels and are with iodine value below 120 I_2 mg/g specified in European standard.

Cetane number (CN)

The Cetane number is a crucial benchmark which measures the ignition quality of a fuel. The high CN of biodiesel contribute to easy cold starting and low idle noise. The CN of biodiesel has up to 100, but diesel fuel has only 40 [12]. The minimum requirement of the cetane number prescribed in biodiesel standard organizations *viz.*, ASTM D6751 and EN14214 is 47 & 51 respectively [15] and the CN of the petro diesel is 42.6 [27]. The upper limit of the CN is 65 as specified in US Biodiesel Standards (ASTMPS 12199). The CN is evaluated as per equation number (iv) [15]. The calculated CN of species under investigation are 60.0 and 55.0 of *HISO* and *IFSO* respectively. Low CN indicates presence of highly unsaturated components like C18:2 and C18:3. Combustion quality is depends on the number of double bonds. As the double bonds increases, the combustion quality of fuel decreases [31]. The CN of species under investigation are comparable with the CNs of the already existing biodiesels as shown in Figure 5.

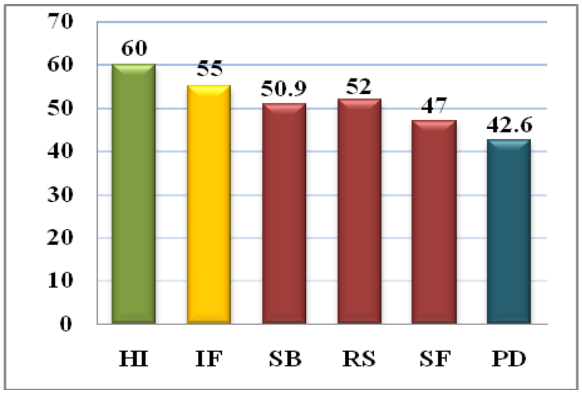


Figure 5 CN of FAMEs of seed oils with existing biodiesel and petro diesel

Higher Heating Value (HHV) and Lower Heating Value (LHV)

The Higher Heating Value and Lower Heating Value measure the total energy content in the fuel in different experimental conditions depends on the Carbon, Hydrogen, Oxygen content of FAMEs of the seed oils. These are evaluated using equation number (v) and (vi) [16-17]. The calculated HHV of *HISO* is more compared to *IFSO*. It is because the degree of unsaturation is more in *IFSO*. Figure 6 and Figure 7 indicates that the calculated HHV and LHV of *HISO* and *IFSO* depicted in Table 3 and are closer to existing biodiesels but slightly less than petro diesel (43.1 MJ/Kg) or petroleum (42 MJ/Kg) but are higher than the heating values of coal (32-37MJ/Kg).

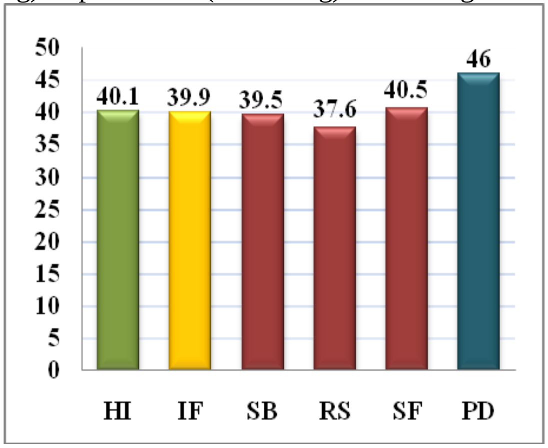


Figure 6 HHVs of FAMES of seed oils with existing biodiesel and petro diesel

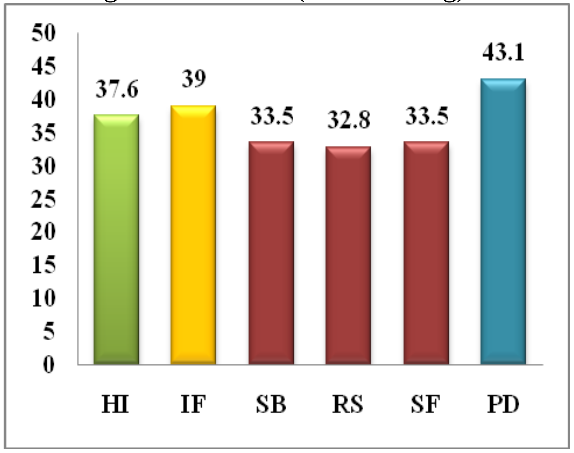


Figure 7 LHV of FAMES of seed oils with existing biodiesel and petro diesel

The European Bio fuel Technology Platform-2011 reported the LHV for biodiesel as 37.1 MJ/Kg. In this work the LHV is calculated using equation number (vi). LHV of FAMEs of *HISO* and *IFSO* are 37.6 MJ/Kg and 39.0 MJ/Kg respectively. The values obtained are appreciable. Comparatively, higher than *Soyabean* biodiesel, *Rape* seed biodiesel and *Sunflower* biodiesel. Obviously, lower than LHV of Petro diesel which is 43.1 MJ/Kg. Interestingly, LHV specified for diesel and biodiesel are 36.6 MJ/kg (ASTM D975) and 32.6 MJ/kg (ASTM PS 121) respectively [28]. The *HISO* and *IFSO* have LHVs are 37.6 MJ/Kg and 39.0 MJ/Kg respectivel*y*.

The calorific values of *HISO* and *IFSO* biodiesel are found to be lower than that of diesel, which may be due to the difference in chemical content or presence of oxygen in molecular structure of oil/FAMES.

Long chain saturation factor (LCSF)

The most important attributions that affect the fuel properties are the number of double bonds and length of the carbon chain. The LCSF is calculated using the equation number (vii). From the Table 3 it is observed that the calculated value of LCSF of *HISO* and *IFSO* are 5.0 and 17.3 respectively. The *HISO* has more saturation content which implies the solidification of its biodiesel in cold temperate countries.

Cloud Point (CP) and Pour Point (PP)

The CP is the temperature at which crystals first start to form in the fuel. The cloud point is reached when the temperature of the biodiesel is low enough to cause wax crystals to precipitate. The Pour Point is the temperature at which the fuel contains so many agglomerated crystals that it is essentially a gel and will no longer flow. Similarly to the cloud point, the pour point values also depend on the quality of feedstock. Although CP and PP are relatively easily determined, they only provide indicative values for the minimum temperature at which the fuel can be used. These are calculated using the equation numbers (ix) and (x) [16]. While, at cloud point the fuel can still be used in acceptable conditions, at pour point this is no longer possible. The calculated values of CP and PP of seed species under investigation are most suitable for warm temperate climate countries. In other words, cloud point overestimates minimum operating temperature and pour point underestimates it [16]. The CP & PP values of the seed species under investigation are compared with already existing biodiesel is shown in Figure 8. From Table 3 it is observed that the *HISO* has high CP & PP compared to *IFSO* due to more saturated fatty acids.

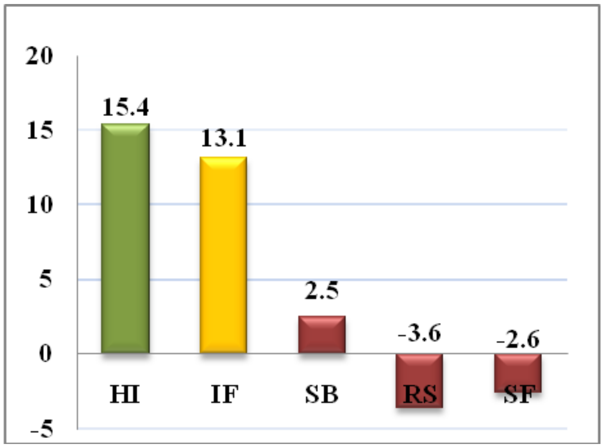


Figure 8 CPs of FAMES of seed oils with existing biodiesel

Cold filter plugging point (CFPP)

Cold filter plugging point is defined as the lowest temperature at which 20mL of the sample safely passed through the filter within 60 seconds. As specified in ASTM D 6371. It is expressed in degrees Celsius (°C). In cold temperate countries, a high CFPP will clog up engines more easily. From the comparative studies it reveals that, both the seed species are not suited for cold temperate climate countries. This test gives an estimate for the lowest temperature that a fuel will give trouble free flow in certain fuel systems [33]. It is evaluated using equation number (viii) [16]. Results are shown in Table 3.

Kinamatic Viscosity (KV)

The high viscosity of plant oil which is more than 10 times with that of diesel fuel, leads to poor fuel atomization and inefficient mixing with air, which contribute to incomplete combustion. This results in the combustion chamber leading to the formation of soot and engine deposit. KV of both FAMEs of seed oil under investigation are slightly higher than ASTM standard, as represented in Figure 9. According to G Knothe et al. 2003, kinematic viscosity increases with fatty acid chain length and with increasing degree of saturation of either the fatty acid or alcohol moiety in a fatty ester. It is calculated using the equation number (xii)[19].The calculated value of KV of *HISO* is less compared to *IFSO* it is due to molecular weight of *HISO*. According to ASTM standards the KV range for biodiesel is 3.3-5.2 mm^2/s [11]. The calculated value KV of seed species under investigation are 3.7 mm^2/s, 3.8 mm^2/s and 3.1 mm^2/s of *HISO*, *IFSO* and petro diesel respectively.

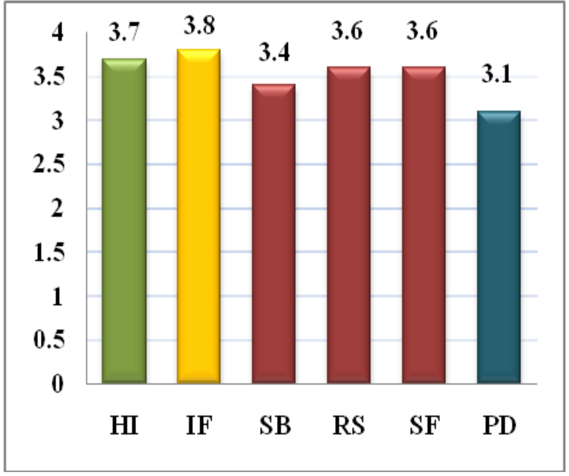


Figure 9 KVs of FAMES of seed oils with existing biodiesel and petro diesel

Flash Point (FP)

The flash point is the temperature where fuel is ready to ignite when exposed to a flame. Higher value of FP of a particular fuel reduces the risk of fire. This is useful in safe handling of fuel during storage and transportation. It is calculated by equation number (xiii) [19]. As per American standards (ASTM) the FP range for biodiesel is 420 K to 450 K [11]. Thus the calculated values of FP of biodiesels under study are 402.6 K and 420.4 K respectively. The flash point value of *HISO* is less than the standard range but it is more than the flash point value of petro-diesel 393K. And also the Flash point value of seed species compared with already existing biodiesel as shown in Figure 10. Flash point prescribed for diesel and biodiesel are 303-353 K (ASTM D975) and 373-443K (ASTM PS 121) respectively [28]. FAMEs of *HISO* and *IFSO* fulfil the expected range of FP for biodiesel.

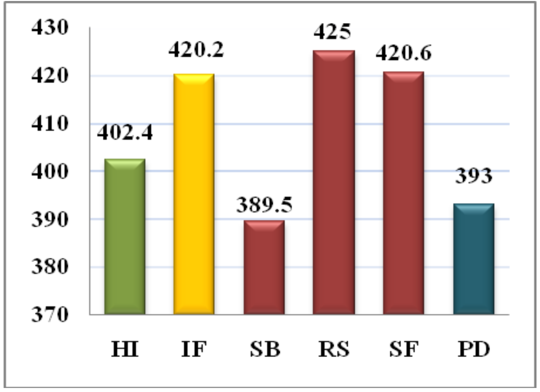


Figure 10 FPs of FAMES of seed oils with existing biodiesel and petro diesel

Based on the percentage component fatty acids, the *Holoptelea integrifolia* and *Ichnocarpus frutescens* seed oils in terms of their corresponding FAMEs are assessed for their biodiesel properties After critical evaluation of the various fuel properties like. Cetane number, Lower heating value, Higher heating value, Long chain saturated factor, Cold-filter plugging point , Cloud Point, Pour point , Degree of unsaturation, Kinematic viscosity, Flash point of these FAMEs are empirically determined. The bio-diesel (FAMEs) properties of these seed oils are compared with standard bio-diesels which confirmed the suitability *HISO* and *IFSO* seed oils for the generation of biodiesel. Therefore, seed oils selected in this investigation convene the major specification of biodiesel standards as per American (ASTM), and European (EN) standard organizations. Cold flow properties like CFPP, CP, and PP of FAMEs of the seed oils under investigation infer the suitability in warm temperate climate.

This work reported the suitability of *HISO* and *IFSO* as reliable candidates for new feedstock in the production of bio-diesel.

Conclusions

The evaluated parameters based on CFAs of *HISO* and *IFSO* are in acceptable range with reference to the prescribed current biodiesel standards. The data presented in this paper regarding biodiesel quality indicate the feasibility of these seed oils for biodiesel synthesis. Both the seed oil species under investigation meet the major specifications of biodiesel standards. However, still further research is required to evaluate the biodiesel (FAMEs) of seed oil species for properties process *viz,* tribological studies, and long term engine testing.

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