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Investigation on Fatty Acid Chemistry and Fuel properties of *Cannarium vulgar* and *Haemostaphis baterii* seed oils: An approach for the production of Clean Fuel

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Abstract: Cannarium vulgar and Haemostaphis seeds yields 63 and 54.5 % of seed oil content respectively. The Fatty acid profile of the seed oils is obtained from the literature. The fatty acid profile of selected seed oils is utilized for the evaluation of various fuel properties by using standard mathematical models. The physicochemical properties like Saponification Value, Iodine Value, Molecular weight and Fuel properties like Cetane Number, Cloud point, Flash point Higher heating value, Lower heating value are evaluated. The results obtained are compared with biodiesel properties with the biodiesels in practice and with petro-diesel. The bio-diesel properties investigation on Cannarium vulgar and Haemostaphis baterii seeds, satisfy the major specifications of biodiesel standards. The fuel properties of seed oils under study shown comparable results. These resulted Cetane Numbers (CN) 59.05 and 43.64, Cloud points (CP) 14.8 0C and -4.23 0C, Flash points (FP) 137 0C and 214 0C, Higher Heating Values (HHV) 40.33 MJ/Kg and 39.02 MJ/Kg, Lower Heating Values (LHV) 38.68 MJ/Kg and 37.7 MJ/Kg, Kinematic viscosities (KV) 3.6 mm2/sec and 3.8 mm2/sec and Pour points (PP) 8.76 0C and -10.2 0C investigated for Cannarium vulgar Seed Oil Methyl Esters (CVSOMEs) and Haemostaphis baterii Seed Oil Methyl Esters (HBSOMEs).

Key Words: Cannarium vulgar, Clean Fuel, Fatty Acid Chemistry, Fuel properties, Haemostaphis baterii.

I. INTRODUCTION

The fossil fuel is depleting day by day due to its heavy consumption in transport and allied sectors. The hydrocarbon fuels after combustion releases exhaust emissions like oxides of sulphur (SOx), oxides of nitrogen (NOx), oxides of carbon (COx), particulate matters etc. The increase in air pollution leads to grave impact on mankind which results into pulmonary disorder, green house effect leading to global warming and associated environmental issues. India is the second most populous developing country and the third largest mineral diesel consumer in the world. At present, more than 80% of the total crude oil consumption is being imported and huge amount of funds being invested which affects the economy of the country adversely. Hence, there is requirement for an alternative liquid fuel which can substitute the fossil fuel and can reduce the air pollution [1]. Many countries have shown their inclination towards biodiesel for resolving the problem of energy needs and environmental crisis. Biodiesel is a green, clean fuel produced from renewable sources like animal fat, vegetable oil or used cooking oil by transesterification [2]. The main advantages of biodiesel over fossil fuel includes that, it is renewable, non-toxic, easily mix with petrodiesel, less viscous than the seed oil having higher cetane number, flash points, low sulphur content and better lubricity. It consists of 10-12 % more oxygen compared to diesel-fuels which helps for better combustion [3],[4].

A wide range of feedstock can be used for the production of biodiesel which include vegetable oil, animal fat, waste cooking oils. Methods used in the production of biodiesel are Pyrolysis, Micro emulsion, Transesterification etc.[5],[6]. Amongst these the transesterification is most popular method employed for the production of biodiesel. Herein, conversion of highly viscous oil (triglyceride) into biodiesel (Fatty acid alkyl ester) in presence of alcohol and catalyst (Acid/base). The glycerol is obtained as byproduct. Thus obtained glycerol has wide range of applications especially in cosmetics industry, phramaectiucal industry and serve as solvent media in organic synthesis. The biodiesel costs higher in comparison with diesel-fuels which is a major barrier to its commercialization [7]. It has been reported that around 70-95 % of the total cost of biodiesel depends on the feedstock used [8]. The biodiesel produced from edible seed oils creates a competition with food market and energy sector which results in increase its demand and soaring prices. Therefore, the use of non-edible seed oils as feedstock for the production of biodiesel is economically viable as they are cheap, easily available and avoids competition with food market [9].

The physical and chemical properties of fatty acid alkyl ester molecules are governed by carbon-chain length, presence of double C=C bonds, the position and geometrical configuration *cis* or *trans* of the double bonds. The commercially available biodiesel fuels are mainly composed of medium to long chain fatty acids methyl esters in the range of C_{14} to C_{22} carbon chain length [10]. Fatty

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acid composition like total percentage of saturated fatty acids (TSFAs) and total percentage of unsaturated fatty acids (TUSFAs) content of biodiesel influence predominately on the fuel properties such as Density, Cetane Number (CN), Iodine Value (IV), Kinematic Viscosity (KV), Cold Filter Plugging Point (CFPP) and Higher Heating Value (HHV) [10],[11],[12]. The determination of biodiesel parameters through the experimental procedures can be a costly and time consuming. 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. In this work, fuel properties of two non-edible seed oils *Canniurum vulgar* and *Hamestobateri barterii* species are investigated by deploying their fatty acid profile by using standard mathematical models and are substantiated with reliable experimental results. Thus the results obtained are compared with biodiesels in practice and verified with biodiesel fuel standards as per ASTM, BIS and EN standard.

Table 1: Mathematical models deployed for screening of seed oils

Eqn. No.	Mathematical model	Denominations	Ref.
(i)	*Molecular weight of oil:* MW oil = 3 (MWi) + 3 (MWglycerol) – 3 (MWalcohol)	where MWi = molecular weight of each fatty acid	[13]
(ii)	*Saponification value:* $SV = \sum \frac{56.03xAi}{Mwi}$	where, Ai is the % of component fatty acids, Mwi is the molecular mass of each component	[14]
(iii)	*Iodine value:* $IV = \Sigma \frac{253.81xNdbxAi}{Mwi}$	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:* $CN = 46.3 + \frac{5458}{SV} - 0.225 \times IV$	where, SV is saponification value and IV is iodine value	[15]
(v)	*Higher heating value:* HHV = 49.43 – (0.015 x IV) – (0.041 x SV)	where, SV is saponification value and IV is iodine value	[16]
(vi)	*Lower heating value:* $LHV = 0.0901\left(\frac{C}{O}\right)^3 - 0.3515\left(\frac{C}{O}\right)^2 + 4.200\left(\frac{C}{O}\right) + 21.066 - 0.100Ndb$ $LHV = 0.0011\left(\frac{H}{O}\right)^3 - 0.0785\left(\frac{H}{O}\right)^2 + 2.0409\left(\frac{H}{O}\right) + 20.992 - 0.100Ndb$ $LHV = 0.0901\left(\frac{C}{O}\right)^3 - 0.3515\left(\frac{C}{O}\right)^2 + 4.200\left(\frac{C}{O}\right) + 21.066 - 0.100Ndb$ 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 x C16) + (0.5 x C18) + (1.5 x C22) + (2 x 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 x UFAME + 43.967	where, UFAME is% unsaturation of FAMEs	[16]
(ix)	*Cloud Point* CP = – 0.576 x UFAME+ 48.3	where, UFAME is% unsaturation of FAMEs	
(x)	*Pour point:* PP = – 0.626 x UFAME + 45.694	where, UFAME is % unsaturation of FAMEs	

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

II. MATERIAL AND METHODS

The *Cannarium vulgar* and *Haemostaphis baterii* seeds yelided 63 % and 54.5% oil content respectively which suffices the basic requirement of feedstock and its abundance as seed oil for the production of biodiesel subsequently the cost and feasibility. [20],[29].

i) ***Cannarium vulgar***

It is a large dense evergreen, dioscious perennial tree belongs to *Bursezacea* family as shown in Figure 1. It is native to eastern Malaysia, Papua, New guinea, Indonesia etc. It has been introduced to India, Sri lanka and in tropical regions [21]. In india it is manily distributed in regions of Andra Pradesh, Tamil nadu and Karnataka. In Karanataka state it is well known as jaava badaami, kaggali beeja, kaggali mara, sambrani, shambrani [22]. The tree grows to 45m in length with buttressed trunk bearing small dense white creamy flowers. Fruit is an ovid-oblong fleshy drupe which is referred as Chinese olive. It has been regarded as to be expectorant, immune stimulant, irritant, rubafacient, stimulant and vulnerary. It has been used for treating cold, gastrosis, gonorrhea, rheumatism, immuno depression [23]. The seeds are black brown in colour as shown in Figure 2 which bear 63% oil content and can act as potent feedstock for the biodiesel production [24].

Table 2. Classification and Fatty acid profile of *Cannarium vulgar*

Classification
Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Sapindales
Family: Bureraceae
Genus: Canarium L.
Species: *Canarium vulgare Leenh*

Figure 1. *Cannarium vulgar* tree

Fatty acid profile [20]

Fatty acids	Nature of Carbon	%
Palmitic acid	($C_{16:0}$)	29
Steraic acid	($C_{18:0}$)	12
Oleic acid	($C_{18:1}$)	49
Linoleic acid	($C_{18:2}$)	10

Figure 2. *Cannarium vulgar* seeds

ii) Haematostaphis barteri

It is a small tree with a crooked bark, and spread branches which grows upto 2 to 8 meters long belonging to *Anacardiaceae* family shown in Figure 3 exclusively found in tropical Africa, Nigeria, Sudan and Cameroon [25]. It is commonly known as ''blood plum''. The flowers are produced during the dry season. The fruits grown in bunch, hanging in perils–smooth– red purple or deep drops nearly 2–5 cm long like the temperate plump. The leaves and bark infusion employed in the treatment of malaria, hepatitis and sleeping sickness [26]. *Haematostaphis barteri* is a plant used in the northern part of Nigeria to manage degenerative diseases such as cancer, anemia and hemorrhage [27],[28]. The seeds are brownish in colour bearing 54.5 % oil content as shown in Figure 4 which can be potent source for biodiesel production [29].

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Table 3. Classification and Fatty acid profile of *Haematostaphis barterii*

Classification Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Sapindales Family: Anacardiaceae Genus: Haematostaphis Hook. Species: *Haematostaphis barteri* Hook	 Figure 3. *Haematostaphis barteri* tree
Fatty acid profile [29] **Fatty acids — Nature of Carbon — %** Myristic acid ($C_{14:0}$) 4.23 Palmitic acid ($C_{16:0}$) 1.35 Steraic acid ($C_{18:0}$) 15.40 Eicosodenic acid ($C_{20:2}$) 69.2 Eruic acid ($C_{22:1}$) 2.7	 Figure 4. *Haematostaphis barteri* seeds

2.1 Oil Extraction

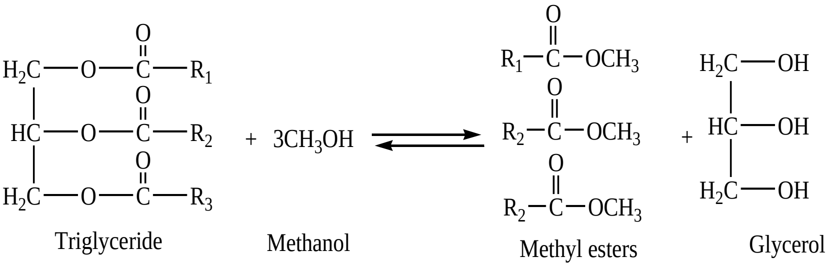
The oil can be extracted from seeds using soxhlet extraction, mechanical pressing. Soxhlet extraction is most common method used in laboratory for the oil extraction, where the dried seeds are grinded into fine powder and loaded into the soxhlet using petroleum ether (40 ^{0}C to 60 ^{0}C) as solvent oil is extracted from the seeds.

2.2 General procedure for synthesis of biodiesel

Seeds which yield more than 20% oil contribute significantly for biodiesel production. The transesterification method is most convenient method employed for the synthesis of biodiesel. In this step 1:6 molar ratio of oil to alcohol is added to preheated seed oil at 60 ^{0}C. The reaction is stirred at 600 rpm for about 1 $^{1}/2$ hours. After completion the reaction mixture is transferred into separating funnel where it is allowed to stand overnight for the separation of FAMEs from glycerol. The FAMEs forms the upper layer or organic phase and glycerol, unspent catalyst and unreacted alcohol forms the lower layer which is drained out leaving behind FAMEs where it is repeatedly washed with hot water to remove any soap, excess methanol and impurities entrapped in it. Finally, the FAMEs are dried over anhydrous calcium chloride to get pure dried FAMEs [30].

General reaction and step wise transesterification reaction

The first step is the conversion of triglycerides 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.



Mechanism of Transesterification

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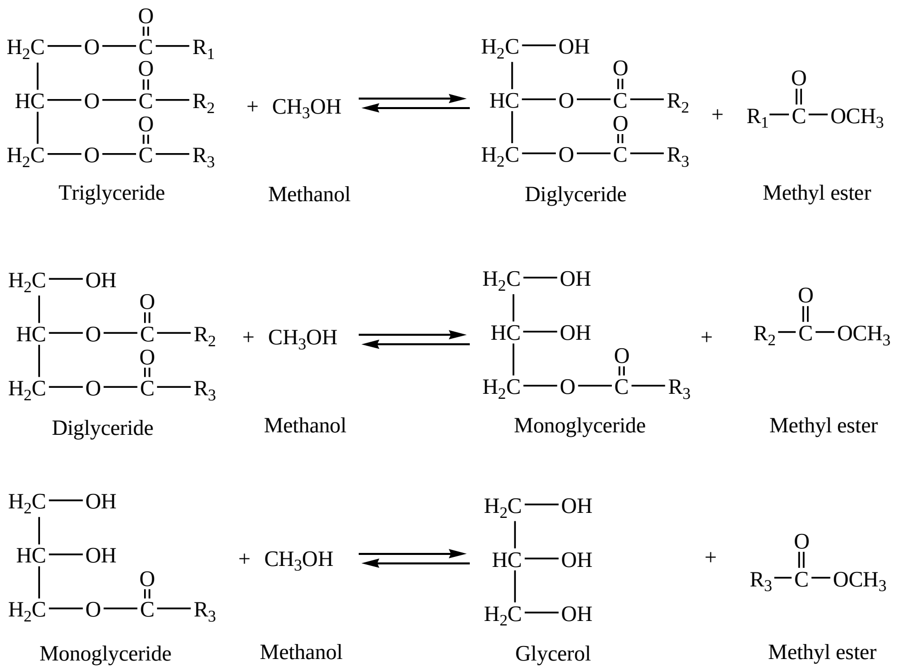

Table 4: Physicochemical properties of CVSO and HBSO

Property	CVSO	HBSO
% Oil content	63	54.5
Saponification value (mg KOH/g of oil)	204.07	213
Iodine value (mg I_2/ g of oil)	62.17	112.7
Molecular weight of the oil (g mol^{-1})	862.8	888.9
DU	69	92
LSCF	8.9	14.7
TSFA	41	27.9
TUSFA	59	72.09

Table 5: Fuel properties of CVSOMEs and HBSOMEs

Properties	CVSOMEs	HBSOMEs	SbSOMEs	RSOMEs	SfSOMEs	PD*	ASTM* D 6751	BIS* 15607	EN* 14214
Cetane Number	59.05	49.64	50.9	52.0	44.0	46	47 to 65	51	51
Cloud point (^{0}C)	10.8	-4.23	-3.6	-3.6	-2.6	-15 to 5	-3 to -12	ND	ND
Cold filter plugging point (^{0}C)	7.8	2.96	-3.0	-2.0	-6.6	ND	ND	ND	ND
Flash point (^{0}C)	137	214	116.5	152	147.6	70	120 min	120 min	120 min
HHV (MJ/Kg)	40.33	39.02	39.5	37.6	40.5	46	ND	ND	ND
KV (mm^2/s)	3.6	3.8	3.4	3.6	3.6	2.6	1.9 to 6	2 to 4.6	3.5 to 5.5
LHV (MJ/Kg)	38.68	37.7	33.5	32.8	33.5	43.1	ND	ND	ND
Pour point (^{0}C)	8.76	-10.2	-4.1	-10.2	-4.2	-20	-15 to 16	ND	ND

* [30], [37] ND= Not Determined

III. Result and Discussion

The fatty acid profile of *Cannarium vulgar* Seed Oil (CVSO) and *Haemostaphis barterii* Seed Oil (HBSO) is shown in Table. 2 and Table. 3 respectively. HBSO consist of palmitic acid and stearic acid are major saturated fatty acids composed of 29 % and 12 % respectively. The oleic acid and Linoleic acids are major unsaturated fatty acids composed of 49 % and 10% respectively. CVSO consist of Myristic acid and Steraic acid are major saturated fatty acids composed of 4.2 % and 15.4 % respectively. Ecisodenic acid is major unsaturated fatty acids composed of 69.2 %. Therefore CVSO consist of 41 % TSFA and 59 % TUSFA and HBSO consist of 27.9 % TSFA and 72.09 % TUSFA. The fuel properties of the biodiesel largely

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depends upon the fatty acid composition of the seed oil or feedstock. The EN 14214 limits percentage content of linolenic acid (18:3) to be up to a limitation of 12 % only. This is due to its high rate of oxidation of linolenic acid affecting the biodiesel quality. Selected seed oil under investigation CVSO and HBSO does not contain linoleic acid. Further, using the fatty acid profile of the seed oil and standard mathematical equation the fuel properties of CVSOMEs and HBSOMEs are assessed and the results are depicted in Table 5.

3. Determination of Physicochemical properties

3.1.Molecular Weight (MW)

Molecular Weight of CVSO and HBSO seed oils are calculated considering their % Fatty acid profile using equation number (i) [13]. The Molecular weight of *CVSO*, and *HBSO* is found to be 862.0 g/ mol, and 888.9 g/ mol respectively. The results are depicted in Table 4.

3.2. Saponification Value (SV)

The SV is very important parameter indispensable for defining the quality of the oil. The saponification value (SV) is defined as the amount of alkali required to saponify a defined weight of sample. It is expressed in mg potassium hydroxide (KOH) per gram of sample and specifies the content of total fatty acids in seed oil (free fatty acids and bound fatty acids). The mean molecular weight of the fatty acids in a lipid system as well as the number of ester bonds per gram sample can be derived from the SV. SV measures amount of free fatty acids present in oils, since this determines in large measure the refining loss in industries and also it measures indirectly the average molecular weight of the triglyceride (oils). In practice SV is determined by titration methods. and it is difficult to obtain reliable results. The Saponification Value of seed oils are calculated by the fatty acid composition estimated by gas chromatography (GC) and using equation number (ii) [14]. The calculated SV for CVSO and HBSO is 204.07 and 213 respectively and results are shown Table 4.

3.3. Iodine Value (IV)

Iodine value is measure of carbon-carbon double bond or degree of unsaturation in a fatty acid chain and it is expressed in terms of the number of centigrams of iodine absorbed per gram of oil sample. As per limitation laid down in European standards EN 14214, the IV must not exceed 120 mg I_2/g of seed oil. The IV is occasionally used in assessing oxidative stability of oils and fats and their derivatives, a subject of significant interest for industrial applications such as fuels and lubricants and for physiological applications. It is calculated by using equation number (iii) [14]. The IV of *CVSO and HBSO* is found to be 62.17 mg I_2/g and 112.7 mg I_2/g of seed oil respectively. The evaluated IV for CVSO and HBSO meet EN 14214 standard and they are within the permissible limit. The structure of fatty acid alky ester decides the quality of biodiesel, an increase in number of double bond in FAMEs lead to increase in iodine value [1**].** Further, NOx emissions increases with increase of number C=C bonds in the biodiesel. The diesel fuel is more resistive to oxidation compared to biodiesel because of absence of C=C bonds and oxygen content in its formulation. The Comparative results are shown in Table 4.

3.4. Degree of Unsaturation (DU) and Long chain saturated fatty acids (LSCF)

Degree of unsaturation refers to the average number of double bonds and is calculated by using equation (xi) [16]. Long chain saturated factor refer to long chain fatty acids ranging C16:0 to C 26:0 and can be calculated using equation (vii) [18]. The calculated DU for CVSO and HBSO is 69 and 92 respectively. LSCF is found to be 8.9 and 14.4 respectively. The results are depicted in Table 4.

4. Determination of Fuel properties

4.1 Cetane Number (CN)

The Cetane number measures the ignition quality of a fuel / biodiesel which decrease with increase in unsaturation and decrease in chain length. It measures the readiness of the fuel to auto ignite when injected into the Internal combustion engine. It is generally dependent on the composition of the fuel and can impact the engine's start ability, noise level, and exhaust emissions. Biodiesel has higher cetane number compared to diesel fuels as their composed of long carbon chain lengths [31],[32]. The Cetane number can be determined with help of standard equation (iv) [15]. The minimum requirement of the cetane number prescribed in biodiesel standard organizations *viz.*, ASTM D6751 and EN14214 is 47 & 51 respectively and the CN of the petro diesel is 42.6. The calculated CN for CVSOMEs and HBSOMEs is 59.05 and 49.64 which are above the desired limits of prescribed biodiesel standards as depicted in Table 5. The Cetane Number of CVSOMEs is higher compared to existing biodiesel standard and petrodiesel as shown in Figure. 5.1.

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

The HHV and LHV are heating values of a fuel. The HHV of vegetable oils ranges from 37.27 to 40.48 MJ/Kg. HHV of a fuel is a function of its carbon content (C, wt %), hydrogen content (H, wt %) and oxygen content (wt %). Lower Heating Value determine the total carbon content or energy content in the fuel material. The lower heating values increase with an increase in carbon chain length for saturated acids and esters. There is a slight decrease in the lower heating value with an increase in the degree of unsaturation. It is due to the fact that a large content of fatty acid/methyl ester constituent includes C_{16}-C_{18} compounds which tend to have identical lower heating values as evident from the calculations. The HHV and LHV are evaluated using equation number (v) and (vi) [16],[17]. The calculated HHV and LHV are 40.3 MJ/Kg, 39.02 MJ/Kg and 38.68 MJ/Kg, 37.7 MJ/Kg for CVSOMEs and

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HBSOMEs respectively. The results are shown in Table 5. The HHV and LHV of CVSOMEs and HBSOMEs are comparable to the mark of existing biodiesel but slightly less than of petro diesel i.e HHV 46 MJ/Kg and LHV 43.1 MJ/Kg but are higher than the heating values of coal i.e 32-37 MJ/Kg and the comparison graph is shown in Figure. 5.2

4.3 Flash points (FP)

The FP is related to the vapor pressure of a flammable liquid and it is defined as the lowest temperature at which its vapour gets ignite when exposed to heat source. It is key parameter of fuel from the point of view of safe transport, handling and storage [33]. Generally, biodiesels have higher flash point than diesel fuel which is advantage over the diesel fuel. It is observed that Flash point increases with increase in USFA content and decreases with increase in SFA content. Higher unsaturation content result in more number of double bonds which increase the bond dissociation energy. Flash point of a biodiesel is calculated by using equation (xiii) [19]. The calculated FP for CVSOMEs and HBSOMEs is found to be 137 ^{0}C and 214 ^{0}C which are in comparable range of prescribed biodiesel standards as depicted in Table 5. The flash point of HBSOMEs is higher compared existing biodiesel and petrodiesel as shown in Figure. 5.3.

4.4 Cold flow properties

The Cold flow properties refers to low temperature fuel parameters which assign the limit for the use of fuels under cold weather conditions. Cloud Point (CP) of fuel refers to a lowest temperature at which fuel forms cloudy appearance when cooled. Pour Point (PP) refers to lowest temperature at which fuel continues to flow. Cold filter plugging point (CFPP) refers to desired quantity of fuel which can safely passes through the filter within the specified interval of time [34],[35],[36]. These fuel parameters largely depends on the nature of fatty acid composition of the biodiesel feedstock. The freezing point of a biodiesel decrease with increase in degree of unsaturation and increase in carbon chain length. Generally, biodiesel have higher CP, PP and CFPP compared to diesel-fuels. The CFPP, CP and PP of a CVSOMEs and HBSOMEs is calculated using equations (viii),(ix) and (x) [16] respectively. The calculated CPs are 14.8 ^{0}C, -4.23^{0}C, PPs are 8.76 ^{0}C, -1.02 ^{0}C and CFPPs are 10.8 ^{0}C, 2.96 ^{0}C for CVSOMEs and HBSOMEs respectively. The CP ,PP and CFPP of CVSOMEs is found to be higher than the existing biodiesels. The results are depicted in Table 5. The CP of HBSOMEs is found to be lower compared with existing standards as shown in Fig. 5.4 The PP of HBSOMEs is found to lower than SbSOMEs and SfSOMEs as shown in Figure.5.5 The CFPP of HBSOMEs is lower than CVSOMEs as shown in Figure. 5.6. The HBSOMEs resulted in lower cold flow properties which is due to presence higher saturated fatty acid composition.

4.5 Kinematic Viscosity (KV)

The viscosity is decisive property which signifies the injector behavior of the fuel. High viscosity leads to poor atomization, vaporization and therefore results in poor combustion and increased emission. The viscosity of CVSOMEs and HBSOMEs are calculated by using equation (xii) [19]. A quality fuel possess lower viscosity which easily flow into the engines and results in better atomization, vaporization and decrease emission [16],[32]. The viscosity of a biodiesel depends on its SFA and USFA content in it. Viscosity increases with increase in USFA content and decreases with increase in SFA content. The viscosity of CVSOMEs and HBSOMEs are found to be 3.6 mm^2/sec and 3.4 mm^2/sec respectively which fall within the limit of prescribed biodiesel standards as depicted in Table 5. The viscosities of CVSOMEs and HBSOMEs are in comparable range of existing biodiesel standard as shown in Figure 5.7.

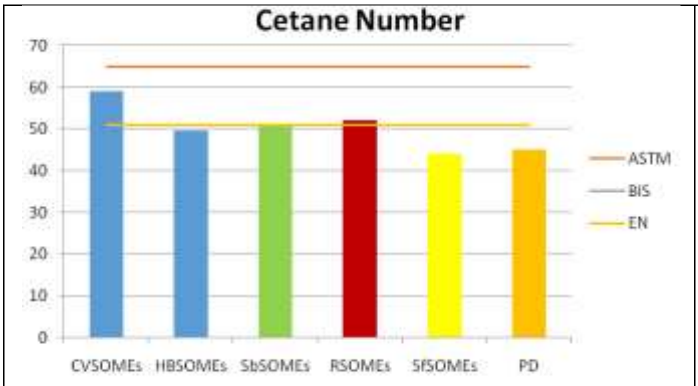

Figure 5.1 Cetane Number

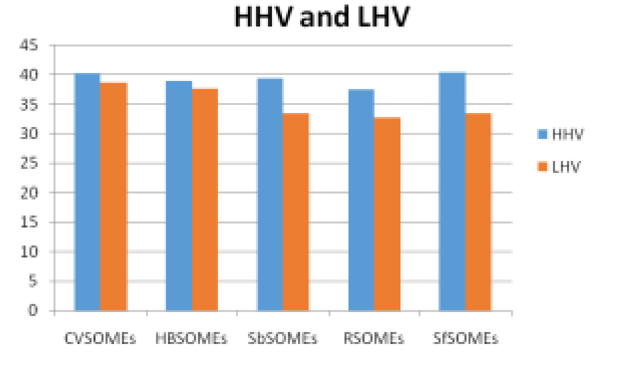

Figure 5.2 HHV and LHV

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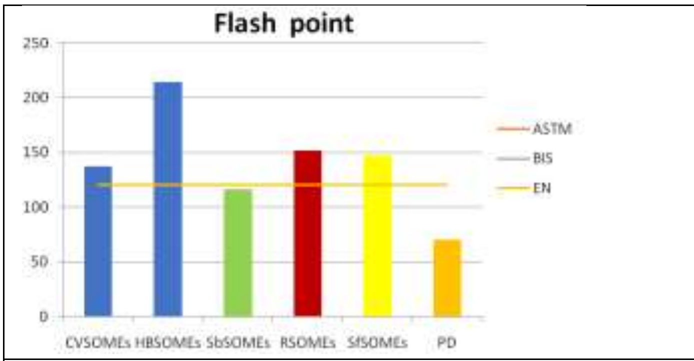

Figure 5.3 Flash point

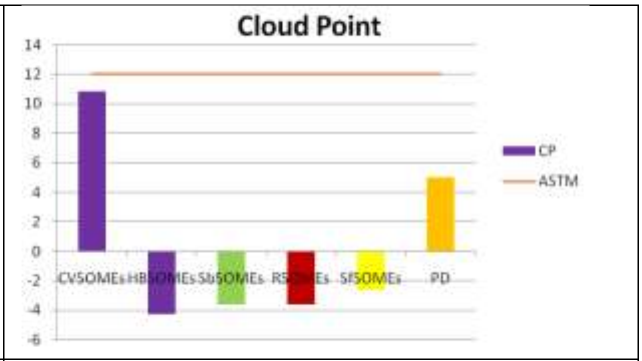

Figure 5.4 Cloud point

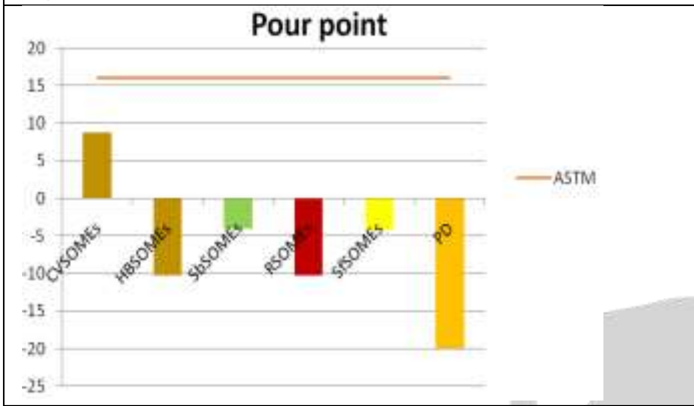

Figure 5.5 Pour point

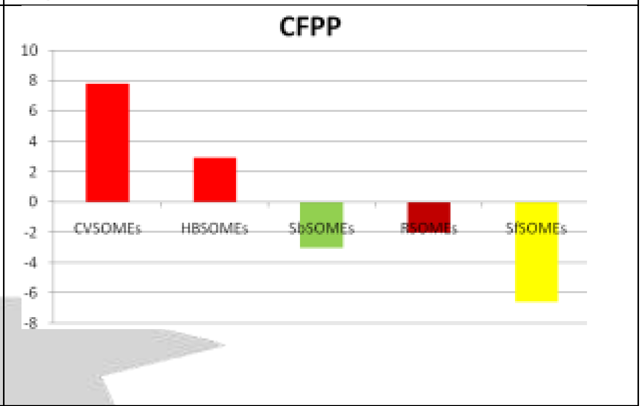

Figure 5.6 Cold Filter Plugging point

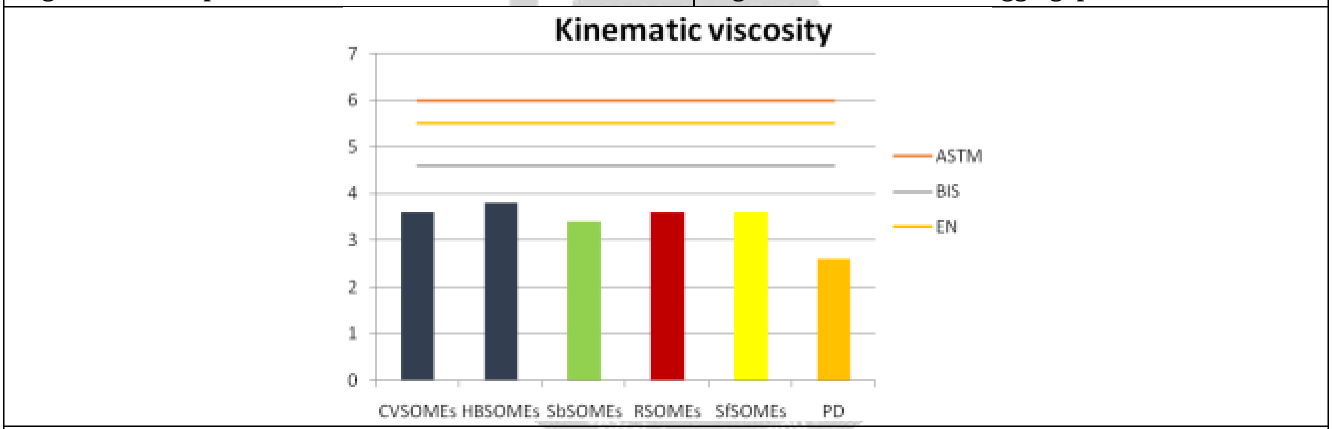

Figure 5.7 Kinematic viscosity

IV. CONCLUSIONS

Based on the percentage component fatty acids, the *Cannarium vulgar* and *Haematostaphis barterii* seed oils in terms of their corresponding FAMEs are assessed for their biodiesel fuel 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 existing standard biodiesels. The data obtained from this paper regarding biodiesel quality indicate the feasibility of CVSO and HBSO seed oils appreciable feed stocks for biodiesel production. Therefore, seed oils selected in this investigation meet the major specification of biodiesel standards as per American (ASTM), Indian (BIS) and European (EN) standard. This work reported the suitability of CVSO and HBSO as new feedstocks and reliable candidates for the production of bio-diesel. However, still further research is needed to evaluate the biodiesel (FAMEs) of these feedstocks for further tribological studies, and long term engine testing evaluations.

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