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Production, Characterisation and Assessment of Biomixture Fuels for Compression Ignition Engine Application

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Abstract**—**Hardly any neat biodiesel satisfies the European EN14214 standard for compression ignition engine application. To satisfy the EN14214 standard, various additives are doped into biodiesel; however, biodiesel additives might cause other problems such as increase in the particular emission and increased specific fuel consumption. In addition, the additives could be expensive. Considering the increasing level of greenhouse gas GHG emissions and fossil fuel depletion, it is forecasted that the use of biodiesel will be higher in the near future. Hence, the negative aspects of the biodiesel additives will likely to gain much more importance and need to be replaced with better solutions. This study aims to satisfy the European standard EN14214 by blending the biodiesels derived from sustainable feedstocks. Waste Cooking Oil (WCO) and Animal Fat Oil (AFO) are two sustainable feedstocks in the EU (including the UK) for producing biodiesels. In the first stage of the study, these oils were transesterified separately and neat biodiesels (W100 & A100) were produced. Secondly, the biodiesels were blended together in various ratios: 80% WCO biodiesel and 20% AFO biodiesel (W80A20), 60% WCO biodiesel and 40% AFO biodiesel (W60A40), 50% WCO biodiesel and 50% AFO biodiesel (W50A50), 30% WCO biodiesel and 70% AFO biodiesel (W30A70), 10% WCO biodiesel and 90% AFO biodiesel (W10A90). The prepared samples were analysed using Thermo Scientific Trace 1300 Gas Chromatograph and ISQ LT Mass Spectrometer (GC-MS). The GS-MS analysis gave Fatty Acid Methyl Ester (FAME) breakdowns of the fuel samples. It was found that total saturation degree of the samples was linearly increasing (from 15% for W100 to 54% for A100) as the percentage of the AFO biodiesel was increased. Furthermore, it was found that WCO biodiesel was mainly (82%) composed of polyunsaturated FAMEs. Cetane numbers, iodine numbers, calorific values, lower heating values and the densities (at 15 ^{o}C) of the samples were estimated by using the mass percentages data of the FAMEs. Besides, kinematic viscosities (at 40 °C and 20 °C), densities (at 15 °C), heating values and flash point temperatures of the biomixture samples were measured in the lab. It was found that estimated and measured characterisation results were comparable. The current study concluded that biomixture fuel samples W60A40 and W50A50 were perfectly satisfying the European EN 14214 norms without any need of additives. Investigation on engine performance, exhaust emission and combustion characteristics will be conducted to assess the full feasibility of the proposed biomixture fuels.

Keywords**—**Biodiesel, blending, characterisation, CI Engine.

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I. Introduction

THE significant threat of environmental pollution and restrictions on exhaust gas emissions have become a crucial concern for internal combustion engine operations. Researchers have been working on alternative fuels to replace diesel for last decades. By far, biodiesel is considered one of the most promising renewable alternative fuels in terms of its properties such as being environmentally friendly, biodegradable, energy efficient and renewable [1]. Biodiesel is produced from organic feedstocks like vegetable oils and animal fats by transesterification method. Its inherent fuel properties allow the usage of biodiesel in Compression Ignition (CI) engines without any major modifications [2]. To illustrate, good lubricity, high flash point and reduction on most of the exhaust gas emissions like CO, smoke opacity and HC make biodiesel a very good candidate as an alternative fuel. Although biodiesel has promising properties, the chemical structures of biodiesel and petroleum diesel are different. The main difference between them is the existence of ester group in biodiesel, Fig. 1. This difference creates variations on fuel properties and engine operation i.e. engine performance, combustion characteristics and exhaust gas emissions. Thus, any biodiesel to be used in the engine has to fulfil the European norm EN14214. However, it is not easy to produce biodiesel which satisfies the norms. Note that biodiesel properties highly depend on its feedstock. Hence, fulfilling the norms could be harder for specific feedstocks. For example, It is difficult to satisfy the norms with biodiesels derived from highly unsaturated feedstocks like WCO [3]. This is mainly because of the direct relationship between the iodine value and the degree of unsaturation. Hence, to make use of biodiesels, various additives are doped into biodiesel. However, biodiesel additives might cause other problems such as increase in the NO_x emission and fuel consumption. For instance, Imdadul et al. addressed that the cetane improver Ethyl Hexyl Nitrate increased the CO and HC emissions when added into n-butanol biodiesel blend [4]. Moreover, Yilmaz and Atmanli tested the 1-pentanol in a diesel-biodiesel blend. As a result of the additive, reductions on heating value and cetane number; as well as an increase in Brake Specific Fuel Consumption BSFC, CO and HC emissions were observed [5]. In addition, some additives such as nanoparticles could be very expensive which may raise the total cost of the biofuel. However, there is a fact that most of engine manufacturers do not provide warranty for 100% biodiesel usage. The maximum allowable biodiesel percentage in the biodiesel-diesel blend

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was defined as 7% in BS EN 590 standard. Nowadays, the side effects of additive usage may not be significant as the maximum allowance of biodiesel is only 7%. However, negative aspects of additive usage will be vital as the biodiesel percentage in diesel blends increases. Both European and UK legislation supports the biofuel usage [7]. Currently, EU Renewable Energy Directive 2009/28/EC declares that 20% of total energy needs should be compensated by the renewables by 2020 [8]. The same directive also addresses that 10% of transport fuel should be from renewables by 2020 [8]. The increase from 2014 target to 2020 targets was doubled (from 5% to 10%). In this regard, it can be forecasted that importance of the biodiesel will be increasing gradually in the upcoming years. Some manufacturers like Volkswagen have already approved that certain models can be used with 100% biodiesel [9]. In this regard, the drawbacks of additives should be minimised as their effects would be more significant in high biodiesel percentage blends. In the light of this issue, this study aims to produce a biomixture by blending two different biodiesels derived from the WCO and sheep oil; and check whether it is possible to satisfy the European EN14214 norms by biomixture without any need of additives. Various blend ratios of the base fuels were prepared and characterised to figure out optimum blending ratio. Objectives of the research could be listed as (i) biodiesel production, (ii) biodiesel blending at different ratios, (iii) characterization of the fuel samples and (iv) analysing the suitability of the biomixtures to the EN 14214 European norms.

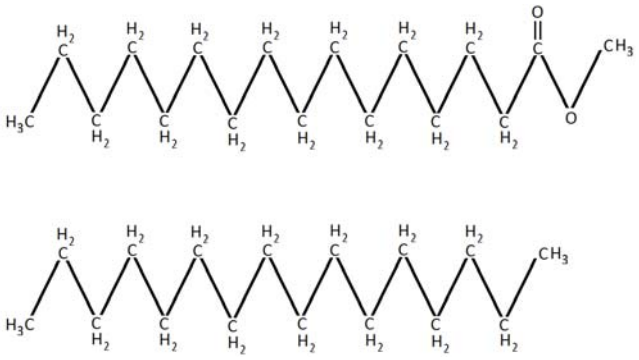


Fig. 1 Typical biodiesel molecule vs petroleum molecule diesel, adapted from [6]

II. Focused Fuel Properties and Feedstock Selection

WCO and AFO are the two feedstocks selected to conduct this research. The common reason with both feedstocks is their high availability in the EU and UK. Restaurants and residential houses are the two main sources of WCO. It is also widely known that a considerable amount of animal fats are disposed of by butchers. However, biodiesels produced from these highly available feedstocks hardly satisfy the EN14214 norms.

Table I illustrates the desired fuel properties for biodiesel (as an engine fuel) according to European and American standards. Some of the parameters listed in Table I are highly critical as they limit the usage of highly available feedstocks in biodiesel production; such as soybean and sunflower oil [10]. To illustrate, according to EN 14214, the maximum allowed iodine value is 120 but it is difficult to obtain biodiesel from highly unsaturated feedstocks within the mentioned iodine value range. However, a highly available feedstock such as WCO, which may contain a significant amount of used sunflower oil in its content, cannot be excluded from biofuel sector. Viscosity, on the other hand, is another popular fuel property which may be an obstacle in biodiesel production from highly available feedstocks i.e. animal fats. Biodiesels derived from animal fats typically have slightly higher viscosity values than the specified value (5.0 mm^2/s for 40°C) in the EN14214.

Apart from the iodine value and viscosity at 40 °C; viscosity at 20 °C, density, calorific value and flash point of the samples were measured in the scope of this study. Moreover, FAME compositions of the samples are investigated through a GS-ms analyser. FAME breakdown of the samples also enables the estimation of other fuel properties like cetane number, iodine value, calorific value, lower heating value, density and pour point. Ultimately, the biomixtures were analysed and compared to standards in the scope of mentioned parameters only. It is believed that covered parameters are reasonable to check satisfaction of any fuel to the standards. The most important parameters which were not involved this study might be the copper strip corrosion and oxidation stability measurements.

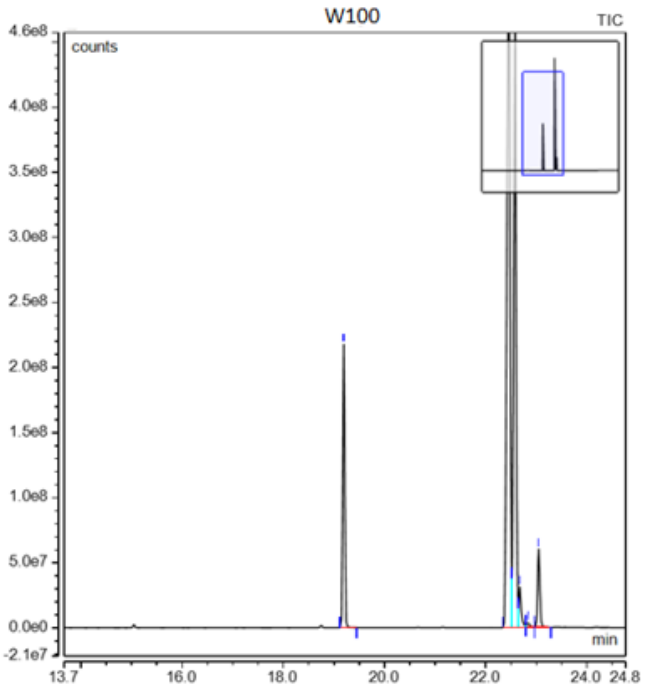


Fig. 2 GC-MS result of WCOB

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TABLE I
EUROPEAN AND AMERICAN STANDARDS FOR BIODIESEL AS ENGINE FUEL [11], [12]

Fuel Characteristic	Test Method	Unit	EUROPE	USA
Specification applies to			EN 14214:2008 FAME	ASTM D 6751-07b FAAE
Density 15 °C	EN ISO 3675; EN ISO 12185	g/cm³	0.86-0.90	
Viscosity 40 °C	EN ISO 3104; ISO 3105	mm²/s	3.5-5.0	1.9-6.0
Distillation		% @ °C		90%,360°C
Flash point	EN ISO 3679	°C	101 min	93 min
Sulphur content	EN ISO 20846; EN ISO 20884	mg/kg	10 max	15 max
Carbon residue (10% distillation residue)	EN ISO 10370	%(mol/mol)	0.3 max	
Sulphated ash	ISO 3987	%(mol/mol)	0.02 max	0.02 max
Water	EN ISO 12937	mg/kg	500 max	500 max
Total contamination	EN 12662	mg/kg	24 max	
Copper strip corrosion	EN ISO 2160	3h/50°C	1 max	3 max
Oxidation stability	EN 14112	hours;110°C	6 hours min	3 hours min
Cetane number	EN ISO 5165		51 min	47 min
Acid value	EN 14104	mg KOH/g	0.5 max	0.5 max
Methanol	EN 14110	%(mol/mol)	0.20 max	0.2 max or Fp <130°C
Ester content	EN 14103	%(mol/mol)	96.5 min	
Methyl esters ≥ 4 double bonds		%(mol/mol)	1 max	
Monoglyceride	EN 14105	%(mol/mol)	0.8 max	
Diglyceride	EN 14105	%(mol/mol)	0.2 max	
Triglyceride	EN 14105	%(mol/mol)	0.2 max	
Free glycerol	EN 14105; EN 14106	%(mol/mol)	0.02 max	0.02 max
Total glycerol	EN 14105	%(mol/mol)	0.25 max	0.24 max
Iodine value	EN 14111		120 max	
Linolenic acid content	EN 14103	%(mol/mol)	12 max	
Phosphorus	EN 14107	mg/kg	4 max	10 max
Alkaline metals (Na,K)	EN 14108; EN 14109	mg/kg	5 max	5 max

III. BIODIESEL PRODUCTION AND PREPARATION OF BIOMIXTURES

The WCO was provided by a local restaurant in Birmingham, UK. Then it was filtered through 5 µm sock filter before the transesterification process to remove solid frying contaminations. The other feedstock was animal fat which was collected from a butcher in Loughborough, UK. The collected sheep fat then cut into smaller pieces and placed in an oven at 160 °C approximately for 30 minutes. Released oil was collected in the liquid state. Around 1400 ml of liquid oil was collected from 1800 kg of solid fat. Before transesterification process, titrations for both feedstocks were carried out to determine the amount of catalyst needed. Both biodiesels from WCO and AFO were produced with same method. Initially, feedstocks heated up to 60 °C. Meanwhile, previously calculated catalyst (KOH) was dissolved in methanol (20% volume of the oil). Then, the catalyst alcohol solution was poured into the feedstock oil and stirred mechanically for 30 minutes. After the stirring, it was transferred into a separatory funnel and left for 24 hours for separation.

Biomixtures were obtained by blending two different biofuels, WCO biodiesel and AFO biodiesel. In this study, apart from the neat biodiesels (W100 and A100), biomixtures at different propositions like 80% WCO biodiesel and 20% AFO biodiesel (W80A20), 60% WCO biodiesel and 40% AFO biodiesel (W60A40), 50% WCO biodiesel and 50% AFO biodiesel (W50A50), 30% WCO biodiesel and 70% AFO biodiesel (W30A70), 10% WCO biodiesel and 90% AFO biodiesel (W10A90) were investigated. Note that all percentages were prepared in volume bases. Moreover, the biodiesels were blended after the transesterification process by the help of scaled cylinders.

IV. FUEL CHARACTERIZATION RESULTS

A. GS-MS Analyses

All seven biofuels, which were W100, W80A20, W60A40, W50A50, W30A70, W10A90 and A100, were tested through the *Thermo Scientific* brand (Trace 1300) Gas chromatography and (ISQ LT) mass spectrum analyser. Initially, the samples required for the test were prepared by dissolving 1 gram of oil sample in 100 ml of butanol. Then 2 ml of the prepared solutions placed into capsules of the device. Oven kept at 100 °C for 1 minute, then heated from 100 °C to 275 °C with. Finally, the 275 °C temperature remained constant for 4 minutes. The mass range was 50-600 m/z. Helium was used as a carrier gas at the 1.25 ml/min flow rate.

The GC-ms analyses carried out in order to figure out FAME contents of the biofuel samples Table II. It is crucial to know FAME breakdown of any biomixture blend to calculate some fuel characteristics. To illustrate, some important parameters like cetane number, calorific value, lower heating value, density and iodine number can be calculated through

mass percentages of each FAME compounds.

TABLE II
NAMES AND MOLECULAR STRUCTURES OF THE FAME'S

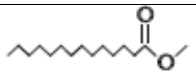
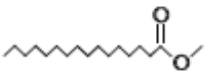
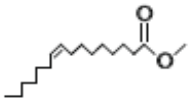
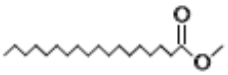
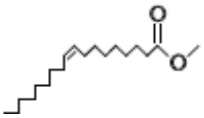
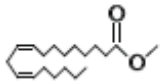
Name of fatty acid	Carbons : No. of double bonds	Formula	Molecular structure	Viscosity at 40°C (mm^2/s)	Iodine Value
Myristic	C14:0	$C_{15}H_{30}O_2$		3.30 [13]	1 [14]
Palmitic	C16:0	$C_{17}H_{34}O_2$		4.38 [13]	1 [14]
Palmitoleic	C16:1	$C_{17}H_{32}O_2$		3.67 [13]	95 [15]
Stearic	C18:0	$C_{19}H_{38}O_2$		5.85 [13]	0 [14]
Oleic	C18:1	$C_{19}H_{36}O_2$		4.51 [13]	94 [14]
Linoleic	C18:2	$C_{19}H_{34}O_2$		3.65 [13]	176 [14]

TABLE III
RELATIVE AREAS OF THE FAMES IN MOLAR BASIS

FAME composition	relative area						
	W100	W80A20	W60A40	W50A50	W30A70	W10A90	A100
C14:0	0.0013	0.0058	0.0114	0.0144	0.0209	0.0278	0.0321
C16:0	0.1193	0.1415	0.159	0.1704	0.1949	0.2204	0.2204
C16:1	0.0000	0.0000	0.0038	0.0111	0.0152	0.0201	0.0095
C18:0	0.0394	0.0907	0.1423	0.1738	0.2188	0.2688	0.2769
C18:1	0.0258	0.037	0.0487	0.0581	0.0665	0.0772	0.4034
C18:2	0.8154	0.7249	0.6276	0.5723	0.4838	0.3858	0.0107

TABLE IV
MASS PERCENTAGE OF FAMES IN EACH FUEL SAMPLE

FAME composition	mass based relative area %						
	W100	W80A20	W60A40	W50A50	W30A70	W10A90	A100
C14:0	0.1	0.5	0.9	1.2	1.7	2.3	2.8
C16:0	11.0	13.1	14.8	15.8	18.2	20.6	21.6
C16:1	0.0	0.0	0.4	1.0	1.4	1.9	0.9
C18:0	4.0	9.3	14.7	17.9	22.6	27.9	30.1
C18:1	2.6	3.8	5.0	5.9	6.8	7.9	43.5
C18:2	82.2	73.4	64.1	58.1	49.3	39.4	1.1
Saturated	15.1	22.9	30.5	34.9	42.5	50.8	54.4
Monounsaturated	2.6	3.8	5.4	7.0	8.2	9.8	44.4
Polyunsaturated	82.2	73.4	64.1	58.1	49.3	39.4	1.1

Each fuel sample was tested twice in GC-ms to check experiment consistency. The results were found the same, which means both experiments were consistent and samples were prepared accurately. Fig. 2 represents a sample GC-ms graph for W100. The peaks were representing different FAME compound and the software was predicting the type of FAME by the area under the curve. Probabilities of the FAME predictions were around 80%. Consequently, molar percentages of the FAMEs were obtained by GC-ms analyses given in Table III. Note that some results were ignored due to very low percentage (less than 1%).

In order to proceed with calculations, the relative areas of the FAMEs in molar basis converted into the mass basis by using molecular weights of each FAME compound. Table IV shows the percent areas of the FAMEs in mass basis. In addition, the total percentage of the saturated acids (having no double bonds), monounsaturated acids (having one double bond) and polyunsaturated acids (having at least two double bonds) were summarised.

According to the GC-ms results provided in Table IV, biodiesel derived from the WCO (W100) was mainly composed of (by 82.2%) polyunsaturated FAME which is C18:2. This particular FAME has the highest degree of unsaturation among the observed biomixture samples as it contains two double bonds. Animal fat biodiesel (A100), on the other hand, has only 1.1% of C18:2 in its content. The main unsaturated FAME that A100 contains is the C18:1 by 43.5% Table IV. Hence the total percentage of unsaturated FAMEs of A100 (45.5%) is less than that of W100 (85.8%). Furthermore, the type of major unsaturated FAMEs are different for A100 and W100 i.e. monounsaturated and polyunsaturated respectively. It can be clearly concluded that the W100 is more unsaturated than the A100. It is also observed that the degree of unsaturation exhibited linearly decreasing trend as AFO biodiesel added into WCO biodiesel.

B. Fuel Properties

It is crucial to know physiochemical properties of any fuel before using it in an engine. Table V provides the measured fuel properties of the test samples, as well as the limits, declared in EN14214 standards whereas, Table VI illustrates the fuel properties which were calculated through the FAME breakdown obtained from the GS-ms analyse. As the

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properties like iodine value, cetane number, calorific value, density and lower heating values are known for the specific FAME's; they can be calculated for the test samples by using mass percentages of the corresponding FAME compounds.

Calorific value and density are two parameters which were both measured and calculated through the GC-ms results. The consistency of the measured and the calculated values validates the calculations. The slight differences can be attributed to precisions of the lab equipments and human errors. In addition, the densities were measured at 21 °C but the calculated densities are stands for 15 °C. Ultimately, although there are slight differences, calculated properties are consistent with the measured values.

In the light of considered fuel properties, none of the test fuels found unsuitable to the EN14214 standards in terms of viscosity at 20 °C, density, calorific value, flash point and lower heating value. However, some samples did not satisfy the standards in terms of viscosity at 40 °C, cetane number and iodine number.

TABLE V
MEASURED FUEL PROPERTIES OF THE TEST FUELS

Fuel	Viscosity 40 °C [mm²/s]	Viscosity 20 °C [mm²/s]	Density [g/cm³]	Calorific value [MJ/kg]	Flash point [°C]
EN 14214 norms	***3.5-5.0***	***NO***	***0.86-0.90***	***NO***	***101 min***
W100	5.00	7.61	0.882	38.4	169
W80A20	4.85	8.47	0.88	39.8	170
W60A40	4.90	8.79	0.874	39.5	168
W50A50	4.93	8.92	0.874	39.4	168
W30A70	5.15	9.35	0.87	39.2	172
W10A90	5.33	9.39	0.868	39.0	172
A100	5.27	8.60	0.872	40.5	170

TABLE VI
CALCULATED FUEL PROPERTIES BY USING FAME CONTENTS OF THE FUEL SAMPLES

Fuel	Cetane number			Iodine	Calorific value	LHV	Density 15 °C
	min	average	max	number	[MJ/kg]	[MJ/kg]	[g/cm³]
EN 14214 norms	***51 min***			***120 max***	***NO***	***NO***	***0.86-0.90***
W100	44.1	49.0	54.0	147	39.6	37.1	0.888
W80A20	47.1	52.7	58.4	133	39.6	37.1	0.886
W60A40	50.1	56.4	62.7	118	39.5	37.0	0.881
W50A50	51.9	58.6	65.3	109	39.3	36.7	0.874
W30A70	54.8	62.1	69.4	95	39.1	36.6	0.869
W10A90	58.1	66.0	74.0	79	39.0	36.4	0.863
A100	64.4	76.1	87.8	44	39.5	36.9	0.872

1) Viscosity

Viscosity is one of the most important fuel properties as fuel flows through lots of components in an engine. The European standard for biodiesel sets the range of viscosity in between 3.5 and 5.0 mm²/s at 40 °C, Table I. Viscosities of the test fuels were measured via *CANNON* viscometer embedded into a water bath. According to the results provided in Table III, neat version of AFO biodiesel A100 does not satisfy the maximum viscosity of 5.0 mm²/s at 40 °C and it exceeds the 5.00 upper limit by 0.27 mm²/s. However, viscosities within the specified range can be obtained when the W100 and A100 blended. For example, W100, W80A20, W60A40 and W50A50 all provide satisfying viscosity values, Table V. The reason underlies on the different viscosity values of the FAME compounds whose amounts vary with blending, Table II.

2) Cetane Number

Three different cetane numbers are presented in Table VI, as minimum, average and maximum. The reason of having various cetane numbers for same FAME compound is the method of CN measurement. Murphy et al. [16] addressed 6 different methods which have been using to determine the cetane number; Blend, Delay, IQT, From ON, D613 and Blank methods [16]. Average of the recorded cetane numbers can be used for further analyses [14]. According to the average cetane numbers, W100 may not satisfy the EN14214 standards as it is estimated less than 51. However, due to the high cetane number of A100, all tested biomixtures as well as the A100 observed within the European range for cetane number.

3) Iodine Value

Iodine value can be defined as the degree of total unsaturation of the biodiesel. The upper limit of iodine value was defined as 120 by EN14214 Table VI. The main reason behind this restriction was declared as the tendency of high iodine value fuels to poymerisation [10]. In addition, the strong relationship between the oxidation instability with high iodine number was observed for the biodiesels [10]. This study shoves that iodine value of WCO biodiesel is higher than the limit declared in the EN14214. This is attributed to the high percentage of unsaturated FAME compound in W100's content, which is C18:2 as 82.2%. However, iodine value can be kept within the range by blending W100 with highly saturated biodiesel, A100. Table VI shows that the tested biomixtures having at least 40% AFO biodiesel satisfies the EN14214 standards in terms of iodine value.

C. Discussion

Fig. 3 demonstrates viscosities and iodine values of the biomixtures at different percentages. Linear reduction on iodine values was observed as the proportion of polyunsaturated FAME (C18:2) decreased with the addition of A100 into W100 Table IV & Fig. 3. In contrast, viscosities of the blends were increasing with the addition of A100. The reason of increased viscosities can be explained by the higher viscosities of the steric (C18:0) and oleic (C18:1) FAMEs which are forming the 73.6% of A100, Table IV.

It has been understood that proportions of FAME compounds were directly affecting the suitability of the biomixture blends to EN14214 standards. In this regard, relations between the saturated, monounsaturated and polyunsaturated FAMEs presented in Fig. 4. According to Table V, the blends W60A40, W50A50, W30A70, W10A90 and A100 satisfy the EN14214 standards in terms of iodine value. This fact reveals that 30% saturated FAME content can be set as a lower limit for iodine value which falls into the yellow zone (right) on Fig. 4. Note that the linoleic acid (C18:2), having 176 iodine value, is the only FAME

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compound increasing the iodine value above the desired limit. Similarly, viscosities of the W100, W80A20, W60A40 and W50A50 are fulfilling the EN14214 standards. In the light of this research, 40% of total saturation limit can be set as an upper limit for the viscosity parameter. The green portion (left) of Fig. 4 represents the acceptable zone in terms of viscosity at 40 °C. The stearic acid (C18:0), having 5.85 mm^2/s viscosity, is the saturated FAME compound which negatively affects the viscosity of biofuel. To sum up, the interstation zone of both iodine value and viscosity parameters fulfils the EN14214 standards and designated by the orange (middle) in Fig. 4.

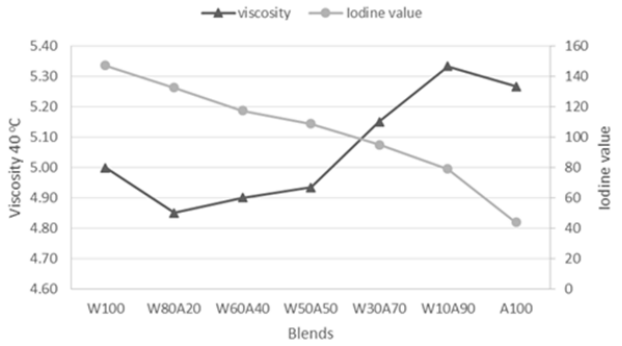


Fig. 3 Variations of viscosity and iodine value parameters with respect to biomixture percentage

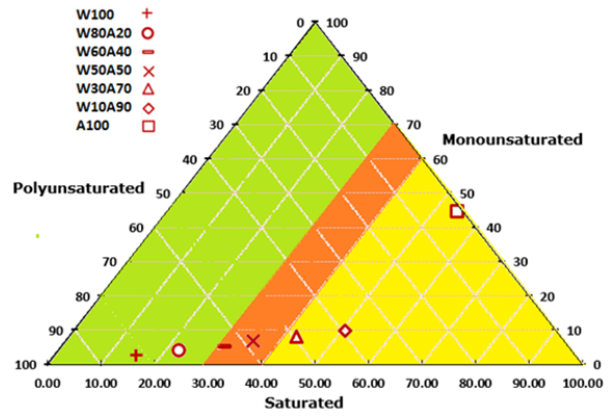


Fig. 4 Analyses of biodiesels according to their degree of unsaturation. Zones satisfying parameters for EN 14214 norms; green area satisfies the viscosity at 40 °C; yellow area satisfies the iodine number; orange area satisfies both viscosity and iodine number

V. Conclusion

In this study, biodiesel blending method was investigated to find a self-sufficient biomixture which satisfies the EN14214 standards. In the scope of the study, biodiesels derived from WCO and AFO were used as base fuels. These feedstocks were selected according to their high availability in the Europe and UK. Neither of the neat biodiesels completely fulfil the EN14214 standards. The WCO biodiesel has high iodine number as it typically consists of unsaturated sunflower oil etc. The AFO biodiesel, on the other hand, has problems with high viscosity due to its high saturation level. Mentioned base biodiesels are blended in various ratios to investigate whether any biomixture can satisfy the EN14214 standards without any need of additive. Initially, GC-ms analyses are carried out to find out FAME compounds of the test fuels and their corresponding proportions. These values are then used to calculate cetane numbers, iodine values, calorific values, lower heating values and densities of the samples. In addition, some crucial fuel properties like viscosities at 20 °C & 40 °C, densities, calorific values and flashpoints were measured experimentally. The results of the analyses revealed that the degree of unsaturation of biomixture blends had a huge impact on total suitability to standards. Especially the particular FAME compounds i.e. the linoleic acid (C18:2) and the stearic acid (C18:0) found to be the most critical components. Investigations showed that it was possible to obtain a self-sufficient biomixture when the percentages of those FAME compounds were kept in certain ranges. To illustrate, W60A40 and W50A50 biomixtures satisfied the EN14214 standards according to the tested parameters. It should be noted that further analysis on untested parameters (such as oxidation stability and copper strip corrosion etc.) have to be done in order to be able to address that W60A40 and W50A50 completely fulfill the EN14214 standards. Engine tests can be done to analyse engine performance, combustion characteristics and exhaust gas emissions of the biomixtures as a future work. Moreover, another biodiesel agent like inedible vegetable oil can be added into biomixture to enhance the fuel properties.

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