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Comparative study of various renewable fuels blends to run a diesel power plant.

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Abstract.

In this paper bioethanol/diesel and bioethanol/biodiesel blends, at several concentrations and temperatures, are studied to find its possible commercial usage as a fuel to run a diesel power plant.

The tested fuels were: net mineral diesel fuel (D100) , 5 % bioethanol/diesel fuel blend (v/v) (E5D95), 10 % bioethanol/diesel fuel blend (v/v) (E10D90), 15 % bioethanol/diesel fuel blend (v/v) (E15D85), neat biodiesel (B100), 5 % bioethanol/biodiesel blend (v/v) (E5B95), 10 % bioethanol/biodiesel blend (v/v) (E10B90), and 15 % bioethanol/biodiesel blend (v/v) (E15B85). The fuels were tested at: 30, 25, 8 and -18 ºC.

This paper shows the observations done in 8 samples during 5 weeks. After each week, each sample was overviewed, and changes related to stability, colour and aggregation were recorded.

It has been proved that additives are not necessary to ensure stability of bioethanol/biodiesel blends under low temperature conditions, as the phase separation never happens. But in case of bioethanol/diesel blends some additives are necessary to keep stability under low temperature conditions.

Based on this study, it can be concluded that blends of biodiesel fuel with bioethanol up to 15% can be used to fuel a diesel power plant if engine performance tests corroborate it. The same conclusion can be applied to blends of diesel fuel with bioethanol up to 15% blends if additives to keep stability are added.

Key words

Alternative fuel, biodiesel, bioethanol, heat engines, fuels blend.

1. Introduction

Nowadays the usage of biofuels is widely extended in the energy field. Biodiesel is Europe's dominant renewable fuel. In 2007 represented 90 percent of global production. By 2010, APPA Biocarburantes estimates that biodiesel production capacity in Spain will be 6.9 million tonnes annually, with a total of 67 manufacturing sites.

The most common biofuels today are biodiesel (made from vegetable oils) and bioethanol (made from sugar and starch crops).

Biodiesel is a biofuel widely studied. Researches are continuing improving this biofuel from the point of view of new row materials and low productions cost. It is usually produced from oleaginous crops, such as rapeseed, soybean, sunflower and palm, but actually new raw materials are being investigated as for example microalgae [1].

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Ethanol can be produced from biomass by fermentation of sugar, by converting the starch content of biomass feedstocks into alcohol or by hydration of ethylene which is obtained from petroleum and other sources. The sugar-containing raw materials are e.g. sugar cane, sugar beet, molasses and sweet sorghum. Starch can be found in very common crops such as corn, potatoes, and wheat.

Nowadays most of the ethanol produced (about 95%) comes from the starch or sugar (bioethanol) in a wide variety of crops, but there has been considerable debate about the usage of ethanol made from edible material. In this sense recent developments with cellulosic ethanol production may allay some of these concerns.

Research is under way to commercialise “second-generation” production techniques that can make biofuels from woody material, grasses and some additional types of waste.

Biofuels are defined as: “transport fuels made from organic material”. But biofuels can also run a diesel-power-plant (or diesel generator), so it could contribute to the electricity generation from renewable energy sources, as they are produced from biomass. Biomass energy along with wind, solar, geothermal, wave, tidal, hydropower, landfill gas, sewage treatment plant gas and biogases are defined as renewable energies under the European Directive 2001/77/EC [2].

A diesel generator is the combination of a diesel engine with an electrical generator (often called an alternator) to generate electric energy. Diesel generating sets are used in places without connection to the power grid or as emergency power-supply if the grid fails. Small portable diesel generators range from about 1 kVA to 10 kVA may be used as power supplies on construction sites, or as auxiliary power for vehicles such as mobile homes.

The promotion of electricity produced from renewable energy sources is a high Community priority as outlined in the White Paper on Renewable Energy, for reasons of security and diversification of energy supply, of environmental protection and of social and economic cohesion.

Biofuels are today the only direct substitute for oil in internal combustion engines that are available on a significant scale. Biodiesel is the only fuel that can be used in an ordinary diesel combustion engine, i.e. in a diesel engine not technically modified or manipulated.

Bioalcohols are usually blended with gasoline with good results. But alcohols blended with mineral diesel, as for example ethanol, can also run a diesel engine.

Bioethanol is an alternative fuel which has the advantages of being a renewable bio-based resource and its chemical composition lead to think that it has the potential to reduce harmful emissions.

Several studies have showed that biodiesel burns in a diesel engine, with much less total hydrocarbons (THC), carbon monoxide (CO) and particulate matter (PM) in the exhaust, although there was an increase in nitrogen oxides (NO_x) [3][4][5][6]. In case of bioethanol-diesel blends, also PM in exhaust decreased substantially and slightly decrease was observed in NO_x. The effect on CO and THC are less clear although both were still well below the regulated emissions limit [7][8][9].

When two different fuels are going to be blended, their chemical composition can leads to some problems related to phase separation and fuel usage at low temperatures. Fuel stability influences fuel injection and combustion processes. Fuel blends must remain homogeneous over the time; else different fuels (as many as components constitute the blend) may be injected into the cylinder, affecting engine characteristics. Those problems justify a previous stability test before engine-performance and emissions characteristic tests, in order to determine if different fuels are being introduced in the combustion chamber which, in this case, would deteriorate the combustion process.

In this work we present the idea of blending bioethanol with diesel and biodiesel, as a way to decrease harmful emissions and to solve the problem of the increasing nitrogen oxides content in exhaust emissions when biodiesel is brunt in a compression ignition engine, always compared to those of diesel fuel. Future works will try to corroborate this supposition, but at the beginning of this research a study of fuel stability is needed.

2. Materials

Stability of 8 samples was determined. The tested samples were net mineral diesel fuel (D100) , 5 % bioethanol/diesel fuel blend (v/v) (E5D95), 10 % bioethanol/diesel fuel blend (v/v) (E10D90), 15 % bioethanol/diesel fuel blend (v/v) (E15D85), neat biodiesel (B100), 5 % bioethanol/biodiesel blend (v/v) (E5B95), 10 % bioethanol/biodiesel blend (v/v) (E10B90), and 15 % bioethanol/biodiesel blend (v/v) (E15B85).

Diesel fuel without additives was purchased from gasoline station Petrol d.d. Ljubljana (Slovenia), and its properties are shown in Table I.

The used biodiesel was purchased from Biogoriva d.o.o (Slovenia). It was produced from rapeseed oil and its characteristics are presented in Table II. According to this, the purity of the tested biodiesel is guaranteed as the ester content is higher than the minimum value prescribed by the biodiesel standard EN14214.

The used bioethanol was purchased from Carlo Erba Company (Milano - Italy); it was produced from the fermentation of sugars and its main properties are shown in Table III.

Table I. - Properties of diesel fuel

Property	Unit	EN 590 Min/Max	D100
Density at 15 °C	kg/m^3	820/845	837.3
Cold filter plugging point (Seasonal specification)	°C	Max. Grade: A= +5, B= 0 C= -5, D= -10 E= -15, F= -20	-8
Cloud Point (only limited for artic winters)	°C	Max. Class: *0* =-10, *1*=-16 *2*= -22, *3*= -28 *4*= -34	-3
Distillation			
50 %V/V	ºC	Min. 85	269.5
90 % V/V	°C	Max. 360	333.6
Flash point	°C	>55	66.0
Lubricity - MWSD	µm	Max. 460	448.0
Cetane index	-	Min. 46	51.8
Kinematic Viscosity (40 ºC)	mm^2/s	2/4.5	2.8
Neat calorific value	MJ/kg	-	42.91
Water content	mg/kg	Max. 200	50
Corrosion Cu, 3 h at 50°C	Rating	Class 1	1a

Table II. – Properties of Biodiesel fuel

Property	Unit	EN 14214 Min/Max	B100
Density at 15°C	kg/m^3	860/900	882.6
Cold filter plugging point (Seasonal specification)	°C	Max.: A= +5, B= 0 C= -5, D= -10 E= -15, F= -20	-10
Flash point	°C	Min. 120	138.5
Sulfated ash	%(m/m)	Max. 0.02	<0.02
Iodine number	g Iodine/100 g	Max. 120	112
Acidity number	mg KOH/g	Max. 0.5	0.27
Ester content	% (m/m)	Min. 96.5	97.3
Linolenic acid methyl ester	% (m/m)	Max. 12.0	6.8
Methanol	% (m/m)	Max. 0.20	<0.01
Phosphorus	mg/kg	Max. 10.0	<5
Oxidation stability, 110°C	h	Min. 6	9.8
Monoglycerides	% (m/m)	Max. 0.8	0.590
Diglycerides	% (m/m)	Max. 0.20	0.138
Triglycerides	% (m/m)	Max. 0.20	<0.050
Free glycerol	% (m/m)	Max. 0.02	0.006
Total glycerol	% (m/m)	Max. 0.25	0.176
Water content	mg/kg	Max. 500	150
Solid impurities	mg/kg	Max. 24	14
Sulphur content, WD-XRF	mg/kg	Max. 10	5.8
Kinematic viscosity at 40°C	mm^2/s	3.5/5	4.477
Carbon residue	%(m/m)	Max. 0.30	0.21
Corrosion Cu, 3 h at 50°C	classification	1	1a

Table III. - Bioethanol (C_2H_5OH) properties (ISO 9001)

Property	Unit	Specification	Result
Assay at 20ºC (Purity)	%(v/v)	>=99.8	99.9
Boiling Point	ºC	Min 78.3/Max 78.8	78.5
Density at 20°/4°	-	Min 0.790/Max 0.793	0,791
Water content	%	<= 0.2	0.04

3. Methodological process

Fuel stability test is performed in order to determine if additional mixing, additives or heating (in case low temperatures produce solid aggregation of the fuel) are necessary.

The samples were tested at: 25ºC (ambient temperature), +30ºC (representative temperature of summer), +8ºC (representative temperature of not critical winter), and -18ºC (temperature at which certainly the samples were solid). Each sample was checked once a week during a 5 week period; we estimate that this is enough time to get to know its behaviour in long periods of storage. After each week the observations about each sample were recorded according the following points:

1) *Sample stability*: 1 or 2 layers.
2) *Sample state*: liquid or solid phase.
3) *Sample color*: no changes, lighter or darker than previous observation.

4. Results and discussion

A. Bioethanol/diesel blends

Results are depicted in Table IV. Below 8ºC all bioethanol/diesel fuel blends separate in two phases. Only samples tested above 25ºC remain in one phase. It means that phase separation starts between 8 and 25ºC. To determine the exact point at which it occurs more stability test are needed.

Table IV. Fuel stability and phase separation of diesel fuel and bioethanol/diesel fuel blends during 5 weeks observation.

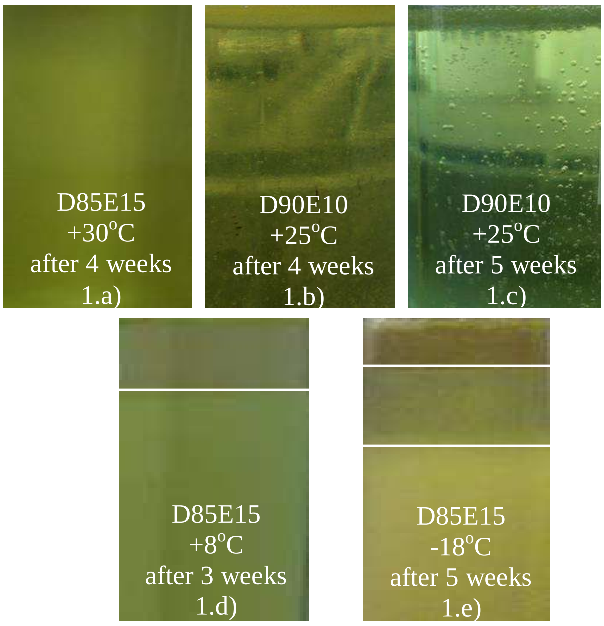
Fuel	Testing temperature (ºC) 30	25	8	-18
D100	*Stability:* *NC. 1 layer *State:* liquid *Colour:* *NC	*Stability:* *NC. 1 layer *State:* liquid *Colour:* After 2 weeks, little less clear	*Stability:* *NC. 1 layer *State:* liquid *Colour:* *NC	*Stability:* *NC. 1 layer After 5 weeks, 2 layers. *State:* After 2 weeks some solid parts in liquid fuel. *Colour:* *NC
E05D95		*Stability:* After 4 weeks, ≈ 10% of bioethanol was separated. After 5 weeks, some bubbles at the surface *State:* liquid *Colour:* *NC		*Stability:* After 5 weeks, 3 layers: bioethanol + 2 layers in diesel fuel. *State:* After 1 week, 2 phases (liquid with some solid parts) *Colour:* *NC
E10D90			*Stability:* After 2 weeks, 2 layers *State:* liquid *Colour:* *NC	
E15D85				

**NC: No changes*

To preserve stability, additives for bioethanol/diesel fuel blends are needed. Previous researches have demonstrated that the presence of water in the blends, low temperatures and high ethanol contents favor the phase separation whereas the presence of additives leads to the opposite effect [10][11]. Nowadays these kinds of additives are increasing as long as energy sources become cleaner and renewable [12]. The optimal choice of additives depends on ethanol concentration and climate where the blend will be used. So this statement justifies further studies to determine the best additives for the blends under study.

The photographs in figure 1 show some of the results recorded in table IV about bioethanol/diesel blends:

1) Photograph **1.a**: No changes in stability, colour and aggregation.
2) Photograph **1.b** and **1.c**: bioethanol separates from diesel fuel, see bioethanol bubbles travelling to the surface.
3) Photograph **1.d**: at +8 ºC bioethanol separates from diesel fuel. Two layers are observed.
4) Photograph **1.e**: at -18 ºC, 3 layers are observed in E15D85 blend (2 layers in diesel fuel).


D85E15 +30°C after 4 weeks 1.a)

D90E10 +25°C after 4 weeks 1.b)

D90E10 +25°C after 5 weeks 1.c)

D85E15 +8°C after 3 weeks 1.d)

D85E15 -18°C after 5 weeks 1.e)

Figure 1 – Stability. Bioethanol-diesel fuel blends.

B. Bioethanol/biodiesel blends

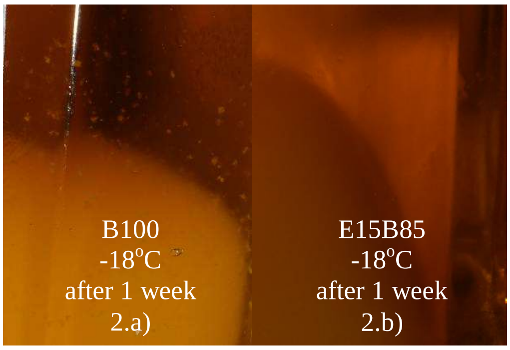
According to results shown in Table V, all bioethanol/biodiesel blends remain in one phase regardless of temperature and bioethanol concentration. Only at -18 ºC all samples are solid.

When B100 warms up and becomes liquid, some white particles can be easily seen (see 2.a). These particles are paraffins. In case of bioethanol/biodiesel blends, bioethanol changes the melting process in such a way that paraffins are different in size and shape; effectively the paraffins are not visible (see 2.b). Invisible paraffins lead to an improvement from the point of view of winter properties, such us cloud point and cold filter plugging point, because these properties are linked to the moment in which paraffins appears during the solidification process. Similar behaviour was observed during subsequent observations. Therefore, bioethanol acts as a winter additive. Bioethanol/biodiesel blends need less time to become liquid than B100.

Table V. – Biodiesel and bioethanol/biodiesel blends stability during 5 weeks observation

Fuel	Testing temperature (ºC)		
	30 25	8	-18
B100	*Stability:* *NC. 1 layer *State:* liquid *Colour:* *NC	*Stability:* *NC. 1 layer *State:* liquid. After 3 weeks, higher viscosity *Colour:* *NC	*Stability:* *NC. 1 layer *State:* After 1 week, completely solid. During melting process paraffins are visible. *Colour:* lightly intensified.
E05B95	*Stability:* *NC. 1 layer *State:* liquid *Colour:* *NC		*Stability:* *NC. 1 layer *State:* After 1 week, completely solid. During melting process paraffins are not visible. *Colour:* lightly intensified.
E10B90			
E15B85			

**NC: No changes*

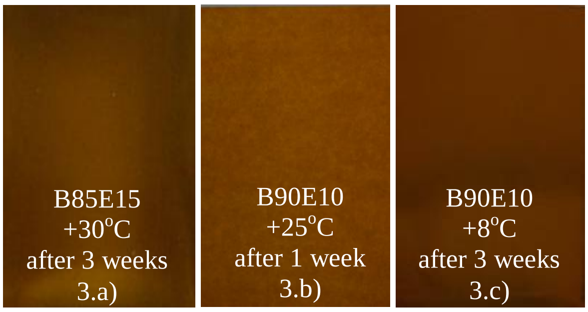

B100 -18°C after 1 week 2.a)

E15B85 -18°C after 1 week 2.b)

Figure 2. a) Paraffins in pure biodiesel during melting process. b) Paraffins are not visible in bioethanol/biodiesel blends

The photographs in figure 3 show some of the results recorded in table V about bioethanol/biodiesel blends:

1) Photographs **3.a, 3.b** and **3.c**: No changes in stability, colour and aggregation. One phase, so no problems related to stability.
2) Photograph **3.d**: all blends tested solidify at low temperatures (-18 ºC). This photograph was taken during the melting process to be able to see that the sample was solid and colour was lightly intensified.


B85E15 +30°C after 3 weeks 3.a)

B90E10 +25°C after 1 week 3.b)

B90E10 +8°C after 3 weeks 3.c)

Figure 3.a, 3.b and 3.c – Stability. Bioethanol-biodiesel blends.

Figure 3.c and 3.d – Stability. Bioethanol-biodiesel blends.

4. Conclusion

In the present work, it has been proved that additives are not necessary to ensure stability of bioethanol/biodiesel blends under low temperature conditions, as the phase separation never happens. Generally, adding bioethanol to biodiesel improves biodiesel usage, because pure biodiesel needs more time to melt down than biodiesel blended with bioethanol, and because bioethanol decreases the size of paraffins leading to an improvement in the behaviour of the fuel at low temperatures.

In case of bioethanol/diesel fuel blends it has been proved that some additives are necessary to keep stability under low temperature conditions, as the fuels separation starts between 8 and 25 ºC.

Based on this study, it can be concluded that blends of biodiesel fuel with bioethanol up to 15% can be used to fuel a diesel power plant if engine performance tests corroborate it. The same conclusion can be applied to blends of diesel fuel with bioethanol up to 15% blends if additives to keep stability are added.

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