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Evaluation of the Emission of Carbon Dioxide in the Combustion of Biofuels and Comparison with Liquid Petroleum Products

KEYWORDS: biofuels, combustion, carbon dioxide emission, liquid petroleum products

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ABSTRACT *Worldwide, biofuels are increasingly beginning to gain ground. The need to allow biofuels to enter our everyday motorized lives is dictated equally by environmental and economic considerations. The paper present a novel calculation model for carbon emissions in the combustion of biofuels and assess the rate of carbon dioxide emissions for a number of biofuels. We compare a series of several biofuels and liquid petroleum products as a function of the emission of carbon dioxide.*

INTRODUCTION

Obtaining heat by conventional methods relies mainly on chemical energy conversion fuels into thermal energy by burning. The need to provide thermal energy when renewable energy is unavailable (no wind, the sky is cloudy) or when drought leads to the use of classic power plants, where both fossil fuels and biofuels can be used. In addition, the significant increase in oil prices has led to interest in the use of other energy sources, including biofuels.

Bio-ethanol is obtained mainly from cereals and sugar cane, and is equivalent to gas. Biodiesel (ethyl stearate and methyl linoleate) is obtained predominantly from oil seeds such as rapeseed, maize, soybean and it is similar to diesel.

If the chemical formula of a fuel is known, $C_mH_nO_r$ then the mass fractions can be determined by the relations [1]:

$$g_C = \frac{12m}{12m+n+16r};\ g_H = \frac{n}{12m+n+16r};$$

$$g_O = \frac{16r}{12m+n+16r} \qquad (1)$$

In complete combustion with minimum amount of air, the oxygen for combustion is taken from the ambient air. Depending on the fuel composition the combustion results in carbon dioxide, sulfur dioxide, water vapor and nitrogen. Under these conditions, the mass of carbon dioxide, expressed in kg CO_2 / kg fuel, is calculated by the formula:

$$m_{O_2} = \frac{g_C}{12} M_{O_2} \qquad (2)$$

Fuels are characterized by the thermal power: the heat developed by complete combustion with minimum air of the unit quantity of fuel. We make the distinction between:

- superior caloric power **H_s** -when the water vapor contained in the fuel gases are discharged as liquid, and thus release in the combustion space the latent heat of condensation;
- inferior caloric power **H_s** -when the fuel gases are discharged with water as vapor in the gaseous state.

Although, of course, the superior caloric power is greater than the inferior one, for technical reasons in most cases the fuel gases are recommended to be discharged containing water vapor (since liquid water can combine with some components of the exhaust gases resulting in corrosive fluids). Therefore, for practical reasons, most often the inferior caloric power is of interest. The mathematical relationship between the superior and inferior heating value is obtained by taking into account the heat necessary for vaporization of water in the fuel gas, which for a fuel that does not contain water has the form:

$$H_i = H_S - 22510 g_H \qquad (3)$$

The caloric power of a biofuel with the chemical formula of **$C_mH_nO_r$** and which does not contain water is calculated as follows:

$$H_i = 3\ 900 g_C + 120\,120\left(g_H - \frac{g_O}{8}\right) \qquad (4)$$

Application of (3) and (4) leads to results expressed in kJ / kg; g_i are decimal fractions.

Carbon dioxide release takes place during combustion of both fossil fuels and biofuels. The coefficient of carbon dioxide emission is used to compare the effects of combustion pollutants:

$$\varepsilon_{O_2} = \frac{m_{O_2}}{H} \qquad (5)$$

Carbon dioxide emissions ε_{O_2} are expressed in g/kWh. We distinguish the following situations depending on whether the mass of carbon dioxide is reported in terms of the inferior or superior caloric power:

- $\varepsilon_{O_2,I}$, carbon dioxide emission relative to the inferior caloric power;
- $\varepsilon_{O_2,S}$ carbon dioxide emission relative to the inferior caloric power, for fuels of null humidity.

By combining (1) – (4) we propose novel relations for calculation of the emission of carbon dioxide:

- $\varepsilon_{O_2,I}$ carbon dioxide emission relative to the inferior caloric power [g CO_2 / kWh]:

$$\varepsilon_{O_2,I} = \frac{1000m}{2.568m + 0.758n - 1.517} \qquad (6)$$

- $\varepsilon_{O_2,S}$ carbon dioxide emission relative to the superior caloric power [g CO_2 /kWh];

$$\varepsilon_{O_2,S} = \frac{1000m}{2.568m + 0.901n - 1.517r} \qquad (7)$$

In these relations m, n, r are the coefficients of the chemical formula **$C_mH_nO_r$**. Relations (6) and (7) are simple and straightforward to apply.

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EXPERIMENTAL PART

Following the documentation, handling and analysis of certificates of delivery from a series of companies producing or distributing liquid petroleum products, the following characteristics shown in Table 1 were selected for calculation of the carbon dioxide emission.

TABLE - 1 CHARACTERISTICS OF LIQUID PETROLEUM PRODUCTS PETROLEUM PROPRODUCTS

Liquid petroleum product	**Relative density (the density of the liquid petroleum fuels relative to water, at 15 °C)** p 15/15
Petrol	0.72…0.775
Diesel	0.820…0.845
Liquid Petroleum Gas	0.506...0.550

RESULTS AND DISCUSSION

To assess the emission of carbon dioxide we used equations (4) and (5). We studied the following biofuels:

- ethanol, which may replace gasoline or can be used in certain proportions in combination with gasoline;
- ethyl stearate and methyl linoleate, which may substitute Diesel in whole or in part.

The obtained results are shown in Table 2.

TABLE - 2 RESULTS CALCULATION OF CARBON DIOXIDE EMISSIONS FOR COMBUSTION OF BIOFUELS

Biofuel	Ethanol	Ethyl stearate	Methyl linoleate
Chemical formula	C_2H_6O	$C_{20}H_{40}O_2$	$C_{19}H_{34}O_2$
Carbon dioxide emission coefficient, relative to the inferior caloric power, $\varepsilon_{O_2,I}$, [g CO_2 / kWh]	245	254	266
Carbon dioxide emission coefficient, relative to the superior caloric power $\varepsilon_{O_2,S}$, [g CO_2 / kWh]	222	237	249

In order to compare the rate of emission of carbon dioxide for combustion of biofuels with the case of liquid petroleum products, specific publications data [2] has been used, shown in Table 3.

Table 2 shows that, for ethanol, the carbon dioxide emission relative to the inferior caloric power is $\varepsilon_{O_2,I,Etanol}$ = 245 g CO_2 /kWh. Given the relative density values (Table 1), this coefficient has the following values (Table 3): for petrol $\varepsilon_{O_2,I,Benzina}$ = 251...262 g CO_2 /kWh; for liquefied petrol gases $\varepsilon_{O_2,I,GPL}$ = 235...243 g CO_2/kWh. Ranking these values leads to the series:

$$\varepsilon_{O_2,I,GPL} < \varepsilon_{O_2,I,Etanol} < \varepsilon_{O_2,I,Benzina} \tag{8}$$

Regarding carbon dioxide emission relative to the superior caloric power, using Tables 1 - 3 we obtain the following values: $\varepsilon_{O_2,S,Etanol}$ = 222 g CO_2 /kWh, $\varepsilon_{O_2,S,GPL}$ = 215…224 g CO_2/kWh, $\varepsilon_{O_2,S,Benzina}$ = 233…244 g CO_2/kWh

The corresponding rankings are thus obtained for

$$\varepsilon_{O_2,S} : \varepsilon_{O_2,S,GPL} \approx \varepsilon_{O_2,S,Etanol} < \varepsilon_{O_2,S,Benzina} \tag{9}$$

TABEL 3 CARBON DIOXIDE EMISSION BY COMBUSTION OF SOME LIQUEFIED PETROLEUM PRODUCTS [2]

Liquefied petroleum products	**Carbon dioxide emission relative to the inferior caloric power [g CO_2 /kWh]**	Carbon dioxide emission relative to the superior caloric power [g CO_2 /kWh]
Liquefied petroleum product,p 15/15= 0.5	235	215
Liquefied petroleum product, p 15/15 = 0.6	243	224
Liquefied petroleum product, p 15/15 = 0.7	251	233
Liquefied petroleum product, p 15/15 = 0.8	262	244
Liquefied petroleum product, p 15/15 = 0.9	274	257

For biodiesel, Table 2 shows that the carbon dioxide emission relative to the inferior caloric power are $\varepsilon_{O_2,I,Stearat\ d\ etil}$ = 254 g CO_2 /kWh and $\varepsilon_{O_2,I,Linoleat\ d\ metil}$ = 266 g CO_2 /kWh. Given the relative density values (Table 1) diesel, this coefficient has values (Table 3): $\varepsilon_{O_2,I,Motorina}$ = 262...274 g CO_2/kWh. The rankings in this case are:

$$\varepsilon_{O_2,I,Stearat\ d\ etil} < \varepsilon_{O_2,I,Linoleat\ d\ metil} \approx \varepsilon_{O_2,I,Motorina} \tag{10}$$

For the biodiesel superior caloric power $\varepsilon_{O_2,S}$ we follow a similar reasoning as in the case of inferior caloric power, thus the emissions values are obtained as $\varepsilon_{O_2,S,Stearat\ d\ etil}$ = 237 g CO_2 /kWh, $\varepsilon_{O_2,S,Linoleat\ d\ metil}$ = 249 g CO_2 /kWh, $\varepsilon_{O_2,S,Motorina}$ = 244...257 g CO_2 /kWh. The corresponding ranking is:

$$\varepsilon_{O_2,S,Stearat\ d\ etil} < \varepsilon_{O_2,S,Linoleat\ d\ metil} \approx \varepsilon_{O_2,S,Motorina} \tag{11}$$

CONCLUSIONS

Biofuels are of substantial interest in the growing worldwide energy market. Replacing fossil fuels with biofuels is a trend that is competitive with rising oil prices. Biofuels can replace some or all fossil fuels without requiring significant changes in combustion plants. Biofuel production can lead to negative aspects such as the use of agricultural land for industrial purposes and not for production of food for humans or animals, and it involves food price increases. The fuel selection grid, along with criteria such as price, distance transport, toxicity and others, could contain the emission of carbon dioxide. To assess the emission of carbon dioxide, the original relationships calculation presented in this paper are simple, easy to apply and provide a quick way to assess this important characteristic in evaluating the effects of combustion pollutants. Use of biofuels does not mean lack of carbon dioxide emissions. The comparative analysis used data from "in situ" samples. When comparing fuels, the results lead to the conclusion that biofuels combustion have an emission coefficient of carbon dioxide which is less than or equal to that in the case of liquid petroleum products.

Nomenclature:

g_i - mass fraction of component *i* in the mixture [kg component *i*/kg fuel];

H - caloric power, [kJ /kg];

M - molar mass, [kg/kmol];

m – coefficient;

m_{O_2} - Carbon dioxide mass, [kg CO2 / kg fuel];

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n – coefficient;

r – coefficient;

ε_{CO_2} - Carbon dioxide emissions, [g/kWh];

ρ_{15}^{15} - Relative density (the density of the liquid petroleum fuels relative to the water, at 15 ^{0} C)

Subscript:
C – Carbon;

CO_2 – Carbon dioxide;

H – Hydrogen;

I, I – Inferior;

O – Oxygen;

S, s – superior;

w- Water

REFERENCE 1. Tudora Cristescu, Termotehnica, Editura Universităţii din Ploieşti, 2009. | 2. Cristescu, T. Liquefied Natural Gases and Liquefied Petroleum Gases as Complementary Sources of Energy, November 3-4, 2011, Bucharest, 5th International Conference on Energy and Environment |