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DETERMINATION OF RAPESEED OILS COMBUSTION HEAT IN CALORIMETER BOMB AND AN ASSESMENT OF THE HEAT VALUE

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Summary. Purpose of research was to determine energy values (combustion heat and heat value) of rapeseed oil. Furthermore, taking into account oil energy value, energy value of oil that can be obtained from 1 hectare of rapeseed culture was established. For fourteen tested varieties, combustion heat was in the range between 37,8 and 40,1 MJ/kg and heat value between 35,4 and 37,7 MJ/kg. Maximum difference of oil energy values calculated in mass units was 6% and in voluminal units 7%. Culture site has a little bit lesser influence on oil energy value and for Lisek variety the difference was less than 5%. Energy value of oil that can be obtained from a cultivation area was in the range between (combustion heat – 62,9 and fuel value – 59,1 GJ/ha) and (combustion heat – 45,3 and fuel value – 42,5 GJ/ha). This indicates that the difference in rapeseed biofuel energy value, obtained from a cultivation area can be even 48%.

Key words: rapeseed oil, combustion heat, fuel value, biofuel

INTRODUCTION

Nowadays a lot of attention is paid to biofuels that can be substitutes for conventional fuels. In November 2001 the European Committee introduced the instruction that implies gradual increase in the use of alternative fuels, whose share in the total amount of fuels should reach 20% by the year 2020. In 2000 this share was only 0,37%. This indicates how dynamically the biofuels sphere is going to develop. For self-ignition engines (diesel) such fuel can become rapeseed oil Methyl Esters – biodiesel type FAME. These fuels are based on rapeseed oil. Oil made of different rapeseed varieties can have different physical and chemical parameters. One of such parameters can be energy value, more precisely combustion heat and heat value. As it was demonstrated by the tests carried out in 2003 by the author of this report, the difference in those parameters can even reach 11% [Szlachta 2002].

AIM AND SCOPE OF RESEARCH

The purpose of research was to determine by calorimetric method the combustion heat and then to calculate rapeseed oils heat value. On the basis of the established fuel value, yield and oil output from rapeseeds, energy value of oil, which may be obtained from 1ha of rapeseed cropped area, was determined.

METHODS

Determining oil combustion heat is the basis for calculating its fuel value. Both combustion heat and the fuel value were identified on the basis of the current Polish Standard PN-86/C-04062. According to the standard, the combustion heat is determined in a calorimeter where fuel sample is burnt in a calometric bomb. The experiments were conducted in KL-5 calorimeter, made in Poland by Precyzja Bit company. A schematic diagram of the calorimeter was shown in Fig. 1. According to the Polish Standard PN-86/C-04062 the mass of burned fuel measured with an accuracy of 0.0002 g should fall into the 0.6 and 0.8 g range. In the experiment samples with c.a. 0.7 g mass were measured to an accuracy mentioned above. The sample was burned in a calorimetric bomb at 6 pure oxygen pressure (> 99%O_2) equal to 3 MPa . The sample was ignited by kanthal resistance wire.

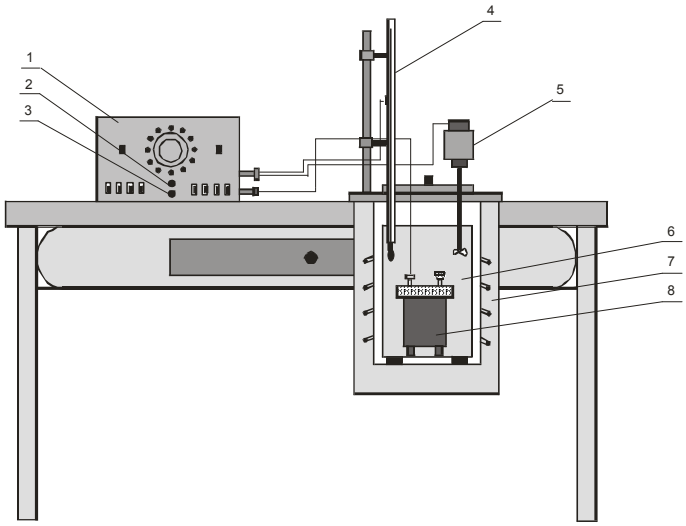

Fig. 1. Calorimeter schematic diagram: 1 – control device; 2 – electrical switch; 3 – sample ignition; 4 – thermometer; 5 – mixer; 6 – calorimeter; 7 – calorimeter water jacket; 8 – calorimetric bomb

DETERMINATION OF COMBUSTION HEAT

Considering calorimeter thermal value, combustion heat is calculated on the basis of an increase in temperature of adequate water volume in calorimeter (calorimeter ves-

sel). Constant water volume is a result of determining calorific capacity of the calorimeter. For the calorimeter used in the experiment, the water volume in the calorimeter vessel was 2.7 dm^3 . The determined combustion heat in a calorimeter is reduced by the combustion heat of the resistance wire which initiates fuel ignition.

CALCULATIONS

The total thermal effect of the burned samples of rapeseed oil were determined on the basis of formula 1.

$$Q_b = \frac{C_k \cdot \Delta t - Q_2 m_2}{m_o} \tag{1}$$

where:

C_k – calorific capacity of calorimeter – 12.908 kJ/^{o}C;
Δt – corrected increase in temperature during combustion (formula 2);
Q_2 – combustion heat of ignition wire (kanthal) – 6 704 kJ/kg;
m_o – mass of tested fuel sample, kg;
m_2 – mass of ignition wire – 0.000007 kg;

$$\Delta t = [(t_n + h_n) - (t_o + h_o)] + a + b \tag{2}$$

where:

t_o – initial temperature of main combustion period (of sample combustion), ^{o}C;
t_n – finish temperature of main period (of sample combustion), ^{o}C;
h_o and h_n – corrections for thermometer calibration at temperatures t_o and t_n;
a – correction for calorimeter heat exchange, ^{o}C;
b – correction for protruding mercury column ^{o}C;

Combustion heat of rapeseed oil samples was determined on the basis of formula 3

$$Q_s^a = \frac{C_k \ \Delta t - Q_2 m_2}{m_o} + \Delta Q_s \tag{3}$$

where:

ΔQ_s – correction for converting fuel combustion heat (acc. to PN-86/C-4062 for diesel oil it is 59 kJ/kg and for heating oil 50 kJ/kg). In calculations for rapeseed oil value of ΔQ_s = 50 kJ/kg was assumed.

The value of rapeseed fuel was computed on the basis of formula 4

$$Q_i^a = Q_s^a - 24{,}42\,(8{,}94 \cdot H - W) \tag{4}$$

where:

H – hydrogen content in the tested fuel %, m/m;
W – water content in the tested fuel %, m/m;

RESULTS

The presented results are approximated values, based on three different measurements. The maximum range of the determined values of combustion heat and heat value did not exceed 2% which indicates that the results are highly repeatable. This error tolerance is admissible according to the applied method and according to the norm PN-86/C-04062.

Table 1 shows the obtained quantities of combustion heat and heat value of oils stamped from fourteen rapeseed varieties harvested in Wielkopolska.

Table 1. Influence of rapeseed variety on combustion heat and heat value of rapeseed oils

Rapeseed cultivar	Combustion heat MJ/kg	Fuel value MJ/kg	Combustion heat MJ/dm^3	Fuel value MJ/dm^3
KASZUB	39.4	37.0	34.7	32.5
MAZUR	39.2	36.8	34.9	32.7
POMORZANIN	40.1	37.7	35.7	33.5
AMOR	38.6	36.2	34.7	32.6
BAZYL	38.3	35.9	34.5	32.3
CAZEK	38.8	36.4	34.1	31.9
CALIFORNIUM	39.0	36.6	34.7	32.5
KANA	39.0	36.6	34.3	32.1
LIBOMIR	38.7	36.3	34.4	32.2
LICLASSIC	39.4	37.0	35.5	33.3
LIRAJET	39.1	36.7	35.2	33.0
LISEK	38.6	36.2	34.4	32.2
RAFAELA	38.5	36.1	34.6	32.4
RASMUS	37.8	35.4	34.0	31.8

As it can be seen from Table 1 combustion heat and heat value of oil presented in mass units had the biggest values for rapeseed variety Pomorzanin, respectively 40.1 MJ/kg and 37.7 MJ/kg. Approximate values of the energy parameters were obtained for the following cultivars: Liclasic – 39.4 and 37.0 MJ/kg, Kaszub – 39.4 and 37.0 MJ/kg, Mazur – 39.2 and 36.8 MJ/kg. The lowest combustion heat value and fuel value were obtained for Rasmus rape – 37.8 and 35.4 MJ/kg. These comparisons indicate that the difference in energy values between the most favorable variety and the least favorable one is 6%. Table 1 also shows that oil energy values presented in volume units have, in general, higher values, which results from oil density (oil density in the temperature of 15^{o}C is between 0.88 and 0.9 kg/dm^3). For other rapeseed varieties combustion heat value was between 38.3 and 39 MJ/kg, and heat value was between 35.9 and 36.6 MJ/kg. The lowest energy values were found in variety Lirajet. The comparisons indicate that the difference in energy values presented in MJ/dm^3 between the best and the worst variety is over 7%.

Table 2 presents research results concerning the influence of rape culture conditions on energy parameters of oil. Tests were carried out on Lisek variety, cultivated in several places. Rapes were grown with different cultivation technology standards.

Table 2. Combustion heat and heat value of rapeseed oils obtained from Lisek variety

Rapeseed cultivar – LISEK				
Cultivation site (province, site)	Combustion heat MJ/kg	Fuel value MJ/kg	Combustion heat MJ/dm^3	Fuel value MJ/dm^3
wielkopolskie, Kruszewnia	38.6	36.2	34.3	32.2
śląskie, Dankowice	37.9	35.5	34.1	32.0
dolnośląskie, Ząbkowice Śląskie	38.5	36.1	34.6	32.5
małopolskie, Węgrzce	39.7	37.3	35.7	33.6
Małopolskie, Zagórze	39.0	36.4	34.7	32.4

Table 2 shows that the difference in energy values of oils calculated in mass unit is about 1.8 MJ/kg . This indicates that energy value of the oil obtained from Lisek variety cultivated in Węgrzce site in Małopolska is almost 5% higher than the respective value of the oil obtained from rapeseed cultivated in Dankowice, Śląsk province. The difference in energy values of oils calculated in volume units was about 2 MJ/dm^3 . As it was expected, the values were higher, but the difference of these values was identical as the difference calculated in mass units and was 5%. As the research shows, the heat value of rapeseed oil is in the range from 36.1 to 37.3 MJ/kg. Whereas according to the norm obligatory in Poland, the heat value of diesel oil should be in the range from 42 to 44 MJ/kg . This shows that the heat value of rapeseed oil is about 15% lower than diesel oil.

DETERMINING THE COMBUSTION HEAT AND FUEL VALUE OF OIL THAT CAN BE OBTAINED FROM 1 HA OF CULTIVATION

The basis for determining energy values of rapeseed oil calculated for 1 hectare of cultivation were exact numbers of combustion heat and fuel value. Additionally, the amounts of oil pressed from a mass or volume unit and the number of crops were taken into account. Table 3 and 4 present the research results on determining the energy values of oil that can be obtained from 1 hectare of rape culture.

As table 3 indicates, the highest combustion heat – 62.9 GJ/ha and the highest heat watt – 59.1 GJ/ha are found in oil obtained from 1 hectare of rape culture Pomorzanin. Similar energy value counted for 1 hectare of culture was obtained for variety Californium – respectively 62.1 and 58.3 GJ/ha. More than 55 GJ/ha fuel value was found in oil obtained from the plantation of varieties: Amor, Kaszub, Liclassic, Kana, Libomir and Lisek. It is worth noticing that for other varieties the heat value of oil is higher than 42 GJ/ha .

Table 3. Influence of varieties on energy values of oil that can be obtained from 1 hectare of rape culture

Rapeseed cultivar	Combustion heat MJ/kg	Fuel value MJ/kg	Oil mass kg/ha	Combustion heat GJ/ha	Fuel value GJ/ha
KASZUB	39.4	37.0	1547	60.1	57.2
MAZUR	39.2	36.8	1400	54.9	51.2
POMORZA-			1568		59.1
NIN	40.1	37.7		62.9	
AMOR	38.6	36.2	1585	61.2	57.4
BAZYL	38.3	35.9	1333	51.0	47.8
CAZEK	38.8	36.4	1454	56.4	52.9
CALIFOR-			1592		58.3
NIUM	39.0	36.6		62.1	
KANA	39.0	36.6	1559	60.1	57.1
LIBOMIR	38.7	36.3	1552	60.0	56.4
LICLASSIC	39.4	37.0	1553	61.2	57.5
LIRAJET	39.1	36.7	1158	45.3	42.5
LISEK	38.6	36.2	1530	59.1	55.4
RAFAELA	38.5	36.1	1390	53.5	50.2
RASMUS	37.8	35.4	1478	55.9	52.3

Table 4. Influence of rapeseed variety Lisek culture site on energy values of oil that can be obtained from 1 hectare of rape culture

Rapeseed cultivar – LISEK					
Cultivation site (province, site)	Combustion heat MJ/kg	Fuel value MJ/kg	Oil mass kg/ha	Combus-tion heat GJ/ha	Fuel value GJ/ha
Wielkopolskie, Kruszewnia	38.6	36.2	1530	59.1	55.4
Śląskie, Dankowice	37.9	35.5	712	27.0	25.3
Dolnośląskie, Ząbkowice Śląskie	38.5	36.1	1357	52.2	50.0
Małopolskie, Węgrzce	39.7	37.3	1075	42.7	40.1
Małopolskie, Zagórze	39.0	36.6	1250	48.7	45.7

As table 4 indicates the difference of energy values of oil obtained from a cultivation area is very big – about 25 GJ/ha. This causes the fact that we can obtain 100% more energy from oil obtained from the rapeseed cultivated in Węgrzce site than from oil obtained from the rapeseed cultivated in Zagórze site. Such a big difference of energy values of oil between plantations is a result of big difference of harvest and quantity of the obtained rapeseed oil.

CONCLUSIONS

1. The highest combustion heat – 40.1 MJ/kg and heat value – 37.7 MJ/kg was found in the rapeseed variety Pomorzanin. The lowest values, respectively 37.8 MJ/kg and 35.4 MJ/kg was found in the rapeseed variety Rasmus.
2. The maximum difference of oil energy values calculated in mass units was 6% and in volume units 7%.
3. Culture site has a little bit lesser influence on oil energy value and for Lisek variety the difference was less than 5%.
4. In conversion to 1ha of cropped area, the highest oil energy value (combustion heat – 62.9 and fuel value – 59.1 GJ/ha) was obtained from Polish Pomorzanin hybrid variety, while the lowest one, only (combustion heat – 45.3 and fuel value – 42.5 GJ/ha) from the population of Lirajet variety. The data show that a difference in energy value of rapeseed fuel obtained per crop may reach even 48%.
5. For Lisek variety cultivated in different places energy value of oil that can be obtained from a cultivation area depends on the quantity of oil, as its energy value is similar.

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