

THE INFLUENCE OF THE HEATING VALUE OF COALS FROM COAL MINE „GRAČANICA“ d.o.o. GORNJI VAKUF ON QUALITY OF COAL AS ENERGYSOURCE IN ENERGY PRODUCTION

Azra Halilović, Šefkija Botonjić, Amila Krnjić, Lamija Sušić
University of Zenica, Faculty of metallurgy and Technology
Zenica, B&H

Keywords: coal, energy, heating value, chemical composition of coal, ash, moisture

ABSTRACT

Coal is the most important and widespread fuel sedimentary rock of organic origin. It is one of the main energy sources today and an industrial raw material for various products. Together with the oil and other natural bitumens, it belongs to the group of fossil fuels or caustobiolite.

Combustion represents one of the fundamental energy transformations by which the primary forms of energy, which are carriers of chemical energy, are transformed into thermal energy. In order to carry out the energy calculation of any process in which the conversion of fuel that is the carrier of chemical energy occurs, it is necessary to know the heating value of that fuel. The heating value of a fuel is directly related to or proportional to its efficiency. The basis for economic (price), environmental (emissions), and technical (energy) comparison of two or more energy sources is the heating value, which differs from energy source to energy source. The heating value of coal varies significantly depending on the ash content, moisture content, and the type of coal, that is, the chemical composition of the coal.

The aim of this work was to examine the influence of the heating value of coal on the quality of coal as an energy source in energy production in the Gračanica Coal Mine, Gornji Vakuf.

1. INTRODUCTION

In addition to being a fuel in industry and households, coal is widely used mainly in iron and steel metallurgy, the chemical industry, and the cement industry [1]. Coal is a black or black-brown sedimentary rock of organic origin that has the ability to burn, and is used as a fossil fuel that is extracted from the ground by mining methods. Natural or fossil coal mined from its natural deposit consists of an organic-combustible part and a mineral-non-combustible part. Coal is a heterogeneous substance composed of organic (85-95 %) and inorganic materials (5-15%) [2]. The basic elements of solid fuel are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S), whereby they form organic or coal mass, of which carbon and hydrogen are of greatest importance during combustion because they release the greatest amount of heat. The non-combustible part is designated as ballast or ballast substance. Ballast refers to mineral substances that appear as a residue during combustion - ash and part of the total moisture, which is called total moisture that leaves the coal during ordinary drying of coal in the air [3,4]. The quality of coal depends on the ratio of fuel, water, and ash. The ash content depends on the coal type. The coal usability limit value is 35% of ash in regard to coal substance [3,5]. Each of these ingredients has its own special influence on the type of coal and can have different meanings, depending on the further application of the coal. The heating value of coal is the amount of potential energy in coal that can be converted into actual heat energy, i.e. the amount of heat that is developed during the complete combustion of a fuel unit (with complete combustion, the final products of combustion are formed: CO₂, H₂O, SO₂ and

the maximum amount of heat produced) is called heating value or combustion fuel heat or calorific value [3]. The calorific value depends on the geographical age, formation, ranking, and location of the coal mine. The higher heating value leads to higher coal costs, but this is offset by lower logistics, storage, and ash disposal costs. The heating value is a complex function of the elemental composition of coal and can be determined experimentally using a calorimeter. From the beginning of calorimetry to the present day many calorimetric methods with specialized purposes and high sensitivity have been developed [6]. This is the most important parameter that determines the economy of thermal power plant operation [7].

2. EXPERIMENTAL PART

The research was carried out in the „Gračanica“ d.o.o. coal mine, Gornji Vakuf. The total number of examined samples is 115.

2.1. Material and methods

The experimental part of this work consisted of the following steps:

1. For all analyzes performed on coal, it is necessary to first determine and remove coarse moisture from the delivered coal. One kg of delivered coal is weighed, placed in a tin tray, and air-dried at a room temperature of 25 °C (it takes 24-48 hours). After drying, weighing is done again and the coarse moisture content is calculated from the difference in weight.

$$C_M = \frac{(m_1 - m_2) \cdot 100}{1000} = \frac{(m_1 - m_2)}{10} \quad (1)$$

C_M – coarse moisture content %,

m_1 – a mass of the container with coal before drying [g],

m_2 – a mass of the container with coal after drying [g].

2. An IKA C5001 type calorimeter operating in adiabatic mode was used to determine the heating value of coal using a calorimeter. The calorimeter consists of a combustion chamber, a container, a mixer, water, a temperature sensor, and wires with connectors necessary for igniting the fuel or wires for the thermometer. It is necessary to weigh up to 1 g of the sample, from which the coarse moisture has been removed, into a pot that is attached to the bomb cover of the calorimeter. A nickel-chromium wire, 4 to 5 cm long, is placed on the electrodes in the designated place. Then the pot with the sample is placed, and the sample is connected to the wire using a cotton thread. This thread ensures that the sample comes into contact with the ignition current, and it is necessary to tie it around a nickel-chromium wire and immerse it in the coal in a pot. Add 3-5 cm³ of distilled water to the bomb. The bomb is then closed and ready for measurement. The bomb thus closed is placed in a calorimeter vessel into which water is added. The bomb is filled with oxygen from a bottle under a pressure of 30 bar. When the temperature in the calorimetric system is stabilized, the sample is burned. In 10-15 minutes, the temperature stabilizes, which ends the test. This test determines the temperatures before and after the combustion of the sample. With these data and knowing the heat capacity of the calorimeter, the higher heating value of coal is determined. The higher heating value of coal is determined on the basis of practically obtained data according to the expression:

$$K_H = [(\Delta t \cdot H_o) - 383 - 515] \cdot f \quad (2)$$

K_H – higher heating value[kJ/kg],
 H_0 – water value of the calorimeter = 10846 kJ/kg,
 Δt – temperature difference of the calorimeter system [°C],
 383, 515 – corrections for wire and thread,
 f – factor which is calculated as follows:

$$f = \frac{100 - C_M}{100} \quad (3)$$

C_M – coarse moisture content.

The lower heating value is calculated according to the expression:

$$K_L = K_H - (23 \cdot T_M) \quad (4)$$

K_L – lower heating value[kJ/kg],

T_M – total moisture content, which is determined by calculation and represents the sum of coarse and hygroscopic moisture, i.e.:

$$T_M = C_M + H_M \quad (5)$$

T_M –total moisture content %.

3. Determining the share of hygroscopic moisture in coal is done by weighing one gram of air-dried coal in a measured glass vessel with a lid and drying it in a dryer at 105°C. Drying is done to a constant mass (on average 90 min). After drying, the measured container is removed from the dryer and placed in the desiccator to cool. The vessel is weighed again on an analytical scale and the hydroscopic moisture content is calculated from the difference:

$$H_M = f \cdot [(m_1 - m_2) \cdot 100] \quad (6)$$

H_M – hygroscopic moisture content %,

m_1 –a mass of vessel, lid, and sample before drying [g],

m_2 – a mass of vessel, lid, and sample after drying [g].

4. Determination of the ash content in coal is done by weighing one gram of air-dried coal on an analytical balance and placing it in a ceramic pot. It is heated in an electric furnace at a temperature of 815°C to a constant mass (3 h). After annealing, the pot is placed in a desiccator to cool, then weighed again and the ash content in the laboratory sample is calculated from the difference:

$$A = f \cdot [100 - (m_1 - m_2) \cdot 100] \quad (7)$$

A – ash content %,

m_1 – a mass of the pot and the sample before annealing [g],

m_2 – a mass of the pot and the sample after annealing [g],

f – factor that is calculated as described while calculating higher heating value.

5. The content of combustible substances in coal is determined by calculation based on the content of total moisture and the previously determined proportion of ash. The share of combustible materials expressed in % (CM) is determined according to the expression:

$$C_M = 100 - A - T_M \quad (8)$$

3. RESULTS AND DISCUSSION

The results of the examination of the lower heating value of coal in the period from April to September are shown in Table 1 and Figure 1. The overall average result is 10591 MJ/t, which confirms the fact that lignite is mined in the mine.

Table 1. Results of the lower heating value in the examined coal samples

Lower heating value [MJ/t]	Minimum	Maximum	Average
Examination I	9775	10860	10318
Examination II	9649	10933	10291
Examination III	10192	10964	10578
Examination IV	9532	10488	10010
Examination V	9567	11440	10504
Examination VI	10513	11346	10930
Examination VII	10047	11301	10674
Examination VIII	9733	11602	10668
Examination IX	9337	11202	10270
Examination X	9312	11749	10531
Examination XI	10175	11943	11059
Examination XII	10506	12023	11265

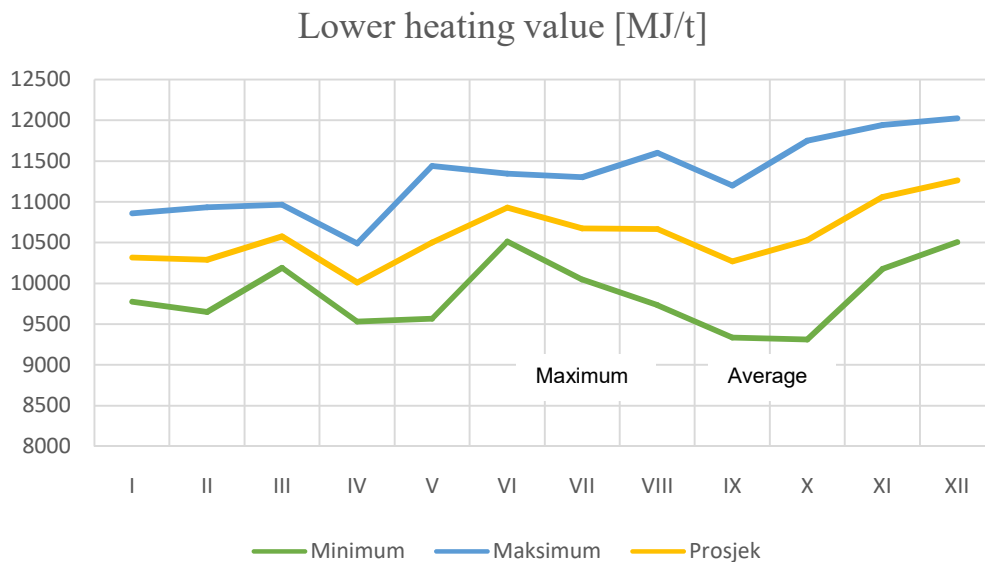


Figure 1. Results of the minimum, maximum, and average lower heating value in examining coal samples

In Figure 1, which shows the results of an examination of the lower heating values in the given period, it can be concluded that the lower heating value of coal is uneven. In the period from April (examinations I and II), the value of the lower heating value is fairly uniform, while from May (examinations III and IV) to June (examinations V and VI), the lower heating value of coal fluctuated significantly, so that the first notice is the increase in its value, then a decrease and finally an increase in value again. In the period from the month of July (examinations VII and VIII) to the month of August (examinations IX and X), the lower heating value drops significantly and has the lowest values. In the month of September (examination XI and XII), the value of the lower heating is constantly increasing and in this period the highest values of the lower heating value were measured.

In Table 2 and Figure 2 is shown the influence of the value of the content of combustible materials on the value of the lower heating value of coal.

Table 2. The average values of the lower heating value and the content of combustible substances in the examined coal samples

Examination	Lower heating value [MJ/t]	Content of combustible substances [%]
Examination I	10318	44.43
Examination II	10291	43.95
Examination III	10578	44.98
Examination IV	10010	43.81
Examination V	10504	46.41
Examination VI	10930	46.87
Examination VII	10674	46.69
Examination VIII	10668	46.01
Examination IX	10270	43.21
Examination X	10531	44.45
Examination XI	11059	47.29
Examination XII	11265	48.00

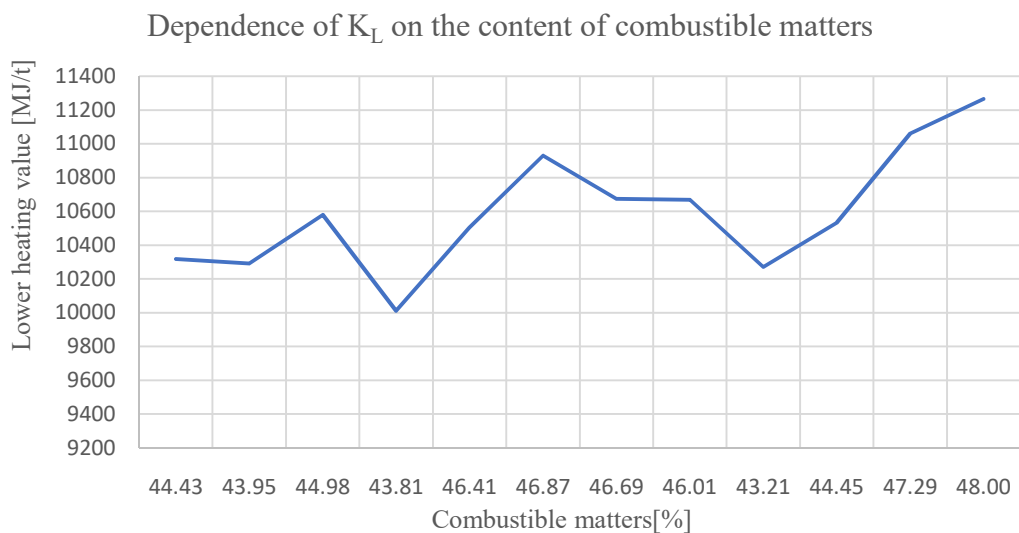


Figure 2. Dependence of the lower heating value of coal on the content of combustible substances

On the basis of the presented Figure 2, it can be concluded that the increase in the lower heating value of coal is proportional to the increase in the content of combustible substances (almost exclusively composed of carbon and free hydrogen) in it. The highest values of the content of combustible materials were measured in the month of September (examination XI and XII), and the highest values of the lower heating value of coal were also observed in that period of the examination.

The results of the examination of the content of coarse, hydro, and total moisture in coals in the period from April to September are shown in Table 3 and Figure 3.

Table 3. The content of coarse, hygro and total moisture in the examined coal samples

	Coarse moisture content [%]			Hygro moisture content [%]			Total moisture content [%]		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Examination I	32.15	33.72	32.94	2.86	3.73	3.30	35.41	37.05	36.23
Examination II	32.09	32.99	32.54	3.18	3.86	3.52	35.30	36.21	35.76
Examination III	31.68	33.48	32.58	3.27	3.60	3.44	35.26	36.86	36.06
Examination IV	29.41	32.69	31.05	2.98	3.40	3.19	32.81	35.97	34.39
Examination V	31.44	32.78	32.11	2.85	3.89	3.37	34.93	36.54	35.74
Examination VI	30.83	32.17	31.50	3.46	4.64	4.05	34.97	35.79	35.38
Examination VII	29.33	31.95	30.64	3.05	4.81	3.93	33.41	35.67	34.54
Examination VIII	29.40	32.80	31.10	3.64	4.70	4.17	33.45	36.51	34.98
Examination IX	28.19	31.82	30.01	3.16	4.70	3.93	31.35	35.47	33.41
Examination X	29.55	32.42	30.99	3.25	5.02	4.14	33.50	37.04	35.27
Examination XI	29.02	32.41	30.72	3.52	5.19	4.36	32.76	36.42	34.59
Examination XII	29.41	32.95	31.18	2.80	5.55	4.18	34.39	37.18	35.79

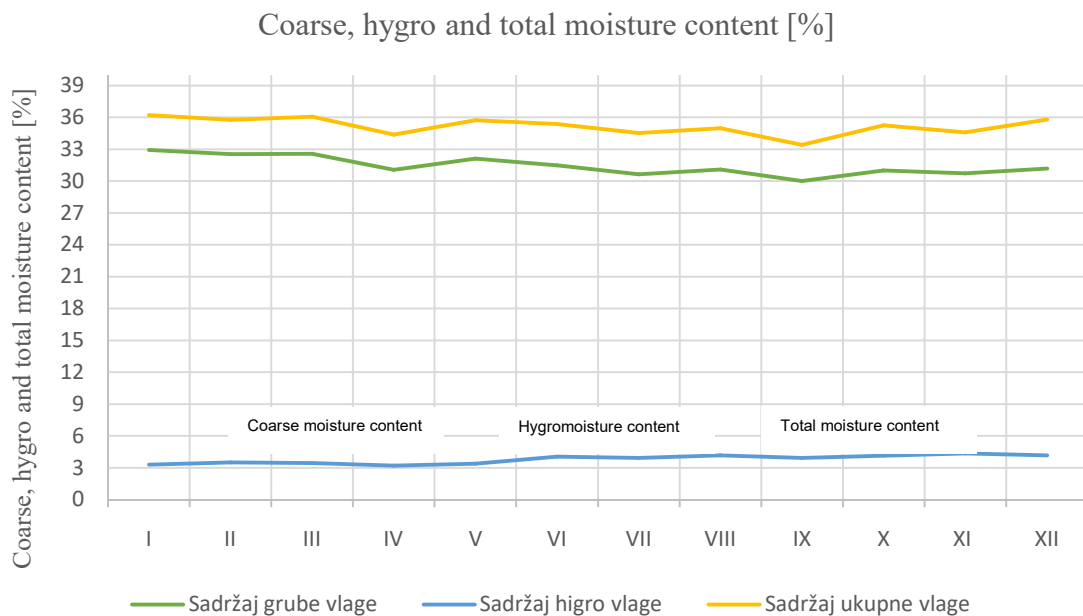


Figure 3. Average values of coarse, hydro, and total moisture content in the examined coal samples

In Figure 3, which shows the content of coarse, hydro, and total moisture in coal, it can be concluded that their content in coal is variable in the period from April to September. The largest drop in course moisture content was recorded in the month of August (examination IX), while the highest values were recorded in the month of April (examinations I and II), which may be caused by more abundant precipitation in that period. The largest drop in hydromoisure content was recorded in the month of May (examination IV), while the highest values were recorded in the month of September (examination XI and XII). The largest drop in total moisture content was recorded in the month of August (examination IX), while the highest values were recorded in the month of April (examination I) and the month of May (examination III).

Table 4 and Figure 4 show the influence of the ash content on the value of the lower heating value of coal.

Table 4. The average values of lower heating value and ash content in the examined coal samples

Examination	Lower heating value [MJ/t]	Ash content [%]
Examinations I and II	10304	19.70
Examinations III and IV	10294	20.27
Examinations V and VI	10717	17.93
Examinations VII and VIII	10671	19.57
Examinations IX and X	10400	22.81
Examinations XI and XII	11162	17.07

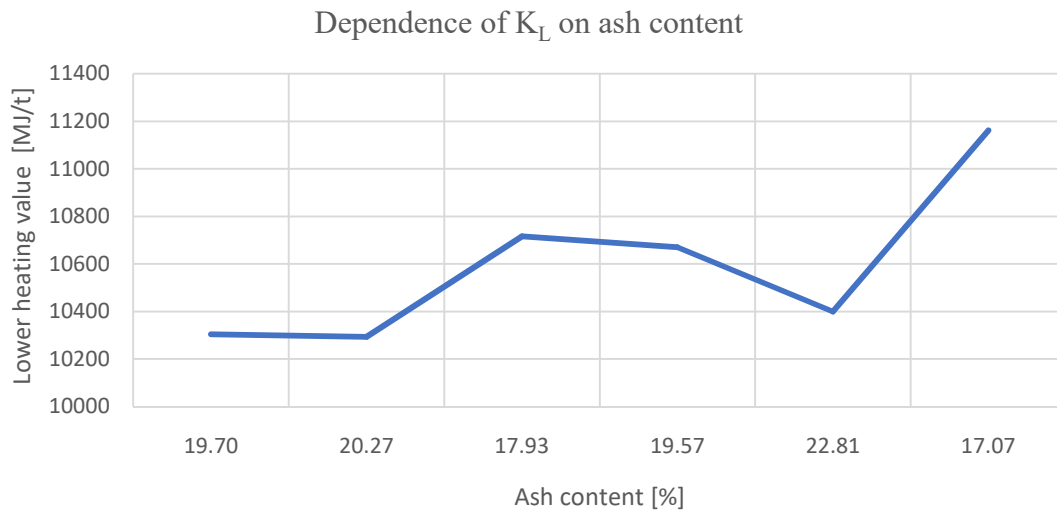


Figure 4. Dependence of K_L on ash content

On the basis of Figure 4, it can be concluded that increasing the ash content in coal decreases the value of the lower heating value of coal and vice versa. The lowest values of the ash content were measured in the month of September (examinations XI and XII), and in addition, the highest values of the lower heating value of coal were observed in that period of the examination.

4. CONCLUSION

In the experimental part of this work, the basic parameters of coal were examined, with a focus on thermal heating value, which affects the quality of coal as an energy source. The basic parameters of coal quality are lower heating value, combustible material content, ash content, and coarse, hygroscopic, and total moisture content. The lower heating values of coal are within the reference values for lignite, which confirms the fact that lignite is mined in the mine and can be used on certain occasions as an energy source in thermal power plants when there is a need for that. An increase in the content of combustible materials leads to an increase in the lower heat capacity of coal and vice versa. An increase in the ash content leads to a decrease in the lower heating value of coal and vice versa, i.e. an increase in the content of combustible substances leads to a decrease in the ash content in the coal. The higher the heating value of coal means the smaller the required amount of coal per unit of electricity. If one wants to achieve greater efficiency of coal as an energy source, it is necessary to use coals with higher heating value. A higher calorific value of coal can be achieved by some of the coal beneficiation processes by removing ballast such as mineral components and moisture, yielding a residue that is richer in combustible components.

5. REFERENCES

- [1] Višković A., Softić B., Živković S. A.: Ugljen: sigurna energija, Graphis, Zagreb, 2011.
- [2] Muhamedagić S., Mahmutović A.: Metalurški koks – proizvodnja i primjena, Zenica 2012.,
- [3] Duraković J.: Goriva i sagorijevanje, Univerzitet u Zenici, Fakultet za metalurgiju i materijale, Zenica, 2017.
- [4] Sadadinović J.: Organska tehnologija, knjiga 1 – Hemijska industrija, Univerzitet u Tuzli, Tehnološki fakultet, Tuzla, 1999.
- [5] Tehnička enciklopedija; Jugoslavenski leksikografski zavod, Zagreb, 1963-.
- [6] Horvat G.: Reakcijska kalorimetrija, Stručni rad, Sveučilište u Zagrebu, Prirodoslovno-matematički fakultet, Zagreb, 2014.
- [7] Šilić Đ., Stojković V., Mikulić D.: Goriva i maziva, Veleučilište Velika Gorica, Velika Gorica, 2012.