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STUDY THE QUALITY OF DIFFERENT TYPES OF PELLETS BY THEIR SPECIFIC CALORIFIC VALUE

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Abstract

The pellets are environmentally friendly bio fuels and have a lot of advantages over conventional firewood or biomass for heating. The European EN 14961-2 standard defining the requirements for pellets has been in force since 2010. Many pellet manufacturers certify their production according to the German standard DIN 51731 or according to the Austrian standard ÖNORM M 7135. All pellet labels state that they are manufactured according to EN 14961-2 standard. But does the inscription on the pellet packaging correspond to reality because the regulation does not require providing data about the specific calorific value on the pellet label. The calorific value of the pellets is one of the most important parameters from the customer's perspective. The aim of this paper is to define the quality of various types of wood and agro pellets as well as of one type of biomass, produced from rose stems by directly measuring of their combustion characteristics and to compare them. The measurements were made under laboratory conditions using a KL-11 calorimeter.

Key words*: biomass, calorific value, calorimeter, pellets.*

INTRODUCTION

A global warming becomes too serious problem recently. Because of the need for urgent actions to combat climate change, the European Council supports the goal of achieving the climate-neutral EU by 2050, in line with the Paris Agreement. However, achieving climate neutrality will require overcoming serious challenges and considerable investments. The European Council recognizes the need to ensure energy security and respects the right of Member States to choose the most appropriate energy technologies (European Council meeting, 2019).

In this regard the renewable energy production from waste is a promising technology, because the large quantities of waste biomass are generated every day from the agriculture and processing industry. The use of biomass for the production of heat may contribute positively to reduce environmental pollution and to cope with environmental problems. This could be a solution for the utilization of this types of waste and contribute to the generation of energy from alternative technologies in countries whose economy is based on agriculture and could encourage economic development (Manrique et al., 2019).

The most important characteristic of biomass used for energy production is its calorific value. Many scientists have examined energetic characteristics of different types of residues - such as biomass fuels (Acar & Ayanoglu, 2012), cashew shell, coconut pith, rice husk and combinations of them (Nakkeeran et al., 2019), winter wheat, maize, sunflower by-products, sweet sorghum and some bio-energy by-products (Jóvér et al., 2018), cardboard, paper, plastics, sewage treatment plants, charcoal (Bouabid et al., 2013), empty cones of pine, spruce, larch as well as husks and stems of silver fir (Aniszewska & Gendek, 2014) and lingo-celluloses materials (Demirbas & Demirbas, 2004).

The measurement of gross calorific values in a bomb calorimeter is especially important for the solid bio-fuels since their chemical and physical composition is usually quite different (Toscano & Pedretti, 2009).

The pellets are environmentally friendly bio fuels and have a lot of advantages over conventional firewood or biomass for heating. The heat of combustion of one kilogram of high-quality pellets is usually from 4.6 to 5.1 kWh.

Pellets are a product that is formed by dry compression of biomass under mechanical pressure (Figure 1) and are intended to fuel heating installations with automation systems for the combustion process. The pellets are produced from waste wood biomass from coniferous and deciduous trees. Biomass for pellets production could also be obtained from residues of agricultural products, such as straw, sunflower stems, cakes and peels, peanut peels, etc. (Mitkov et al., 2016). Today, around 8-10 million tonnes of pellets are produced worldwide. They are produced without the addition of binders (Hiegel et al., 2009; Mladenov), but they may also contain binders that reduce their friability or increase their calorific value and lower their initial ignition temperature. The only requirement for pellets is that they comply with the European standards for calorific value, ash content and environmental friendliness, explained below.

The European standard EN 14961-2 for pellets has been in force since 2010. It sets out uniform rules for all pellets sold and burned in Europe. This includes the length and diameter of the pellet, ash remaining after combustion, moisture content etc. With the adoption of a uniform EU pellet standard EN 14961-2 in 2010, an EN plus certificate for pellets used in domestic boilers and an EN-B certificate for commercial pellets used industrial boilers were introduced. There are two classes of qualities A1 and A2 in the EN plus certificate. Class A1 introduced strict limits on the ash content in the pellets while in class A2 ash content is up to 1.5%. The EN-B certificate for commercial pellets has significantly reduced restrictions.

Figure 1. General view of fire pellets

The introduction of a uniform quality standard for domestic and commercial pellets will allow a clear accounting of pellet consumption and quality (Hiegel et al., 2009; Mladenov).

The main difference between standards and certificates is that standards are not controlled. Certificates are compulsory for the whole chain from production to consumption (Hiegel et al., 2009; Mladenov). As you can see the use of standards alone is not enough. Certification and control of the products and of the entire supply chain is desirable. Existing national and international certification systems contributed to ensuring the quality of produced pellets and to win the trust of consumers. However, they all have certain disadvantages. There are no certificates covering the entire supply chain within one system (Hiegel et al., 2009).

In this regard, a large range of pellets are available on the market. All labels state that the pellets are manufactured according to EN 14961-2 standard or that they are EN plus certified. However, in many cases the pellets offered on the Bulgarian market are not even labelled and it is difficult for the end user to make the right choice. The price range is also wide. And despite the labels, the consumers eventually feel the difference in the quality of the pellets as a larger or smaller consumption of pellets for heating. As a result, it is difficult to predict the cost of heating, as well as the harmful emissions that will be released during the pellets combustion.

This article focuses on the experimental determination of the quality of seven different types of pellets marketed in Bulgaria and one type of biomass, produced from rose stems by determining their specific calorific value and ash content.

MATERIALS AND METHODS

Seven types of pellets and one type of biomass, produced from rose stems are investigated using a standardized methodology (Official Methods of Analysis of AOAC International) (Atanasov et al., 2010; Horwitz & Latimer, 2007), involving the determination of dry matter (by drying the samples at 105^0C) and the ash content (by burning the samples at 480-550^0C). The study presents the most widespread types of pellets on the market in Bulgaria.

The composition of the studied types of pellets is shown in Table 1. One type of pellet (No 2) is produced from foreign manufacturer. Four of pellet types are made from wood and the rest types are made from agricultural waste. The bulk density of all samples is within 650 kg/m^3 and is indicated on the pellet packaging.

Table 1. Baseline data for the pellets tested

No	Type of pellets	Material description	Diameter, mm
1	Wood pellets	Coniferous wood without bark	6
2	Wood pellets	A mixture of 60% deciduous, 40% coniferous wood	6
3	Agropellets	Sunflower seed husks	6
4	Wood pellets	Coniferous wood with bark	6
5	Wood pellets	Coniferous wood mixture	6
6	Agropellets	Sunflower husks of seeds and stalks	6
7	Agropellets	Peanut flakes	6
8	Agropellets	Sticks of roses	6

Determining of combustion characteristics of pellets is done according to the calorimetric method by complete combustion of a sample in an oxygen environment by means of the KL 11 Mikado calorimeter (Figure 2). Pellets and biomass are grinded with the use of mill for particles below 1 mm and fragmented material is dried in a laboratory drier for 24 hours at temperature 105^{0}C until the dry mass obtained. Research is based on complete combustion of one-gram samples in oxygen atmosphere, under pressure of 3 MPa and determination of the increase in water temperature in the calorimetric vessel. Combustion takes place in a calorimeter bomb. A temperature of 17-20^{0}C is set in the vessel 5 of the calorimeter.

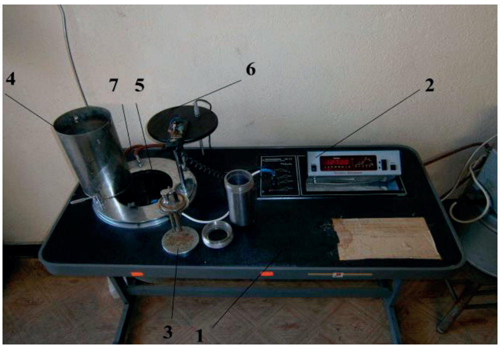

Figure 2. View of the KL-11 Mikado calorimeter:
1 working table; 2-meter; 3-fuel system; 4-outer casing; 5-vessel; 6-cover; 7-cooling part

Two kilograms of distilled water is placed in the calorimetric vessel at a temperature lower than that in the casing. The inner walls of the bomb are poured by 10 ml of distilled water to dissolve the nitrogen and sulphur oxides. Figure 3 shows the equipment for operating with the calorimeter. The mass of 100 mm of kanthal resisting wire 5 and of 1 gram of ground pellets are measured (to an accuracy of 0.0001 g).

Figure 3. Equipment for the KL-11 calorimeter:
1-block press; 2-container of the calorimeter; 3-power electrodes; 4-block of combustible material;
5- kanthal resisting wire; 6-crucible

The ground pellets are pressed with the block press 1 shown in Figure 3 around the kanthal wire 5. The block 4 is inserted into the calorimeter and the two ends of the kanthal wire are clamped to the electrodes 3 of the ignition system. The container 2 is closed tightly and oxygen is supplied through the valve to a pressure of 3 MPa. Thus, prepared system is placed into the calorimeter and the automatic mode is started. The cycle duration is 10-30 minutes and is controlled by a microprocessor. At the end of the experiment, the specific heat value is read directly from the display in Joules (Atanasov et al., 2010). The container is removed from the calorimeter and opened, and then unburned kanthal wire residues are removed from the crucible 6. Their mass is subtracted from the original mass of the kanthal wire. The rest of the mass is burned. This mass is multiplied by 6688 J/g (specific heat of the kanthal wire) and the value obtained is subtracted from the energy determined by the sample and the burnt kanthal wire (Atanasov et al., 2010).

All results obtained for the ash content and calorific value of the pellets are recalculated and commented referring to absolutely dry matter (105^0C).

During the tests, absolutely dry matter is initially extracted at 105^0C. The experiments are carried out under gradual heating to 580^0C (Horwitz & Latimer, 2007). Experiments are performed on the natural samples, and the values obtained are related to absolutely dry matter.

For the accuracy of the results obtained, the experiments are performed with double repetition. Data are processed and arithmetic mean values are displayed.

RESULTS AND DISCUSSION

The results of the experiment after the necessary mathematical processing are given in Table 2. Analysing the results of the experiments, it is noticed that pellets produced from agro residues have higher ash content than those from wood. Ash in natural samples is normally to have lower value than that of absolutely dry matter because of the humidity contained therein. It is noted that the ash varies within 0.22% for pellets made from a mixture of coniferous and deciduous wood. The amount of ash is greatest (within 6.4% relative to absolutely dry matter) in the pellets produced from sunflower shells and stems. In the pellet calorific value examination, the native samples have lower calorific values than the samples compared to the absolutely dry mater, because of their moisture content. It is observed that the humidity of the pellets is within 9-10% for all pellet types. However, the pellets obtained from peanut shells give the highest calorific value due to the fact that they contain traces of fat in the shell. The calorific value of these pellets is 20029.65 J/g. Coniferous pellets with bark have a lowest calorific value - 17376.8 J/g, probably because of the higher percentage of bark in pellets. Pellets produced from agricultural residues have almost identical Calorific value as pellets produced from wood. The average calorific value of pellets from agricultural residues is 18943.96 J/g and that of wood pellets is 18528.33 J/g.

Table 2. Experimental results

No	Absolutely dry matter (ADM), %	Ash		Energy	
		Native, %	In absolutely dry matter, %	Native, J/g	In absolutely dry matter, J/g
1	90.2142	0.32772420747	0.36327335699	17364.168621701	19247.5
2	91.6745	0.20072359617	0.2189525059	17167.478121402	18726.55
3	90.7726	2.20612280834	2.43038454235	17007.241550388	18736.1
4	91.3815	0.21466206986	0.23490763996	15879.168728522	17376.8
5	91.3015	0.24453024453	0.26781672343	17131.765847348	18763.2
6	90.5151	5.79240713181	6.39938482359	17202.475394421	19005.1
7	90.1198	3.20785597381	3.55954459331	18050.689199118	20029.65
8	90.4737	2.46188527021	2.72110564101	16289.773325268	18005.00

Table 3 summarizes the caloric values of the pellets in units according to current European standards.
The energy content from a unit [J/g] is converted to units [MJ/kg] and [kWh/kg]. The values in [kW/kg] are based on the absolute dry matter.
Obviously, only peanut shell pellets meet the DINplus and ÖNORM M7135 standards. These standards require the caloric value of the pellets to be more than 18 MJ/kg at an ash content of 0.5%.

Table 3. Calorific value and cost of studied types of pellets

No	Calorific value, MJ/kg		Power at ADM, kWh/kg
	Nativ	Absolutely dry matter (ADM)	
1	17.36	19.25	5.35
2	17.12	18.73	5.21
3	17.00	18.74	5.21
4	15.88	17.38	4.83
5	17.13	18.76	5.22
6	17.20	19.00	5.28
7	18.05	20.00	5.57
8	16.30	18.01	5.00

Analysing the ash content, an increase in this indicator is observed for pellets obtained from agricultural residues. All types of pellets, except those made from coniferous wood with bark and roses stems, cover EN 14961-2 standard and EN plus certification. Standard EN 14961-2 provides that the caloric values of the pellets should be greater than 16.5 MJ/kg (or than 4.6 kWh/kg) at an ash content of 0.5% for ENplus A1 certificate. It is clear that with the exception of pellets made from coniferous wood with bark and roses sticks, all other pellets cover this certificate in terms of calorie content. As regards the ash content, the certificate is covered only by wood pellets. To reduce this ash content, facilities that burn pellets from residues of agricultural production should be switched to a higher working temperature. The pellets made from rose stems cover the ENplus B certificate in terms of calorie content but do not cover it in terms of ash.

In terms of price (Table 4), pellets produced from agricultural residues are about 25 to 100% lower than those produced from wood. Due to their good caloric content, the consumption of these pellets will be the same as that of wood pellets, but with an increase in ash when they are burned. This is probably due to the density of these residues compared to the density of the wood.

Table 4. Cost of the studied types of pellets per unit mass and calorific value

No	Price, €/kg	Cost, €/MJ
1	0.24	0.0125
2	0.26	0.0139
3	0.13	0.0069
4	0.19	0.0109
5	0.18	0.0096
6	0.13	0.0068
7	0.13	0.0065
8	0.04	0.0022

The lowest cost (in €/MJ) has the biomass produced from rose stems, followed by the cost of pellets produced from peanut shells. Pellets made from a mixture of coniferous and deciduous wood have the highest cost.

CONCLUSIONS

The energy content of pellets on the market is strongly influenced by their storage method and hence by their moisture content. There must be a requirement for traders to protect the pellets from the direct contact with atmospheric moisture during their storage so that their moisture content does not exceed 10-12%.
The pellets produced from agricultural residues cover the ENplus A1 certificate except those produced from rose stems. The calorific value of pellets produced from rose stems is within the certificate required ranges but their ash content don't cover the certificate required ranges.
Almost all types of pellets produced from agricultural waste could successfully replace the wood pellets for heating in domestic and industrial installations with a certain

combustion system adjustment. Their main advantage is their significantly lower prices.

Pellets made from coniferous wood with bark do not cover any ENplus certification, and those made from rose stems cover the ENplus B standard and are suitable for burning in industrial combustion facilities.

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