INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN, 1/2014 (5): 118–126

EVALUATION OF ENERGY POTENTIAL OF WOOD PELLETS

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ABSTRACT

The paper presents basic energy characteristics of wood pellets from different producents. We took the samples from producents in Bulgaria and in Slovakia. Energy characteristics of the pellets, such as their dimensions, moisture content, content of ash, gross and net calorific value were estimated in accordance with European technical standards. We used the standard STN EN 14961-1:2010, Solid biofuels as a basic platform for estimation. Values of net calorific value belonged to interval between 16,103 MJ.kg^{-1} and 17,120 MJ.kg^{-1}, moisture content values were in interval 7,2÷12 %. We observed ash content of the samples from 0,43 to 1,47 %. All of tested samples met the requirements of the standards for ecological biofuel.

Key words: Wood Pellets, Technical Standard, Gross calorific value

1. INTRODUCTION

Pellets, which are made of biomass, belong to the group of modern heating fuels. The pellets provide heating energy, which is comfortable for users (both households and industrial buildings), because of high level automation of combustion process (fire feeding and ash cleaning). Great advantage of the biomass pellets is easy transport of energy from wood or agricultural leftovers, in compressed form to terminal customer.

Wooden pellets are made from by-products of wood processing – sawdust and shavings by compression with high temperature and pressure. The process is called pelletizing and it was originally developed for preparation of animal fodders. Wooden pellets became more important with invention of heating system which is capable of efficient combustion of the pellets. Lignin and resins contained in wood play a role of bonding compound and newly obtained type of fuel possesses with high energy content, good combustion properties and easy manipulation (Židek 2006).

The highest increase in production capacity was observed in North America (the U.S., Canada) and Russia, followed by traditional European producing countries such as Germany, Sweden and Austria. Czech Republic, Slovakia, Hungary and Bulgaria are the last countries in production of pellets from the biomass according to IEA Bioenergy (Cocchi 2011).

Estimation of the most important qualitative parameters of wooden pellets made in Bulgaria and in Slovakia and their comparison are the main goals of the paper. Measured values of relative moisture content, combustion heat, heat capacity and ash content were compared with standard STN EN 14961-1 (Solid biofuels - Fuel specifications and classes – Part 1: General requirements).

The European Committee for Standardization, CEN, is currently published 37 technical specifications for solid biofuels (CEN/TC 335). The work for preparing international ISO standards is ongoing under

ISO/TC 238. Both committees have three standards for pellets. EN 14961-1 and ISO 17225-1 standards include all kind of biofuel pellets and also classification of raw material. The classification of solid biofuels is based on their origin. The fuel production chain of fuels shall be unambiguously traceable back over the whole chain (Alakangas 2012).

Properties of the pellets are defined in technical standards. Primary characteristic of the pellets is their origin and according its origin the standard contains following types of the biomass:

- woody biomass;
- herbal biomass;
- biomass from fruits;
- defined and undefined mixtures.

Next parameter is dimension specification, where the length (*L*) and the diameter (*D*) in mm are given (Fig. 1). Specifications of the pellets according to their dimensions are presented in the table (Tabl. 1). The pellets with diameter of 6 mm are the most suitable for burning in the fireplaces and in heating systems of households. In heating systems of the bigger households, or industrial buildings is possible to use the pellets with diameter 8 – 12 mm. It is possible to produce the pellets with D = 25 mm, but it is a specific size and it is necessary to close a long time contract for production of such pellets.

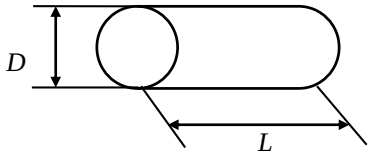

Figure 1: Measurements of the pellets according to EN 14961-1

Table 1: Specification of the pellets according their dimensions (EN 14961-1)

Dimensions (mm)	
Diameter (*D*) *and length* (*L*)	
D 06	6 mm ± 1,0 mm and 3,15 < *L* < 40 mm
D 08	8 mm ± 1,0 mm and 3,15 < *L* < 40 mm
D 10	10 mm ± 1,0 mm and 3,15 < *L* <40 mm
D 12	12 mm ± 1,0 mm and 3,15 < *L* < 50 mm
D 25	25 mm ± 1,0 mm and 10 < *L* < 50 mm

Moisture content (*M* %) is also one of the most important characteristics of the pellets. It is measured according to standards EN 14774-1, EN 14774-2. Commonly, the relatively moisture content is used according to the standards (Tabl. 2).

Table 2: Moisture content of the pellets according to the standard EN 14961-1

Moisture, M	*[% (m/m)* delivered status], EN 14774-1, EN 14774-2
M10	<10%
M15	<15%

Estimation of relative moisture content in the pellets using the drying method is described in next chapter.

Another quality characteristic of the pellets is content of ash (% (m/m), compared with dry sample) is estimated on the base of STN ISO 1171, Estimation of the Ash Content (STN 44 1378). This ISO standard is nowadays changed with new standard EN 14775. The pellets are divided according the standard EN 14961-1 into groups A 0,5 – A 10,0+ (Tabl. 3).

Table 3: Ash content according to EN 14961-1

Ash, A [**%** *(m/m)* to dry status], EN 14775	
A 0.5	< 0,5%
A 0.7	< 0,7%
A1.0	< 1,0%
A 1.5	< 1,5 %
A 2.0	< 2,0 %
A 3.0	< 3,0 %
A 5.0	< 5,0 %
A 7.0	< 7,0 %
A 10.0	< 10,0 %
A 10.0+	> 10,0 %

Mechanical ruggedness against abrasion is tested in so called ligno-tester. The bigger value of the ruggedness, the lower weight losses occur during transport of the pellets (Tabl. 4).

Table 4: Specification of the mechanical ruggedness (EN 14961-1)

Ruggedness, DU [% *(m/m)* from pellets after the test], EN 15210-1
> 97,5 %
> 96,5 %
> 95,0 %
< 95,0 % (minimal value)

Estimation of the content of fine particles smaller than 3,15 mm after production or packing is described in standard STN EN 15149-2 (Tabl. 5).

Table 5: Content of fine particles EN 14961-1

Content of fine particles, F [% *(m/m,* < 3,15 mm] after production, loading, or packing, STN EN 15149-2	
F1.0	< 1,0 %
F2.0	< 2,0 %
F3.0	< 3 , 0 %
F5.0	<5.0 %
F5.0+	> 5,0 % (the highest value)

Every producer must declare content of additional components, such as moulding additives, sintering inhibitors, or whatever other additives. Austrian Ö NORM M 7135 allows content of the additives up to 2 %, only at natural base, such as corn, or potato starch, or wheat, which help with better compaction of pellets.

Heating value of the biomass immediately after delivery Q (MJ.kg^{-1} or kWh.kg^{-1}) is one of the most important values for its energy use. It is estimated on the base of calorific value and relative moisture content of the biomass. This value is measured with use of the calorimeter in isoperibolic or adiabatic conditions.

2. METHODS

The experiment was aimed to estimate selected values of wooden pellets taken from two Bulgarian and two Slovak producers.

Samples were taken from producers in Kostadovo and Aitos in Bulgaria, in Banská Bystrica and Lučenec from Slovakia. Evaluation of qualitative parameters of the biomass is presented in works of various authors: (Miklúšová, Bejda 2002), (Židek 2006), (Klobušník 2003), (Dzurenda, Jandačka 2010), (Alakangas 2012).

2.1. Estimation of the relative moisture content

Estimation of moisture content in sample was based on drying method according to EN 14774-1, EN 14774-2 Solid biofuels, Solid biofuels - Determination of moisture content - Oven dry method. These standards describe estimation of moisture content in biomass suitable as fuel. The principle is based on estimation of fresh and dried sample with accuracy of 0,01 g. Drying took place in laboratory drier Memmert with temperature 103 ± 2 °C until the weight of the sample stayed constant. Weight of the sample could be considered as constant, when difference between two weightings repeated after two hours was lower than 0,01 g. Relative moisture content of the sample (W_r) may be calculated from weight of fresh sample and from weight of dry sample:

$$W_r = \frac{m_w - m_o}{m_w}.100 \qquad \textbf{(1)}$$

Where W_r is the moisture content of the sample, %;

m_w – weight of fresh sample, g;

m_o – weight of dry sample, g.

2.2. Measurement of gross calorific value and calculation of net calorific value of the biomass

Gross calorific value Q_s [kJ·kg^{-1}] is defined as energy released in complete combustion of 1 kg of the fuel and after cooling the exhausts and ash to starting temperature (20 °C), when water vapours condensate. Combustion heat is estimated experimentally with use of calorimeter.

Net calorific value Q_n [kJ·kg^{-1}] is defined as energy released in complete combustion of 1 kg of the fuel and after cooling the exhausts and ash to starting temperature (20 °C). Water contained in the sample is in this case in gas matter. Measurement of gross calorific value from the sample is necessary for calculation of net calorific value. The measurement was realized with use of the IKA C 200 calorimeter.

Measurement of gross calorific value

Analytic material was thoroughly mixed and we prepared samples of which weight was between 0,8 – to 1,5 g (mean error ± 0,0002 g). Weight of sample should have been so, that the temperature of water inside the calorimeter increased by 2 – 3 °C after input of the sample in the calorimetric can. We put prepared sample into inner vessel. Cotton fibre was attached to ignition wire for ignition of the sample. Then we closed the can and pressurized it with oxygen until the pressure reached values between 2,5 to 3,5 MPa. The can was then inserted into calorimeter. Temperature of water in water jacket of calorimeter was not different more than ± 0,5 °C than air temperature in the laboratory. After the filling of the water jacket of the water (calorimeter did it automatically), we closed the calorimeter and started the test.

The calorimeter recorded data about temperature of the water during the test every minute. Main part of the test started after ignition of the sample through cotton fibre. The calorimeter recorded temperatures, which intensively increased. Then the growth slowed down and after 7th – 8th min temperature of the water reached its maximum. During the next five minutes the temperature decreased. Test ended after recording the last value of

the temperature (automatically). The calorimeter showed resultant value of gross heating value on its display. The resultant value was calculated by calorimeter according to following formula:

$$Q_S = \frac{C(D_t - K) - c}{m} \quad \textbf{(2)}$$

Where Q_S is gross calorific value, kJ·kg^{-1};

C – heating capacity of calorimetric system, J.°C^{-1};

D_t – total increase of temperature during measurement, °C;

K – correction for heat exchange with surrounding atmosphere, °C;

c – correction for heat produced by burning of the cotton fibre, 50 J;

m – weight of the sample, g.

Calculation of net calorific value according to STN ISO 1928:2003

Net calorific value is determined by the formula (3):

$$q_{V,net,m} = [q_{V,gr,d} - 206.w(H)_d].(1 - 0{,}01.M_T) - 23{,}05.M_T \quad (3)$$

Where $q_{V,net,m}$ is net calorific value of the fuel with constant volume and with water content, kJ·kg^{-1};

$q_{V,gr,d}$ – gross calorific value of the fuel with constant volume without water content, kJ·kg^{-1};

M_T - relative moisture content of the sample, %;

$(H)_d$ – content of hydrogen in the sample, %.

2.3. Ash content

Work procedure for estimation of ash content is based on requirements of standards STN ISO 1171 Solid fuels and STN 44 1378 Estimation of the ash content. The method is based on the principle of burning the sample in the air, heated to 815 °C ± 10 °C, until weight of the sample stay constant. We put the sample with weight about 2 g into porcelain dish after estimating of the weight of the sample using the laboratory scale with accuracy 0,0001 g. The sample was pre-dried into constant weight in muffle furnace with temperature 103 ± 2 °C. Following procedure was burning of the sample in the furnace using high temperature. Temperature increasing process was divided into three phases. During the first phase (60 min) temperature gradually increased to 500 °C. In the next phase (30 min) the temperature stayed constant. In the last phase we increased the temperature to 815 °C ±10 °C and kept constant at least 60 min. After the burning the sample was cooled for 10 min and then put into desiccator, where the sample cooled down to temperature of the room. Weight of cooled sample was estimated using laboratory scale with accuracy 0,0001 g. Calculation of the ash content is calculated as a ratio of dry ash from prepared sample.

1.4. Content of fine particles

Estimation of fine particle content of the pellets is based on sieve analysis. Diameter of the sieve mesh was 3,15 mm and time of sieving was 5 min using automatic vibrating sieve. Then we estimated the weight percentage of particles smaller then 3,15 mm from whole sample. This percentage allowed us to classify the content of the fine particles in sample, according to CEN/TS 15149-1 (Tabl. 5).

3. RESULTS

Basic data about the samples and place of their origin are presented in the table (Tabl. 6). The samples were placed into hermetic packing and transported into laboratory immediately after taking. All of the samples

belonged to category – woody biomass without additions.

Table 6: Basic data about the pellet samples

Sample number	Country	Producer	Date of taking	Dimension grade
1	Bulgary	Kostandovo	21.7.2012	D 06
2	Bulgary	Aitos	24.7.2012	D 06
3	Slovakia	Slovpellet, Banská Bystrica	03.9.2012	D 06
4	Slovakia	Quercus, Lučenec	03.9.2012	D 06

3.1. Relative moisture content

We found out that the lowest relative moisture (7,2 %) was contained in sample from Kostandovo (sample 1). Sample from Banská Bystrica (sample 3) contained the highest water content – 12%. On the base of the results we assigned the samples from Bulgaria into M10 category (relative moisture content less than 10 %). Pellets from Slovakia were assigned into M 15 category (Tabl. 7).

Table 7: Moisture content of samples

Sample number	**[1]**	**[2]**	**[3]**	**[4]**
Date of drying start	27.7.2012	27.7.2012	05.09.2012	05.09.2012
Date of drying end	28.7.2012	28.7.2012	06.09.2012	06.09.2012
Weight of fresh sample [g]	353,69	183,80	251,19	94,00
Weight of dry sample [g]	331,36	172,57	226,60	88,82
Weight of dish [g]	44,25	44,37	46,11	45,87
Weight of water [g]	22,33	11,23	24,59	5,18
Weight of dry peletts [g]	287,11	128,20	180,49	42,95
Resulting moisture content [%]	**7,2**	**8,1**	**12,0**	**10,8**

3.2. Gross and net calorific value

Gross calorific values of individual samples were from 19,439 MJ.kg^{-1} (pellets from Kostandovo, sample 1) to 20,257 MJ.kg^{-1} (sample 4). Calculated net calorific values were between 16,105 and 17,108 MJ.kg^{-1}. We recorded difference between the best value of sample from Aitos and the worst value of sample from Banská Bystrica, which was 5,86 %. Development of temperatures during combustion is presented in the picture (Fig. 2) and the results are visible in the Table 8.

Table 8: Combustion heat and caloric volume of selected samples

Sample number	**[1]**	**[2]**	**[3]**	**[4]**
Weight of the sample [g]	0,9262	1,5843	1,1522	1,0518
Gross calorific value [MJ.kg^{-1}]	**19,439**	**20,044**	**19,849**	**20,257**
Net calorific value [MJ.kg^{-1}] according to STN ISO 1928	16,727	17,120	16,103	16,726

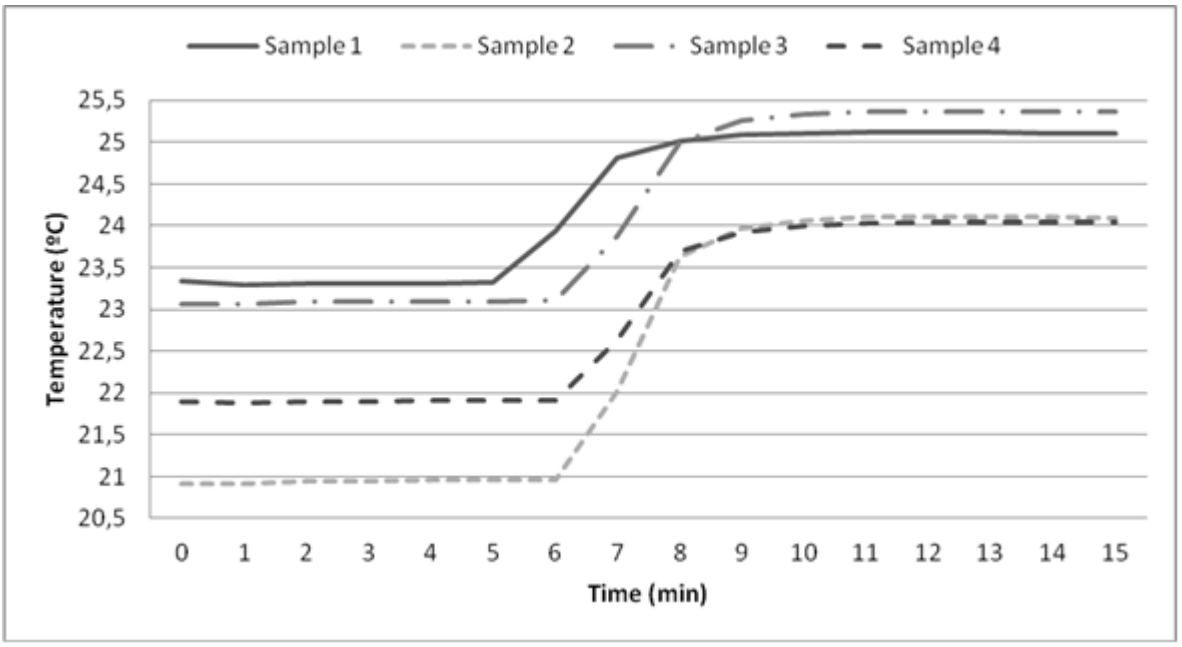

Figure 2: Temperature development during isoperibolic estimation of gross calorific value in the IKA C 200 calorimeter

3.3. Estimation of the ash content

We made 4 measurements of ash content for every sample. Individual samples were arranged into categories A 0.5, A 1.0 and A 1.5. Ash content from all of measured samples met the requirements of the EN 14961-1 standard. More detailed information is visible in Table 9.

Table 9: Estimation of the ash content

Sample	1		2		3		4	
	x	s_x	x	s_x	x	s_x	x	s_x
Sample weight [g]	3,2	0,67	2,5	0,38	2,6	0,64	3,2	0,81
Weight of ash [g]	0,03	0,01	0,03	0,01	0,04	0,01	0,01	0,004
Ash content [%]	**0,95**	**0,05**	**1,35**	**0,03**	**1,47**	**0,04**	**0,43**	**0,02**

3.4. Estimation of fine particles content in samples

Amount of fine particles in pellets after their production characterizes their mechanical ruggedness and quality of their compacting process. Results processed in accordance with standard EN 14961-1 are presented in TabLe 10. Samples 1 – 3 were classified into F 1.0 and sample 4 into F 2.0 category.

Table 10: Estimation of fine particles in samples

Sample number	[1]	[2]	[3]	[4]
Weight of sample [g]	277,92	111,72	341,03	171,89
Weight of particles < 3,15 mm [g]	1,3	0,3	1,4	1,9
Percentage of particles < 3,15 mm [g]	0,45	0,28	0,40	1,08

4. CONCLUSION

Pellets as a renewable biofuel for heating are becoming more and more important substitution for fossil fuels. Undoubtedly their biggest advantage is automation of heating process and high comfort of their use (comparable with natural gas). For increasing of demand for the pellets, there must be kept quality standards of these biofuels. Technical standards allow precise evaluation of pellets made by various producers and require sustainable control of their production process. Product with price about 200 €.t^{-1}, with calculated price about 11,5 – 12 € per one GJ of energy is result of such process. We evaluated pellets made by 2 producers from Bulgaria and by 2 producers from Slovakia. Table 11 describes summary characteristics of the samples.

Table 11: Properties of individual samples

Sample number	1	2	3	4
Country	Bulgaria	Bulgaria	Slovakia	Slovakia
Producer	Kostandovo	Aitos	Slovpellet	Quercus
Date of sample taking	21.7.2012	24.7.2012	3.9.2012	3.9.2012
Size class	D 06	D 06	D 06	D 06
Relative moisture [%]	7,2	8,1	12	10,8
Gross calorific value [MJ.kg^{-1}]	19,439	20,044	19,849	20,257
Net calorific value [MJ.kg^{-1}]	16,727	17,12	16,103	16,726
Ash content [%]	0,95	1,35	1,47	0,43
Particles < 3,15 mm [%]	0,45	0,28	0,4	1,08

None from evaluated samples was the best in all off measured parameters, so it is impossible to present some of the products as the best. Most important thing is fact, that all of the samples met the requirement of EN 14961-1 standard and it is possible to sell them in whole EU.

REFERENCES

1. Alakangas, E., (2012). Towards international pellet standards, VTT: http://www.enplus-pellets.eu/wp- content/uploads/2012/01/Bioclus_posteri_EAA_jamk_final.pdf.
2. Cocchi M. et al. (2011) Global Wood Pellet Industry Market and Trade Study, IEA Bioenergy, p. 190: https://docs.google.com/viewer?url=http://bioenergytrade.org/downloads/t40-global-wood-pellet-market-study_final.pdf&chrome=true.
3. Dzurenda L., Jandačka J., (2010). Energetické využitie dendromasy. Zvolen, Vydavateľstvo – TU, 162 s. ISBN. 987-80-228-2082-0.
4. Miklúšová V., Bejda J., (2002). Vlastnosti peliet z dezintegrovaných fytosurovín. In: Acta Montanistica Slovaca 2002, roč. 7, č. 1, 40–43 s.
5. Židek, L. a kolektív, (2006). Vykurovanie drevnými peletami, Vydavateľstvo: BIOMASA - združenie právnických osôb, ISBN: 8096946587, 133 s.
6. Klobušník L., (2003). Pelety - palivo budoucnosti, Stružení Harmonie, 112 s., ISBN 802-3919563.
7. Dzurenda L., (2005). Spaľovanie dreva a kôry. Zvolen, Vydavateľstvo Technickej univerzity vo Zvolene, 124 s. ISBN 80-228-1555-1.
8. Ö-NORM M 7135: (2000). Compressed wood and compressed bark in natural state – Pellets and briquettes.
9. STN EN 15149-2: (2011). Solid biofuels. Determination of particle size distribution. Part 2: Vibrating screen method using sieve apertures of 3,15 mm and below.
10. STN ISO 1171 (2003). Solid mineral fuels. Determination of ash.
11. EN 14774-1, Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method.

12. EN14774-2, Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified procedure.

13. STN EN 14961-1: (2010). Solid biofuels – Fuel specification and classes – Part 1: General requirements.

The article is result of research made on base of the project. APVV SK-BG-0013-10 and CSTC/Slovakia 01/8, Complex Biomass Utilization for Energy.