DOI: 10.2429/proc.2015.9(1)012 2015;9(1)

Ewa JACHNIAK[1] and Michal HOLUBČIK[2]

CHARACTERISTICS OF PELLETS MADE FROM DIFFERENT PLANT MATERIALS

CHARAKTERYSTYKA PELETÓW WYKONANYCH Z RÓŻNYCH MATERIAŁÓW ROŚLINNYCH

Abstract: The aim of this research was estimation of the characteristic properties (energy and qualitative) of pellets, which were made from different plant biomass. In this research the spruce wood sawdust pellets, straw wheat pellets, straw rape pellets and hay pellets (produced in a large scale companies) were used. In addition, in this research the same kinds of these pellets were used, but produced in domestic conditions. The analyses were conducted in the laboratory of the Faculty of Mechanical Engineering University of Žilina, in February 2014. The following parameters were analyzed: moisture content, total heating value (calorimeter LECO AC 500 was used) and calorific value. The aim of the qualitative evaluation of these pellets, water test was conducted and mechanical durability was estimated. The research indicated that the spruce wood sawdust pellets and straw rape pellets (produced in a large scale companies) were characterized the lowest moisture content (respectively 6.88 and 6.91%) (this is main parameter, which influences on energetic value of pellets) and the highest values of total heat (respectively 20.16 and 18.65 MJ/kg). The highest content of moisture and the lowest energetic value characterized the every pellets, which were produced in domestic mill.

Keywords: pellets, total heating value, biomass

Introduction

The development of renewable energy constitutes a crucial role for the future. Many studies in this field are conducted on the whole world. One of the main sources of this energy is plant biomass. The conducted studies indicate that biomass plant will be basic sources of renewable energy in the coming years [1]. The easy process of the biomass combustion and easy availability of this material cause that plant biomass becomes a competitive for fossil fuels [1-3]. In addition, combustion of the plant biomass causes reduction of sulfur oxides and nitrogen oxides [4, 5]. Pellets are usually produced from a variety of residue feedstocks, for example: straw, sawdust, wood (agricultural and forest biomass). They are produced from shell of some fruits and seeds, too. They are easy to store and transport [6-8]. It can cause that they are relatively cheap and they may also be used for production of energy through combustion, gasification and other chemical conversion processes [9, 10]. They are cylinders with a diameter of 6-10 mm and a length of 10-50 mm manufactured from raw wood (chips, sawdust). They are made by compression process called pelletizing [11, 12]. They don't usually contain chemical additives [11, 13]. Sometimes, pellets contain additives, for example limestone [14], dolomite, diatomite and potato starch [15, 16]. These additives are used for improve their qualitative and calorific properties. In opinion Ewida et al [17] addition kaolin to pellets can

[1] Institute of Engineering and Environmental Protection, University of Bielsko-Biala, ul. Willowa 2, 43-300 Bielsko-Biała, Poland, phone +48 33 827 91 61, email: ejachniak@ath.bielsko.pl
[2] Department of Power Engeneering, Faculty of Mechanical Engineering, University of Žilina, Slovakia, email: michal.holubcik@fstroj.uniza.sk
[*] Contribution was presented during ECOpole'14 Conference, Jarnoltowek, 15-17.10.2014

improve their sintering characteristics. The production of pellets in Slovakia achieved 120 000 Mg in 2008 year in turn, in Poland production of pellets in 2008 achieved 400 000 Mg, which 220 000 Mg were exported [8]. It indicates the development this sectors of the economy.

The aim of this research was evaluation of the characteristic properties (energy and qualitative) of pellets, which were made from different plant biomass.

Methods

In this research were used different types of biomass pellets:

- the spruce wood sawdust pellets (SWSP)
- the straw wheat pellets (SWP)
- the straw rape pellets (SRP)
- the hay pellets (HP).

These pellets were produced in large scale companies. These companies have usually perfect working automatic technology and it can work with no failures. Pellets made by them have appropriate certifications [18]. Cost of these pellets is usually very high.

Sometimes some people, who want to save money, produce pellets in domestic conditions. These pellets have usually the lower quality, because used pressures of compression are much lower. For comparison, in this research pellets produced on experimental domestic pellet mill were presented. There were:

- the spruce wood sawdust pellets ex (SWSP ex)
- the straw wheat pellets ex (SWP ex)
- the straw rape pellets ex (SRP ex)
- the hay pellets ex (HP ex).

The aim of the energetic estimation of these pellets the following parameters were determined:

- Moisture content - it was measured according to EN 14774; it was used drying analytical scale RADWAG 50 SX. A sample of pellets (approx 10 grams) was placed on a metal plate in the analytical scale. Then it has been recorded the wet pellets weight. The sample was dried at about 120°C [11] and after that it was recorded the dry pellets weight. The moisture content of the tested samples was estimated based on the weight difference (between the wet pellets weight and the dry pellets weight). The 2 measurements were made for each sample. The result of the moisture content was the average value.
- Total heating value - it was determined according to ISO 1716 by using of calorimeter LECO AC 500. The tested samples of pellets with weight about 1.0 g were burned in combustion vessel, which was filled with oxygen to a pressure 31.0 bar. Combustion vessel was immersed in 2.0 dm^3 of distilled water. During burning of the samples, the increasing temperature of water was measured.

  Calorific value of fuel, Q_i - it was calculated based on the following formula [11]:

$$Q_i = 18.84 - 0.217 \cdot w \quad (1)$$

where w - moisture content of fuel.

The aim of the qualitative evaluation of these pellets the following parameters were determined:

- Water test - this method allows only approximate qualitative assessment of pellets and serves only to compare different pellets (which are made from various plant biomass). This method based on the measurement of the total disintegration time of chosen pellets. From each sample two large pellets at the same size were selected. These pellets were placed in a glass beaker filled with water of about 0.2 dm^3. Then the disintegration time was measured until the pellets have disintegrated completely. The longer the disintegration time of pellets was indicated higher quality of these pellets.
- Mechanical durability (DU test) - this parameter is a measure of biofuel resistance on the impacts and abrasion, which are caused by transport and transhipments [6, 19]. This parameter was determined according to EN 15210 by using of special device - LignoTester (Fig. 1). There 100 g of pellets sample placed in stream of air for 60 s with pressure of air 70 mbar and after this was sample weighted.
- Amount of fines (F test) - this parameter was also measured in Lignotester (Fig. 1), where samples were placed in stream of air for 30 s with pressure of air 30 mbar. After this was weighted amount of fines under the sieve. Fines should preferably be less than 1% by weight. If fines arrive in the burning chamber, the flame may get too hot as fines particles burn faster than pellets. In the worst case the ash might sinter, which means that the burner must be cleaned after it has cooled down.

The high quantities of fines are produced in the storage system. It can cause operational failures. In turn, minimal amounts of fines in the storage system indicate on a high quality of pellets [3, 20].

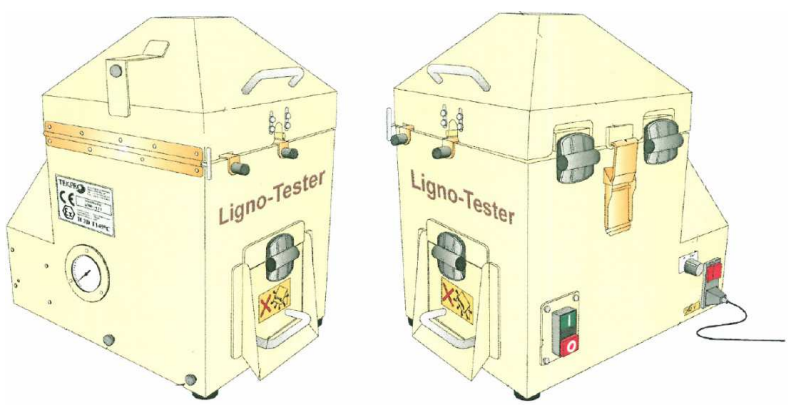

Fig. 1. Lignotester [21]

Results

As a result of conducted research was ascertained, that the spruce wood sawdust pellets and straw rape pellets were characterized the lowest moisture content (respectively 6.88 and 6.91%). This value of moisture content is very good, because commercially made pellets have normally moisture content about 7-10%. These pellets were also characterized the

highest values of total heat (respectively 20.16 and 18.65 MJ/kg) and the highest values of calorific values (respectively 17.35 and 17.34 MJ/kg) (Fig. 2). These values depend on input material properties, kind of pellets and preparation technique, too (not only moisture content) [6].

For comparison, there was presented the results of the pellets, which were made at the domestic conditions. These results are very interesting. The SWSP ex achieved the high value of moisture content (9%), but the values of total heat were almost the same how straw rape pellets (18.67 MJ/kg).

Other pellets made at the experimental conditions were characterized by highest values of moisture content (9.6% for SRP ex, 10.2% for SWP ex and 10.3% for HP ex) and at the same time they achieved the very low values of total heat (respectively 18.11, 18.01 and 17.94 MJ/kg) and calorific values.

It can indicate that SWSP ex pellets were made from better input material during production than others.

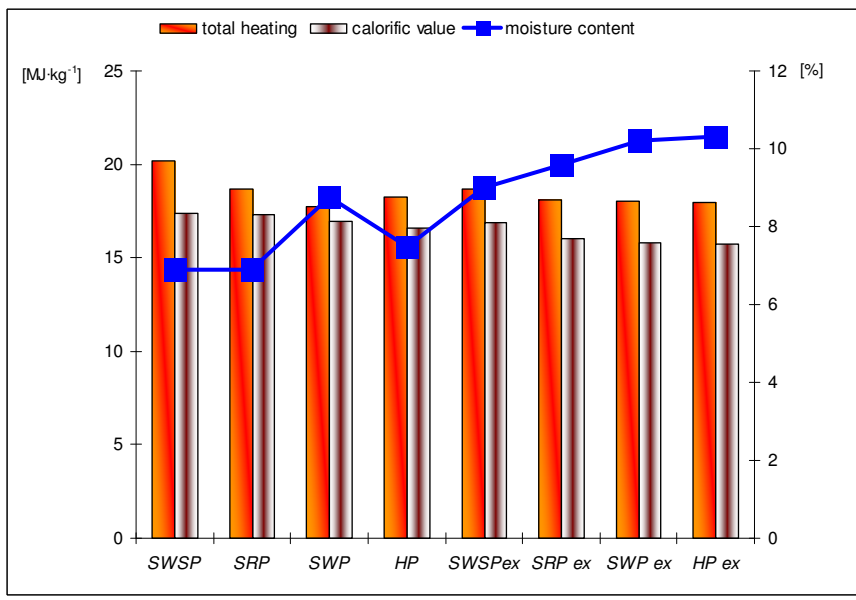

Fig. 2. Moisture content [%], total heating value [MJ·kg^{-1}] and calorific value [MJ·kg^{-1}] of pellets samples

The results of qualitative analysis indicated that the straw wheat pellets and straw rape pellets were characterized the longest time of disintegration in water test (respectively 20 and 18 min). Very interesting results were received for the SWSP and SWSP ex (there was decay after respectively 4 and 1.5 min) and for the HP and HP ex (there was decay after respectively 6 and 1 min) (Table 1). It can indicate that these kinds of pellets were characterized by the bad quality.

In contrast to the relatively high energetic values, these pellets achieved very poor quality in water test. Pellets with good quality can achieve 15-20 minutes disintegration

time. These pellets disintegrated after very short time. It is probably caused by bad conditions of packaging and lack of or poor of assemblage binder (for example glycerol, lignin and dolomite). The suitable content of binder improves their molecular structure and influences on final quality of product.

DU test showed that every pellets produced in a large companies achieved the high mechanical strength, which was oscillated between: 97.6% in DU test (SWSP and HP) and 99% in DU test (SRP). In turn, pellets produced in domestic conditions achieved the lower values. They were oscillated between: 91.1% in DU test (SWSP ex) and 57.6% in DU test (HP ex) (Table 1).

The lower values of abrasion durability for these pellets can result from bad conditions of storage and transport. If there was the high of temperature in storehouse, it could influence on the lower mechanical strength.

Part by weight of the small particles (F test) oscillated between 0.05% (SRP) and 0.34% (SWSP). It was ascertained that pellets, which were made in experimental conditions, were characterized by the higher percent participation the small particles (0.92% in F test for SWSP ex and 7.27% in F test for HP ex) (Table 1). The high last values can result from bad quality of packaging. If the pellets are packed loosely, probably they will move and wipe out for each other. Then can arise the greater fraction of fine dust. The worst results were obtained for both types of hay pellets (both in DU test and F test).

Differences between pellets produced in large companies and domestic conditions are caused by pressure difference in production. Pellets produced of experimental domestic pellet mill don't achieve high pressure of compression. It probably causes crushing and shredding of pellets.

Table 1

Quality parameters of pellets samples

Samples	**DU test**	**F test**	**Water test (disintegration time)**
Unit	**[%]**	**[%]**	**[min]**
SWSP	97.6	0.34	4
SWP	98.9	0.12	20
SRP	99	0.05	18
HP	97.69	0.274	6.30
SWSP ex	91.1	0.92	1.5
SWP ex	69.02	3.75	3
SRP ex	78.69	2.81	3.40
HP ex	57.69	7.274	1.10

Discussion and conclusions

The conducted research expressly indicated that the best quality properties (DU test and F test) achieved straw rape pellets produced in large companies. In turn, the spruce wood sawdust pellets ex achieved the best quality properties from pellets made of domestic mill. Other pellets from this group characterized the significantly worse quality (DU test and F test mainly indicated for this).

The best calorific properties achieved three groups of pellets: SRP and both SWSP and SWSP ex. The similar results referring to straw rape pellets were achieved by Kachel-Jakubowska et al [19]. The best quality and calorific properties of straw rape pellets

investigated by her were achieved. In opinion Jakubiak and Kordylewski [22] the significance of straw rape pellets increases and will grow, because they are useful for combustion in the different kinds of boilers (for example dust boilers and grate boilers). The good quality of different pellets depends on the content of moisture and the method of stored [3].

In turn, the worst calorific properties characterized the every pellets, which were made of domestic mill. These pellets stand out the relatively high water content (9% - SWSP ex, 10.3% - HP ex). This feature influenced on deterioration of the energetic properties of these pellets. The every pellets produced in domestic conditions were characterized by very short disintegration time in water test. This time oscillated between 1.10 min (HP ex) and 1.5 min (SWSP ex). It was probably result the lack of good binder or small its contents. In opinion Holubcik and Jandacka [21], Sarenbo and Claesson [14] the addition of talc, dolomite and limestone to wood pellets causes improve qualitative structure and extension of pellets disintegration time.

Pellets without good binder easily can be liable crushing and shredding during packaging and transport [14, 23]. The every pellets produced in domestic conditions achieved the worst abrasion resistance (91.1% - SWSP ex and 57.6 - HP ex in DU test) and the highest amount of small particles (respectively 0.92% and 7.27% in F test). The relatively high amount of small particles can influence on that the part of the fuel can fly to flue gas. It can result from bad packaging methods [24]. In conclusion, it can be said, that pellets, which are produced in experimental domestic pellet mill didn't achieve good quality.

Acknowledgements

This work was prepared within the project "Modern Heat Sources for Heating" KEGA 070ŽU-4/2013.

References

[1] Niedziółka I, Żak W, Szpryngiel M. Evaluation of pellets quality produced from chosen raw materials. Agricult Eng. 2012;2(137):231-240.
[2] Cernecky J, Neupauerova A, Janosko I, Soldan M. Technika životného prostredia. Zvolen: Technická Univerzita vo Zvolene; 2010.
[3] Ferreira PT, Ferreira ME, Teixeira JC. Analysis of industrial waste in wood pellets and co-combustion products. Waste Biomass Valor. 2014;5:637-650. DOI: 10.1007/s12649-013-9271-6.
[4] Roy MM, Corscadden KW. An experimental study of combustion and emissions of biomass briquettes in a domestic wood stove. Applied Energy. 2012;99:206-212.
[5] Jandačka J, Holubčík M, Nosek R. Effect of additives on the emissions production during combustion of dendromass. Forestry and Wood Technology. Annals of Warsaw University of Life Sciences. 2013;81:117-122.
[6] Mustelier NL, Almeida MF, Cavalheiro J, Castro F. Evaluation of pellets produced with undergrowth to be used as biofuel. Waste Biomass Valor. 2012;3:285-294. DOI: 10.1007/s12649-012-9127-5.
[7] Shang L, Nielsen NPK, Stelte W, Dahl J, Ahrenfeldt J, Holm JK, et al. Lab and bench-scale pelletization of torrefied wood chips - process optimization and pellet quality. Bioenerg Res. 2014;7:87-94. DOI: 10.1007/s12155-013-9354-z.
[8] Goliński T, Foltynowicz Z. Pellet - a key to biomass energy. Inter J Econom Practic Theories. 2012;2(4):197-204.
[9] Li X, Mupondwa E, Panigrahi S, Tabil L, Adapa P. Life cycle assessment of densified wheat straw pellets in the Canadian Prairies. Int J Life Cycle Assess. 2012;17:420-431. DOI: 10.1007/s11367-011-0374-7.

[10] Blokhin AV, Shishonok MV, Voitkevich OV. Thermodynamic properties of cellulose of various structures in the temperature range 5-37 K. Russian J Appl Chem. 2012;85(2):303-308. DOI: 10.1134/s1070427212020255.
[11] Jandačka J, Papučik Š, Nosek R, Holubčík M, Kapjor A. Environmentálne a energetické aspekty spal'ovania biomasy. Žilina: GEORG; 2011.
[12] Kobojima Y, Yoshida T. Testing method for determining water resistance of wood pellets. Eur J Wood Prod. 2015;73:193-198. DOI: 10.1007/s00107-014-0868-7.
[13] Kaliyan N, Morey V. Factors affecting strength and durability of densified biomass products. Biomass Bioenergy. 2009;33(3):337-359.
[14] Sarenbo SL, Claesson T. Limestone and dolomite powder as binders for wood ash agglomeration. Bull Eng Geol Env. 2004;63:191-207. DOI: 10.1007/s10064-003-0223-4.
[15] Stegelmeier M, Schmitt VEM, Kaltschmitt M. Pelletizing of autumn leaves - possibilities and limits. Biomass Conv Bioref. 2011;1:173-187. DOI: 10.1007/s13399-011-0016-0.
[16] Nazarov VI, Makarenkov DA, Bichev MA, Trefilova YA. Development of energy-conserving and ecologically safe processes for production of construction materials and fuel pellets. Chemical Petroleum Eng. 2014;49(9-10):588-593.
[17] Ewida KT, El-Salmawy H, Atta NN, Mahmoud MM. A sustainable approach to the recycling of rice straw through pelletization and controlled burning. Clean Techn Environ Policy. 2006;8:188-197. DOI: 10.1007/s10098-006-0043-x.
[18] Skála Z, Ochodek T. Biomass energy parameters. Ostrava: VŠB-TU Ostrava; 2007.
[19] Kachel-Jakubowska M, Kraszkiewicz A, Szpryngiel M, Niedziółka I. Analysis of raw materials used for the production of solid biofuels. Agricult Eng. 2013;2(143):103-111.
[20] Buczynski R, Weber R, Szlek A, Nosek R. Time-dependent combustion of solid fuels in a fixed-bed: measurements and mathematical modeling. Energy Fuels. 2012;26;(8):4767-4774.
[21] Holubčík M, Jandačka J. Using of Mg - containing additives in wood biomass. Forestry and Wood Technology. Annals of Warsaw University of Life Sciences. 2013;82:324-329.
[22] Jakubiak M, Kordylewski W. Pellets - basic biofuel for power engineering. Archive Combust. 2008;8(3-4):1-12.
[23] Kraszkiewicz A, Kachel-Jakubowska M, Szpryngiel M. Analysis of chosen qualitative features of pellets produced from plant raw materials. Agricult Eng. 2013;2(143):167-173.
[24] Rynkiewicz M. Physical and mechanical properties of the pine sawdust pellets with added sawdust of the deciduous trees. Agricult Eng. 2013;2(143):299-306.

CHARAKTERYSTYKA PELETÓW WYKONANYCH Z RÓŻNYCH MATERIAŁÓW ROŚLINNYCH

[1] Instytut Ochrony i Inżynierii Środowiska, Akademia Techniczno-Humanistyczna w Bielsku-Białej, Polska
[2] Katedra Energetyki, Wydział Inżynierii Mechanicznej, Uniwersytet w Żylinie, Słowacja

Abstrakt: Celem badań była ocena charakterystycznych (energetycznych i jakościowych) właściwości peletów, wykonanych z różnorodnej biomasy roślinnej. W badaniach wykorzystano: pelety wykonane z trocin drzewnych świerkowych, słomy pszenicznej, słomy rzepakowej oraz z siana (produkowane w dużych firmach). Dodatkowo w badaniach tych wykorzystano te same rodzaje peletów, ale produkowanych w warunkach eksperymentalnych. Analizy prowadzono w laboratorium Katedry Techniki Energetycznej Uniwersytetu Żylińskiego w Żylinie w lutym 2014 r. Brano pod uwagę następujące parametry: zawartość wilgotności, ciepło spalania (wykorzystano kalorymetr LECO AC 500) oraz wartość opałową. W celu oceny jakościowej badanych peletów przeprowadzono także test wodny oraz zbadano ich mechaniczną wytrzymałość. Badania wykazały, że najniższą wilgotnością (główny parametr wpływający na wartość energetyczną peletów) charakteryzowały się pelety wykonane z trocin drzewnych świerkowych oraz słomy rzepakowej (odpowiednio 6,88 i 6,91%) (ale produkowanych na dużą skalę w wielkich firmach) i uzyskały też najwyższą wartość ciepła spalania (odpowiednio 20,16 i 18,65 MJ/kg). Najwyższą zawartością wilgotności i najniższymi energetycznymi właściwościami cechowały się wszystkie pelety, które były produkowane w warunkach eksperymentalnych.

Słowa kluczowe: pelety, ciepło spalania, biomasa