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ENERGY PROPERTIES OF PELLET AS A RENEWABLE ENERGY SOURCE OF THE FUTURE

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ABSTRACT

The objective of the paper was to analyse the impact of the moisture level on energy properties obtained by the manufactured heating pellet in the selected enterprise which produces pellets in Lubelskie Voivodeship. Therefore, measurements concerning moisture of supplied biomass and the level of moisture of the manufactured pellet were carried out. The straw pellet production process on the example of the selected enterprise with annual production of 60 thousand tonnes was discussed. During the research period almost 6 thousand tonnes of biomass were supplied to the plant. Moreover, moisture measurements of chaff during the pelletization process were made. Average moisture of supplied raw materials was approximately 19% but the manufactured fuel pellet obtained moisture of approximately 14%. These values are assumed by the company.

Introduction

The paper undertakes a still important issue of renewable energy sources in the energy and heat engineering sector on account of their inexhaustible energy sources. Both in Poland as in the world, renewable energy resources are shrinking very fast. They are also harmful for the environment not only during their conversion but also during exploitation, transport and storing. Such a situation causes greater engagement in alternative and pro-ecological energy sources, such as solar, wind, geothermal, liquid diffusion and oceanic currents and mainly biomass. A global sector of energy systematically increases participation of renewable energy sources to exceed 50% in the energy balance in 2050.

Energy, which may be obtained from biomass, constitutes only 15% of the energy consumed in the world. In the developing countries it is as much as 38%. A global potential is used only in 7% (Johansson et al., 1993).

According to the energy policy of Poland to 2030, participation of biomass on the renewable energy market will rise each year. According to forecasts, it will reach 35 million tonnes in 2020 (Uchwała, 2009).

Biomass is the most widely used renewable energy source because it includes waste from a household, agricultural production, forestry as well as industrial and municipal waste. Its use is very essential because it is less bothersome in comparison to carbon (energy inputs in the process of preparing fuel cause emission, which is not balanced in the vegetation process) – the amount of carbon dioxide, which is emitted to atmosphere during biomass combustion, is balanced with the amount of carbon dioxide, which is absorbed by plants. Moreover, biomass is very competitive on account of price. Thus heating with this renewable energy source has become more profitable (Demirbas, 2000).

On account of the increase in biomass production, pellets production also raises - high yielding calorific pellets manufactured from wood waste, energy crops or straw. Research confirmed the thesis that due to high content of volatile parts it is very effective. At the low content of ash, pellet is characterized with high calorific value. In recent years, pellet produced from straw gets more and more popular. It mainly results from opportunity to obtain "green certificates", thanks to which enterprises which produce pellet from renewable energy sources may obtain great subsidies.

The objective of the paper is to confirm rightness of the scientific hypothesis according to which, moisture and presentation of pellet as a renewable energy source of the future with regard to parameters with which pellet obtains the highest quality and calorific value is the main factor which translates into both the pellet quality as well as its energy value. The paper covered the research in the selected enterprise which processes plant biomass into fuel pellets, located in Lubelskie Voivodeship (the owner consent to provide neither the name of the enterprise nor its location). The research period was two months - July and August 2013. The research includes the data concerning plant biomass moisture (chaff from grain straw), from which fuel pellet is manufactured, and the production of the ready one, namely pellet.

Plan biomass pellet

Pellet also is also called a fuel pellet. Its characteristic property is low moisture, which is 8-14%. It includes low amount of substances which are harmful for environment and ash and its energy value is high (Igliński et al., 2009). Straw pellets have energy value of 18.1 $MJ \cdot kg^{-1}$ (Denisiuk, 2007). Fuel pellet is an environment friendly product at it is easy in transportation, storage and distribution.

We might have observed development of local heat and power stations, which are heated with biomass pellets, and increasing consumption of pellet in big coal power stations for the last years. Thus, production of new generation pellet was developed. It consists in processing not only wood waste but also leaves, straw, grass and waste activated sludge.

A pellet production technology comes from the production process of granulated animal fodder. Not so long ago, wood material was used for this process. Raw material designated for energy purposes should meet specific technological and thermal requirements (Jakubiak and Kordylewski, 2008). In case of straw, its calorific value, a withering degree and mainly moisture are determined. The calorific value as well as straw combustion heat is thermophysical parameters, which mainly depend on moisture and its chemical composition (Łucka, 2010).

Almost each type of biomass may be pelletized. High quality material must be used for pelletization. Pelletized raw material should not be contaminated with stones or sand since they deteriorate its quality and may cause damage to the production line. Biomass for fuel pellet production should have 12-14% moisture (Kotowski and Konopka, 2013). In order to obtain such degree of moisture, raw material should be seasoned and then dried or moistened.

Fuel pellet production consists of three stages. Raw material is subjected to drying, mincing and pressing. Pellets are pressed under great pressure in the rotational press with dry mass which was first ground. No adhesive substances are used for this purpose. The final product consists of small cylindrically shaped pellets with diameter of 6-25 mm and the length of few centimetres.

There are many advantages of pelletization:

- high energy or calorific value means that 2.1 kilo of pellets may replace 1 l of calorific oil, pellet with good properties has a calorific value, which exceeds even 70% of the calorific value which comes from the best carbon kinds, while 1.4 t of pellet may replace 1 tonne of carbon - half a tonne of pellet equals 2.5 m^3 of wood chips or 1 m^3 of solid wood,
- low emission of carbon dioxide and sulphur dioxide – by replacing grannulate with pellet we reduce carbon dioxide emission by 2.5 kilo on each saved litre of fuel oil,
- fuel pellet is produced from renewable energy sources, which may be obtained locally,
- for production of pellet there is no need to use additional chemical substances, such as glue or varnish, which are recognized as harmful substances,
- pellet is an energy material, which is simple in use,
- low transport costs,
- resistance to self-ignition and decay,
- during pellet combustion, small amount of ash is formed, which later may be used as a fertilizer in horticulture; a tonne of a combusted pellet produces only 10-20 kilo of ash (ash content in pellet from straw is at the level of 6%).

Through the increased energy concentration in the volumetric unit and in the uniform geometry of pellet, the process of its distribution is simpler than unprocessed biomass. Due to the necessity of limiting the use of wood for pellet production, straw becomes even more important material in fuel pellet production. It increases the significance of rapeseed straw in power energy. Pellets produced therefrom are used in retort burners, pulverized-fuel boilers and grate-fired boilers.

Pellet production in the European Union is developing dynamically, in particular on account of environmental protection requirements. Pellets may be widely used, which increases demand and therefore mass production as well as reduces distribution and production costs. Fuel pellets and devices for production of pellets are produced by several countries in Europe. The most developing countries with regard to pellet production are: Sweden, Denmark, Finland, Germany and Italy. The biggest producer of pellet in the world is the USA while Sweden takes the second position.

The pellet market in Poland is still developing. Only since 2007 enterprises which manufacture machines and devices for straw pelletization have been dynamically developing. A considerable increase may be reported also in the number of farms which produce pellets. In the EU countries in 2010 there were approx. 7.8 million tonnes of pellet produced, whereas in Poland it was 350 thousand tonnes (Popczyk, 2013). Pellets are packed by producers in 25 kilo bags for manual packing of a furnace bin or 1000 kilo bags, which serve for loading stores or silos. Pellets production cots are approx. 350-450 $PLN \cdot t^{-1}$, at the straw price which is approx. 140 $PLN \cdot t^{-1}$ (Popczyk, 2013).

In 2012 pellet production increased to as much as 900 thousand tonnes, including 600 thousand tonnes of wood pellet and straw pellet of approx. 200 thousand tonnes. Taking into consideration import of pellet from east, the Polish market had 1 million tonnes of pellet (Wach and Wach, 2013).

Properties of pellet produced in the investigated enterprise

A company, where research was carried out, is a leading company in the field of energy projects based on the renewable energy sources. The company bases its business activity on development, implementation and management of projects related to electric energy and heat production, and energy fuels production. The enterprise, managing its facilities, generates over 8% of renewable energy in Poland, which is, inter alia, obtained from biomass combustion.

Biomass is a renewable source with the highest resources. It is used in power energy through direct combustion of wood and its waste, straw, plant production waste or energy plants. In 2008, the enterprise started to execute projects related to supplying biomass pellets, mainly straw ones, for the power industry. The plant decided to process straw into fuel pellet due to the increase in the demand of the Polish energy sector for agricultural biomass, which still has a limited supply. The enterprise has chosen straw for pellet production, because it has low costs of transport, good physical and chemical parameters and has very good conditions of co-firing with carbon. It cooperates with power stations based on long-term contracts for supply of biomass fuel in the form of pellets, on principles adjusted to customers' individual needs.

The establishment produces annually 60 000 tonnes of straw pellets. Thus, it may serve big energy plants and heat and power stations.

The investigated plant was founded in Lubelskie Voivodeship on account of great number of raw materials, which are needed to produce fuel pellet in this region. To obtain the highest possible quality of the ready product, fuel pellet in this case, a modern technology and pellet production devices were applied.

A pellet production plant consists in two production lines. One of the production lines is equipped with a node which supplies calcium, which is necessary during pellet production to absorb moisture from material with higher moisture. The second line is for straw with moisture up to 15%, and it has an additional line, which introduced ground raw material to a buffer feeder without prior grinding.

Each production line in the plant consists of particular nodes: accepting pressed straw (common for both lines), mixing dry and wet raw material and then supplying it to the grinder, tearing straw and removing contaminations, careful grinding, transportation and stabilization on the buffer feeder, dosing and pelletization, cooling, transport, storing and giving out pellets from the warehouse (common for both lines),

Except for the above mentioned nodes in production lines, also a node for filtration of devices space, which is an auxiliary node, is applied.

Plant biomass pellet (chaff from straw) is produced in the plant. Its physical and chemical properties are presented in table 1.

Fuel pellet, produced in the investigated enterprise, has he following composition: carbon (47.71%), oxygen (46.8%), hydrogen (4.59%), nitrogen (0.52%), sulphur (0.10%), chloride (0.27%).

Table 1
Physical and chemical properties of straw pellet

Parameter	Value
Heat of combustion (dry state and without ash state)	19818 kJ·kg^{-1}
Calorific value (dry state and without ash state)	18093 kJ·kg^{-1}
Moisture	10.5%
Content of ash in the straw pellet	6.0%
Specific weight	0.75 Mg·m^{-3}

Source: Documentation of an enterprise which generates renewable energy

The provided values are assumed by the production plant, however, they can differ from those obtained during production on account of the type of the used raw material and technological condition of the devices used.

Evaluation of the plant biomass pellet quality

Production of pellet produced in the investigated enterprise is assumed at the level of 4.5 thousand tonnes per month and over 60 thousand tonnes annually. Over 70 thousand tonnes of biomass are needed for production of such amount of pellet.

The most important parameter which describes straw with regard to energy is its moisture, which translates the most into calorific value of the ready product.

According to the assumptions of the enterprise, moisture for particular types of straw is as follows: wheat straw (15-20%), barley straw (15-22%), rapeseed straw (30-40%), maize straw (45-60%).

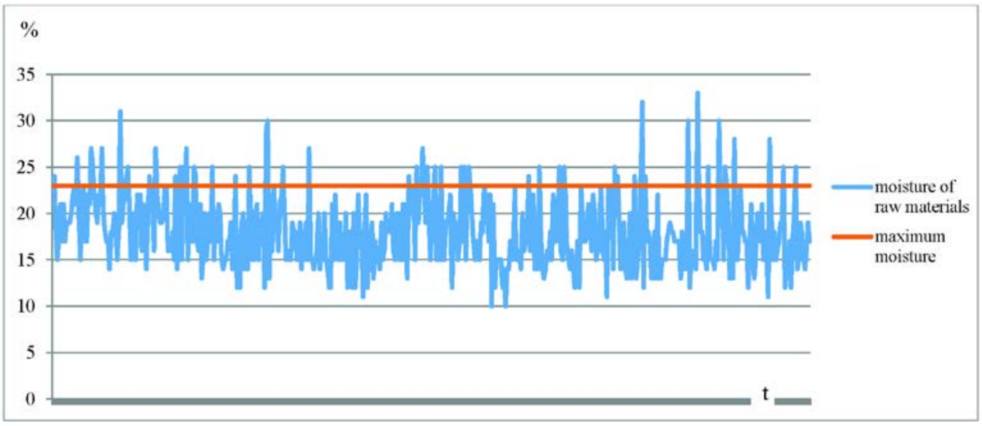

Figure 1. Moisture of raw material for production of pellet

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The plot presents moisture of raw material for production of pellet in Lubelskie Voivodeship. The highest value is 33% and the lowest is 10%. These parameters are not within the general moisture range, assumed by the production plant, but it does not translate into improper moisture of the produced pellet. Discrepancy between the highest and the lowest moisture of raw material is 23 units, which is quite high. On the other hand, taking into consideration the fact that raw materials with varied moisture – higher or lower are added to production, in order to obtain appropriate average moisture of the ready product and to improve its quality – there is a possibility to accept raw material with varied moisture. Moisture of raw material designated for production of fuel pellet is also regulated with calcium carbonate added during the pelletization process.

Average moisture of raw material accepted for production during the research period was 23% – it is a satisfactory result. However, 17% moisture is desirable.

Fuel pellet is the main product produced in the investigated enterprise. A diameter of pellet is a variable size in the process of pellet production – it is from 6 mm to 10 mm. The length is more than 25 mm. Bulk density of pellet is within 0.44 to 0.68 $Mg \cdot m^{-3}$. However, it depends on raw material, which will be used during production of fuel pellet.

Figure 2. Fuel pellet produced in the pellet production plant

The above figure presents a sample of the pellet produced in the selected enterprise. Dimensions of one pellet were presented. The pellet length is 45 mm while the width is 7 mm. A proper thickness of a pellet after production is 6 mm, but with time material is loosened and its volume increases. The smallest pellet presented in figure is 20 mm long and 6 mm thick. These dimensions are within norms assumed by a plant. The manufactured pellet is of high quality. It has a smooth and shiny surface and it is dark green in colour. A calorific value of the produced pellet is high due to high concentration of biomass in one pellet.

In order to carry out a correct production process and to produce pellet with suitable moisture, measurements of chaff moisture are taken, which is similar to the moisture level of the produced pellet. It is a control measurement, to increase or decrease the level of moisture of raw material.

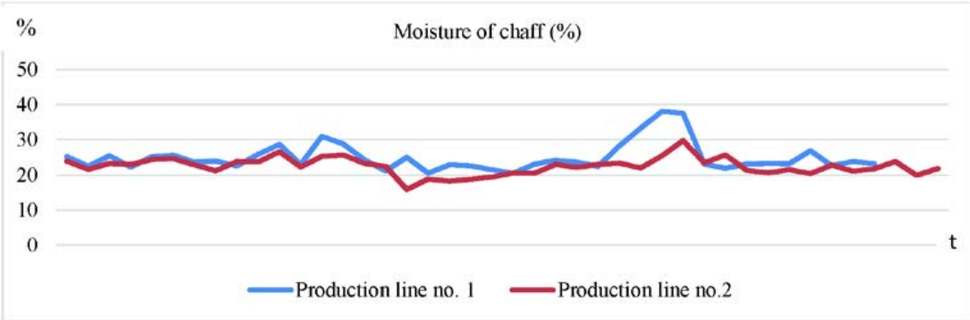

Figure 3. Comparison of chaff moisture on production lines

The above plot presents moisture of chaff measured during a two-month production of fuel pellet. In the scientific research, precise devices should be used for measuring moisture. Unfortunately, there is no possibility to use a conditioner for measurement. A conditioner saturates raw material with suitable amount of vapour or water to facilitate binding during the process of pelleting of raw material with lower moisture. Average moisture of chaff on the 1st production line during research was 24.5% whereas average moisture of chaff on the 2nd production line was 22.5%. A difference between those measurements was slight, however, it agreed with assumptions, that the production line no.1 is adjusted for raw materials with higher moisture.

The main parameter which influences the energy value of pellet is its moisture. Fuel pellet production plant assumes that moisture after production should achieve the value of 12-14%.

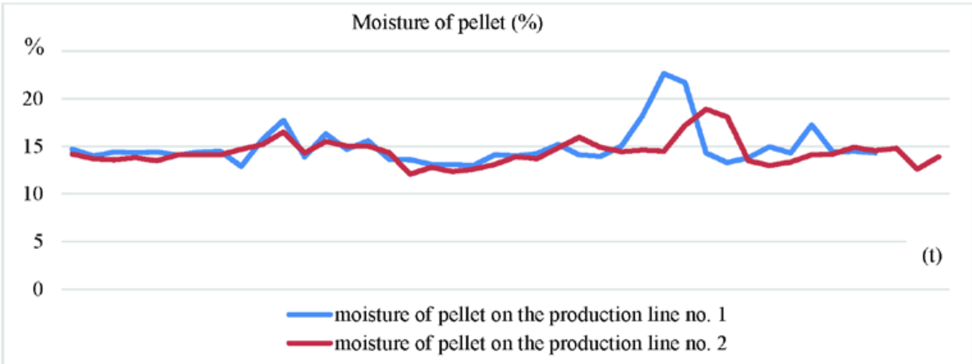

Figure 4. Comparison of moisture in the manufactured pellet

The above plot presents moisture in pellet produced on two production lines, measured during the research period. Average moisture of the produced pellet is very similar. On the production line no. 1, the moisture reached the value of 14.93%, whereas on the production line no. 2 it was 14.39%. Despite the fact, that raw materials supplied to the production line no. 1 have higher moisture than raw materials designated for production on the line no. 2, the obtained moisture of the ready product is very similar on both production lines. Even at the measurement of moisture in chaff, a difference in moisture on two production lines can be reported. However, in order to obtain similar moisture of the ready product, the produced pellet is respectively moistened on account of the level of chaff drying.

Conclusion

The main parameter, which translates into the energy value of pellet is a fuel pellet value, which shortly after production should be within 12-14%. Moisture of the produced pellet during the research was 14%. This value is within the norm, assumed by the enterprise. Additionally, chaff moisture is measured in order to control moisture during production. These measurements are made following the stage of grinding of raw material. Chaff moisture should be approximately 6 units more than the moisture of the ready pellet. During the investigations, average moisture of chaff was 23%. A difference between the produced pellet and chaff in this case is a little less than 9 units. Although the value is higher than the assumed one – moisture of the obtained pellet is correct. The measurements of chaff moisture show how to dose water and vapour, which enables binding of fuel pellet.

Negative linear tendencies between moisture and the calorific value and between moisture and endurance and the positive ones between calorific value and endurance of discussed pellets were reported, but the strongest relation was between moisture and the calorific value of agglomerate (Kraszkiewicz et al., 2013).

The tests show that both the variety of straw used for production of pellets as well as its moisture have a significant impact on efficiency and the specific energy consumption and the pellets quality determined as a bulk density and calorific value.

Pellet due to its energy properties is a renewable energy source of the future.

References

Demirbas, A. (2000). Mechanisms of liquefaction and pyrolysis reactions of Biomass. *Energy Conversion & Management, 41*, 633-646.

Denisiuk, W. (2007). Brykiety/pelety ze słomy w energetyce. *Inżynieria Rolnicza, 9*(97), 41-48.

Igliński, B., Buczkowski, R., Cichosz, M. (2009). *Technologie bioenergetyczne.* Toruń, Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 98-99.

Jakubiak, M., Kordylewski, W. (2008). Pelety podstawowym biopaliwem dla energetyki. *Archiwum Spalania, Vol. 8*, 3-4.

Johansson, I.B., Kelly, H., Reddy, A.K.N., Williams, R.H. (ed.). (1993). *Renewable Energy – Sources for Fuels and Electricity*. Washington, DC: Island Press, 7.

Kotowski, W., Konopka, E. (2013). Innowacje w technologii produkcji pelet. *Czysta energia, 2*, 44-45.

Kraszkiewicz A., Kachel-Jakubowska M., Szpryngiel M., Niedziółka I. (2013). Analiza wybranych cech jakościowych peletów wytworzonych z surowców roślinnych. *Inżynieria Rolnicza, 2(143)*, 167-173.

Łucka, A.I. (2010). *Brykiety ze słomy.* Barzkowice, Zachodniopomorski Ośrodek Doradztwa Rolniczego, 6.

Popczyk, J. (red.). (2013). *Energetyka alternatywna. Zagadnienia wybrane.* Polkowice, Wydawnictwo Dolnośląskiej Wyższej Szkoły Przedsiębiorczości i Techniki, 67-68.

Uchwała Nr 202/2009 z dnia 10 listopada 2009 r. *w sprawie Polityki energetycznej Polski do 2030 roku*.

Wach, E., Wach, L. (2013). Biomasa i pelety – rozwój rynku w Polsce i Europie. *Czysta Energia, 6*, 38-39.

Zarajczyk J. (2013). Uwarunkowania techniczne i technologiczne produkcji peletu z biomasy roślinnej na cele energetyczne. *Inżynieria Rolnicza, 1(142)T.2*, 1-77.

WŁAŚCIWOŚCI ENERGETYCZNE PELETU JAKO PRZYSZŁOŚCIOWEGO ŹRÓDŁA ENERGII ODNAWIALNEJ

Streszczenie. Celem opracowania jest analiza wpływu poziomu wilgotności na właściwości energetyczne, jakie uzyskuje wyprodukowany granulat opałowy w wybranym przedsiębiorstwie produkującym pelety na terenie województwa lubelskiego. W tym celu wykonane zostały pomiary wilgotności dostarczanej biomasy, a także poziom wilgotności wyprodukowanego peletu. Omówiony został proces produkcji peletów ze słomy na przykładzie wybranego przedsiębiorstwa, którego roczna produkcja sięga 60 tys. ton. Podczas okresu badawczego do zakładu produkcyjnego dostarczono prawie 6 tysięcy ton biomasy. Wykonane zostały również pomiary wilgotności sieczki podczas procesu peletyzacji. Średnia wilgotność dostarczonych surowców wyniosła około 19%. Natomiast wyprodukowany granulat opałowy uzyskał wilgotność około 14%. Wartości te mieszczą się w założeniach firmy.

Słowa kluczowe: biomasa, słoma, pelet, proces peletyzacji, wilgotność