Scientific quarterly journal e-ISNN 2449-5999

Agricultural Engineering

2015: 3(155):149-156

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.155.145

IMPACT OF PLANT BIOMASS MOISTURE ON EFFICIENCY, UNIT ENERGY CONSUMPTION AND QUALITY OF PELLET

Grażyna Paulina Wójcik*, Monika Kostrubiec

Department of Production Organization and Engineering, Warsaw University of Life Sciences

*Contact details: ul. Nowoursynowska 164, 02-787 Warszawa, e-mail: grazyna_wojcik@sggw.pl

ARTICLE INFO

Article history:
Received: January 2015
Received in the revised form: April 2015
Accepted: June 2015

Key words:
straw
types of straw
moisture
calorific value

ABSTRACT

The objective of the paper was to evaluate the impact of moisture in plant biomass designed for pellet production on its heating properties. The research was carried out in a pellet plant, located in Lubelskie Voivodeship. The research consisted in determination of moisture of the supplied biomass and the level of moisture of the manufactured pellet. The paper discusses the straw or hay pellet production process on the example of the selected enterprise with annual production of 60 thousand tonnes. During the period, when the tests were carried out, almost 6 thousand tonnes of raw materials i.e. grain, rapeseed, hay, camomile straw as well as a combination of straw and hay or rapeseed and rapeseed with hay were supplied to the plant. Average moisture of supplied raw materials was approximately 19%. On the other hand the manufactured heating pellet obtained moisture of approximately 14%. These values were within the range of those assumed by the company.

Introduction

The article evaluates heating properties of straw for pellet production depending on its moisture. Straw defined as stalks of grain plants or stalks of rapeseed, flax or leguminous plants (Gradziuk et al., 2002), which were subjected to drying, is a side product in agriculture. In farms, where animals are bred, straw is mainly used as litter and a component of feed. In farms which do not carry out animal production, straw is usually ploughed up on fields. Straw may be also used as a component for bases in common mushroom and mushroom production.

Based on the literature, one may state that for few years, straw has been used to a higher extent in power energy (Gradziuk, 2012; Lewandowski, 2008; Zarajczyk, 2013). Investigation of its heating properties is not often undertaken. As a result, this is a still up-to-date activity. A characteristic property of straw is its ability to absorb water and gases and a high content of dry mass, which is approx 85%. Its basic components are polysaccharides namely multimolecular polysaccharides. It contains 45-55% of fibre – cellulose, 26-32% of pentosan – hemicellulose and 16-21% of lignine (Król and Smagacz, 2008).

The objective of the study was to confirm the rightness of scientific hypothesis according to which moisture is the main factor which translates into both the quality of pellet as well as its calorific value. The intention was also to present pellet as a renewable energy source of the future at which the heating pellet obtains the highest quality and a high calorific value. The scope of the paper covers the research in the pellet production plant which processes plant biomass into fuel pellet, which was located in Lubelskie Voivodeship (the owner did not give his consent to provide the name and the city of the plant). The research was carried out in July and August of 2013. The structure of biomass supply was related to the period of vegetation of particular plants (the period of haymaking, harvesting etc.). The research concerned measurement of the plant biomass moisture (chaff from grain straw), from which fuel pellet was manufactured, and the production of the ready one in the agglomerated form.

There are two types of straw in literature: yellow one – fresh and grey – wilted. Fresh straw is composed of many compounds of chloride and alkali metals. A high content of these compounds results in slag formation during combustion. Thus, straw, which was previously subjected to the process of wilting consisting in leaching of harmful compounds by atmospheric precipitation, is used for heating purposes (Grzybek et al., 2001).

Composition of grain straw differs in relation to its type. Differences in the content of particular components are slight. Barley and rye straw includes chloride, whereas maize more sulphur. Bigger differences may be noticed when comparing rapeseed and grain straw since there is more sulphur, chloride, hydrogen and carbon in rapeseed straw (Kołodziej and Matyka, 2012).

For heating purposes, each type of straw, both of grain origin as well as buckwheat or rapeseed one may be used. However, the best properties are in case of wheat, buckwheat, rye straw and rachis and maize straw. The use of straw from cultivation of oats is not recommended, because it has low temperature of ash formation.

In order to use straw for heating purposes it must meet particular technological requirements. Evaluation of straw quality is made based on its moisture, calorific value and degree of wilting. A calorific value and heat of combustion depends mainly on straw moisture and its chemical composition (Grzybek, 2010) – Table 1.

Table 1
Relation of the calorific value of straw to its moisture

Type of straw	Moisture (%)	Calorific value ($MJ\cdot kg^{-1}$) in a fresh	
		state	dry
Wheat	15-20	12.9-14.1	17.3
Barley	15-22	12.0-13.9	16.1
Rapeseed	30-40	10.3-12.5	15.0
Maize	45-60	5.3-8.2	16.8

Source: Niedziółka and Zuchniarz, 2006

Properties of straw in comparison to other fuels are presented in table 2. Fresh straw has moisture on the level of 12-22%, which may fluctuate in relation to the plant species and atmospheric conditions, where these plants are harvested. Extensively moist straw contributes to the increase of emission of pollution during its combustion. It also causes reduction of its calorific values.

Table 2
Properties of straw in comparison to other fuels

Parameter	Unit	Straw		Carbon	Gas	Chips
		Yellow	Grey			
Moisture	%	15	15	12	0	40
Content of ash	%	4	3	12	0	0.6-1.5
Content of carbon	%	42	43	59	75	50
Content of oxygen	%	37	38	7.30	0.90	43
Content of hydrogen	%	5.00	5.20	3.50	24	6
Content of chloride	%	0.75	0.20	0.08	-	0.02
Content of nitrogen	%	0.35	0.41	1.00	0.90	0.30
Content of sulphur	%	0.16	0.13	0.80	0.00	0.05
Volatile components	%	70	73	25	100	70

Source: Wichowski 1994

Straw, due to its structure incites problems with transport and storing. Thus, it is harvested with presses, which allow its compression. There are two types of presses: a forming press (a chamber one) and a rolling one – table 3. Before harvesting, straw must be subject to wilting, and its moisture should not be lower than 16% (Lewandowski, 2008).

Table 3
Basic division of presses

Press type	Bale size	Bale shape	Compression degree
Forming	Small	Prismatic	130 $kg \cdot m^{-3}$
Rolling	Large-size	Cylindrical	150 $kg \cdot m^{-3}$
Forming	Large-size	Prismatic	180 $kg \cdot m^{-3}$

Source: Author's own research based on Gradziuk et al., 2002

The amount of straw, which may be collected, depends mainly on the acreage of cultivated plants but also on other factors such as: yield, fertilization, atmospheric conditions and used cultivars (Lewandowski and Ryms, 2013). In recent years, there are more short-straw varieties used, due to which a yield may be higher by 50% but the straw harvesting increases by 20% (Gradziuk et al., 2002).

In Poland approx. 25 million tonnes of straw is produced each year which is comparable to 12.5 million tonne of coal. Even 8-10 million tonnes of straw may be used annually for heating purposes, which would cause reduction of coal consumption by 4-5 million tonnes. It would also contribute to the decrease of carbon dioxide emission to atmosphere by approximately 8-10 million tonnes (Sobierajski et al., 2009). Unfortunately, in 2011 only 500 thousand tonnes of straw were used for heating purposes (Gradziuk, 2012).

The objective and scope of research

The objective of the research was to evaluate physical properties of raw materials designed for pellet production. The moisture, type and form in which raw material is supplied were assessed. Plant biomass, which was subject to analysis, came from the enterprise which produces pellet in Lubelskie Voivodeship. The research was carried out in July and August 2013.

Methodology of research

Investigations were carried out in a pellet production enterprise. Moisture was measured with a gravimetirc method when raw materials were accepted to the plant. It was measured on the spot basis, during each supply of raw materials.

Moisture was calculated with a dry-oven method, whereas the weight - with a truck scale.

Raw materials, which were used for production of heating pellet, came from farms in Lubelskie Voivodeship. A pellet plant bought raw material such as: hay, straw, rapeseed, mixture of straw with rapeseed, straw with hay and hay with rapeseed.

Plant biomass was supplied to the plant in the pressed form with assuming the following parameters:

- average moisture of straw: 15-25%,
- average bulk weight of pressed straw: 0.130 $Mg·m^{-3}$,
- average bulk density after the use of a shredder: 0.045 $Mg·m^{-3}$,
- average bulk density after the use of a beater grinder 0.065 $Mg·m^{-3}$

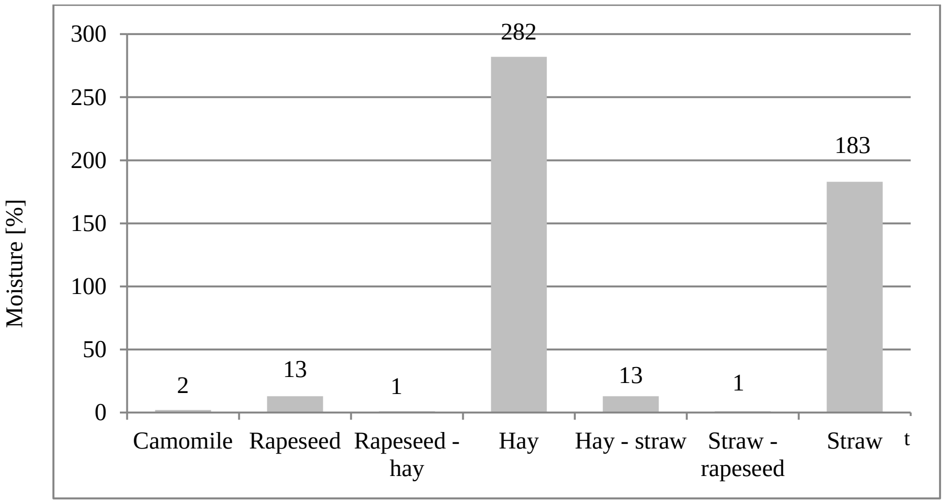

Figure 1. Distribution of raw material supplied to the plant in the research period

Distribution of raw material supplied to the plant is presented based on the weight of raw materials supplied within the research period.

Straw is the main raw material, from which pellet is produced in the discussed enterprise. Distribution of raw materials accepted to the enterprise is presented in figure 1.

From the plot we may read out that hay was most often supplied (57%). Straw constitutes 37% of all the supplied raw materials. Approx. 6 thousand tonnes of plant biomass were supplied to the enterprise in the research period.

Moisture is the main parameter which describes straw and other raw materials, from which pellet is produced. It is the most significant at the evaluation of the calorific value of heating pellet. The discussed pellet plant assumes the following level of moisture for particular types of straw: wheat straw: 15-20%, barley straw: 15-22%, rapeseed straw: 30-40%, maize straw: 45-60%.

Analysis and assessment of moisture of the investigated raw materials

Figure 2 presents moisture of raw materials accepted to the plant. The highest moisture was 33% and the lowest was 10%. These values are not within the range of moisture which is determined by the plant, but they are within ranges for particular types of straw. Discrepancy between the highest and the lowest value was 23 units. For the process of agglomeration, raw materials with varied moisture were selected. The maximum accepted value was 23% (Fig. 2). Average moisture of raw materials supplied to the plant in the research period calculated with a weight method was 19%.

In cases, when the level of moisture of raw materials designed for production of pellet exceeded the value of 23%, a component in the form of lime was added. The amount of lime was regulated automatically depending on the level of moisture of ground raw materials. The maximum amount of lime added to raw materials was limited to the amount of approx. 1% of raw material mass, whereas the recommended value was 0.5%.

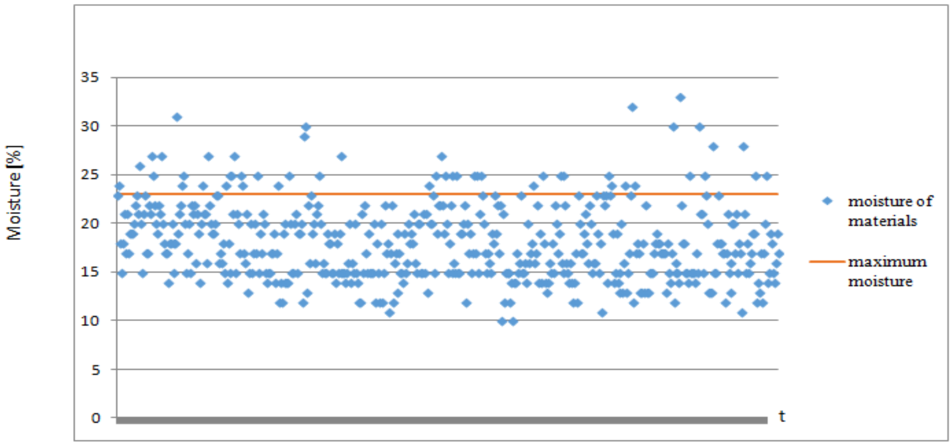

Figure 2. Moisture of raw materials supplied to the pellet plant with designation of the maximum (assumed by the pellet plant) moisture of raw material designed for production

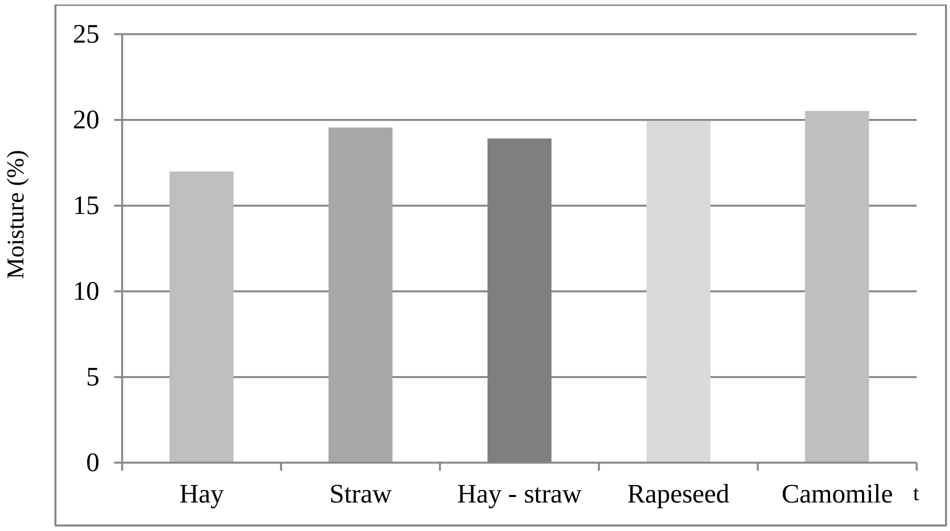

Figure 3. Average moisture of particular raw materials supplied to the plant

Average moisture for particular raw materials is as follows: hay: 16.98%, straw: 19.55%, hay – straw: 18.9%, rapeseed: 19.94%, camomile: 20.5%. Whereas, standard deviations for particular raw materials were: hay: 3.27%, straw: 4.41%, hay – straw: 3.65%, rapeseed: 3.57%, camomile: 4.95%.

Kraszkiewicz et al. (2013) claim that there are negative linear tendencies between the moisture and a calorific value and resistance and positive ones between the calorific value and resistance of the discussed pellets, but the strongest relation was between the moisture and the calorific value of agglomerate. The research carried out by the authors indicates the changes in mosture, the increase of which results in deterioration of the pellet quality and reduced their calorific value.

A subsequent test, which was carried out in the pellet plant consisted in determination of forms in which raw materials are supplied to the plant.

Figure 4 presents the distribution of raw materials accepted to the plant on account of the form in which it is supplied. Data show that during the research period, 75% of cylindrical bales with a compression degree of 150 $kg \cdot m^{-3}$, were accepted to the plant, 24% of big-size prismatic bales with a compression degree of 180 $kg \cdot m^{-3}$ and 1% of raw materials were supplied in the loose form. This data present how straw is pressed in Lubelskie Voivodeship. It may be also stated that rolling presses are more often used than the forming ones.

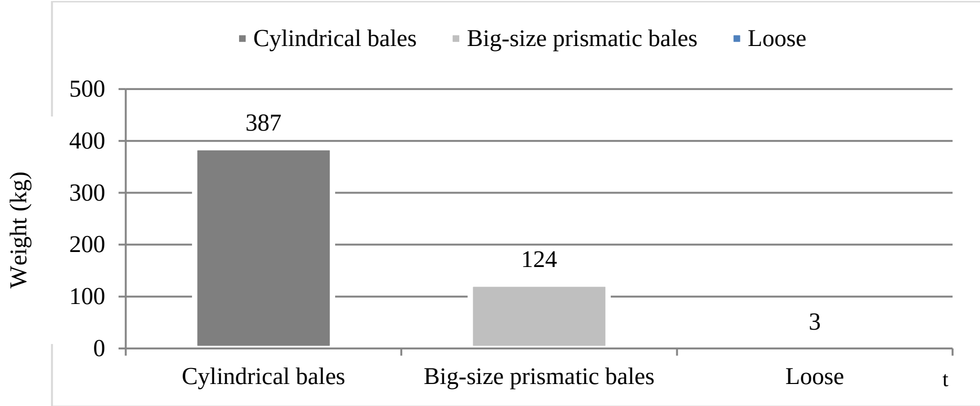

Figure 4. Distribution of particular forms in which raw materials were accepted

Conclusion

Moisture is a basic parameter, which translates into the calorific value of pellet. Thus, it is so important to supply raw materials with a level of moisture corresponding to the values assumed by the pellet plant: 15-25%.

In order to obtain the heating pellet with the highest quality, the composition of plant biomass for production should be carefully selected (moisture, calorific value). The research shows that the moisture of raw materials supplied to the plant is at the level of 19% which corresponds to the sizes, assumed by the pellet plant.

According to Zarajczyk (2013) both the variety of straw used for pellet production as well as its moisture have a significant impact on the efficiency and unit consumption of energy and the quality of pellet (determined as its bulk density and calorific value).

Moisture is not the only factor, which translates into the quality of pellet. Moreover, a degree of plant biomass contamination and the raw materials cultivation culture are significant. A next factor is a bulk weight of the supplied biomass. According to the assumptions made by the pellet plant, bought raw materials should have a bulk weight at the level of 0.130 $Mg \cdot m^{-3}$ (despite the fact that the plant bought raw materials with the bulk weight of 0.150 $Mg \cdot m^{-3}$ and 0.180 $Mg \cdot m^{-3}$).

The observation of the production process in the pellet production plant (not from the algorithm or assumptions for the mixing process) it may be stated that there is no need to accept raw materials only with specific moisture because thanks to mixing of various types of plant biomass with varied parameters we may obtain a desired level of moisture. The described pellet production plant obtained the assumed level of moisture by mixing raw materials with moisture above 23% (it is a maximum moisture of raw materials designed for production), in some cases even 33% with material of 10% moisture.

References

Gradziuk, P., Grzybek, A., Kowalczyk, K., Kościk, B. (2002). *Biopaliwa*. Warszawa, Wydawnictwo Wieś Jutra Sp. z o. o., ISBN 83-7160-217-0.

Gradziuk, P. (2012). *Pozyskanie i wykorzystanie słomy na cele energetyczne w ciepłownictwie i energetyce zawodowej w Polsce*. XI konferencja Odnawialne źródła energii obecnie i w nowej perspektywie po 2013 roku. Płońsk, Wydawnictwo MORD Warszawa Oddział Poświętne w Płońsku, 31.

Grzybek, A. (2010). *Modelling of biomass utilisation for energy purpose*. Fokus Biofirsk Vol. 5 No. 6 Institute of Technology and Life Sciences, Copyright © by Norwegian Institute for Agricultural and Enviromental Research Norway 2010, 134.

Grzybek, A., Gradziuk, P., Kowalczyk, K. (2001). *Słoma energetyczne paliwo*. Warszawa, Wydawnictwo Wieś Jutra Sp. z o. o., 23-24.

Kołodziej, B., Matyka, M. (red.). (2012). *Odnawialne źródła energii. Rolnicze surowce energetyczne*. Poznań, Państwowe Wydawnictwo Rolnicze i Leśne, ISBN 978-83-09-01139-2.

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.

Król, M.J., Smagacz, J. (2008). *Rozkład resztek pozbiorowych w glebie*. Puławy, Dział Upowszechniania i Wydawnictw IUNG - PIB, ISBN 8375620203.

Lewandowski, W.M. (2008). *Współczesne technologie wykorzystania biomasy do celów energetycznych, w rola biomasy w produkcji energii*. Białowieża, Polski Komitet Naukowo-Techniczny FSNT-NOT, Federacja Stowarzyszeń Naukowo-Technicznych, 47.

Lewandowski, W.M., Ryms, M. (2013). *Biopaliwa. Proekologiczne odnawialne źródła energii*. Warszawa, Wydawnictwo Naukowo-Techniczne, 141-143.

Niedziółka, I., Zuchniarz, A. (2006). Analiza energetyczna wybranych rodzajów biomasy pochodzenia roślinnego. *Metrol, 8A*, 234.

Sobierajski, J., Starzomska, M., Piotrowski, J. (2009). *Odnawialne źródła energii, wiadomości ogólne*. Kielce, Wydawnictwo Politechniki Świętokrzyskiej, 63.

Wichowski, R. (1994). *Wykorzystanie słomy jako źródła energii odnawialnej w rolnictwie na przykładzie Danii*. Seminarium krajowe Wykorzystanie energii odnawialnej rolnictwie. IBMER, 28.

Zarajczyk, J. (2013). Uwarunkowania techniczne i technologiczne produkcji peletu z biomasy roślinnej na cele energetyczne. *Inżynieria Rolnicza, 1*(142), 3.

WPŁYW WILGOTNOŚCI BIOMASY ROŚLINNEJ NA WYDAJNOŚĆ, JEDNOSTKOWE ZUŻYCIE ENERGII ORAZ JAKOŚĆ PELETU

Streszczenie. Celem opracowania była ocena wpływu poziomu wilgotności biomasy roślinnej przeznaczonej do produkcji peletu na jej właściwości opałowe. Badania przeprowadzono w wytwórni peletu, którego siedziba znajdowała się na terenie województwa lubelskiego. Badania polegały na wyznaczeniu wilgotności dostarczanej biomasy, a także poziomu wilgotności wyprodukowanego peletu. Omówiony został proces produkcji peletów ze słomy lub siana na przykładzie wybranego zakładu, którego roczna produkcja wynosi 60 tys. ton. Podczas okresu, w którym wykonywano badania do zakładu produkcyjnego dostarczono prawie 6 tys. ton surowców tj. słomy zbożowej, rzepakowej, siana, rumianku oraz mieszanki słomy z sianem lub rzepakiem, jak również rzepaku z sianem. Średnia wilgotność dostarczonych surowców wyniosła około 19%. Natomiast wyprodukowany pelet opałowy uzyskał wilgotność około 14%. Wartości te mieściły się w założeniach firmy.

Słowa kluczowe: słoma, rodzaje słomy, wilgotność, wartość opałowa