TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2014, Vol. 14, No. 3, 51–54

The Influence of the Kind and the Moisture Content of Straw on its Heating Value

Józef Kowalczuk[1], Janusz Zarajczyk[1], Norbert Leszczyński[1], Ignacy Niedziółka[2], Mariusz Szymanek[2], Paweł Sobczak[3], Kazimierz Zawiślak[3], Alicja Wieczorkowska[4]

[1]Department of Horticultural and Forest Machinery, [2]Department of Agricultural Machines,
[3]Department of Food Engineering and Machinery,
University of Life Sciences, Głęboka 28, 20-612 Lublin, Poland,
[4]Polish-Japanese Institute of Information Technology Warsaw POLAND

Received July 15.2014; accepted July 30.2014

Summary. The goal of the presented research was to determine the influence of the kind and moisture content of straw on its heating value. The research was conducted on four kinds of straw: rape, rye, wheat, and maize straw, and for four moisture levels: 12%, 16%, 20% and 26 %. The results show that the highest heating value has been obtained for rape straw, and the heating value for rye straw is insignificantly lower. Maize and wheat straw reveal significantly lower heating value than rape straw. Additionally, this research has proven that the heating value decreases with increasing moisture content of straw.
Key words: straw moisture content, heating value

INTRODUCTION

Biomass is one of numerous renewable energy sources, and both its big energetic potential and ecological effect speak for its energetic exploitation. This is because the pollution (carbon dioxide) emission to atmosphere during the combustion of biomass is practically equal to zero [21, 2, 23, 10].

According to Miciuła [16] ecological, economic and social benefits resulting from utilizing biomass include:

- Decreased emission of substances having damaging effect on the environment including sulfur dioxide, nitrogen oxides and organic contamination,
- Reduction of carbon dioxide emission, responsible for the greenhouse effect (correlation with the amount of burned biomass),
- Limitation of environment degradation resulting from fossil fuel mining and the depositing biomass-type waste in the environment,
- Exploitation of energetic potential of biomass,
- Development of local labor markets,
- Development of numerous sectors of economy,
- Increase of energetic safety of the country.

Heat is obtained as a result of biomass burning, and this heat can be processed into other types of energy, e.g. electric energy. Besides, burning biomass leaves 4 times less ash than burning other solid fossil fuels which can be used as fertilizer [1, 4, 5, 11, 19].

Vegetable unprocessed biomass reveals relatively low bulk density, which influences transport and storage costs, as well as practical use. Therefore, the increase of the biomass concentration and energy through briquetting and pelleting significantly increases the comfort of distribution and use of this biofuel [6, 7, 12, 13, 18].

Straw is the basic vegetable resource for briquette or pellet production. After the required amount of straw is used for bedding, fodder, and incorporation into soil by plowing, the surplus of straw can be successfully applied for briquette or pellet production [3, 8, 9, 20, 22].

According to Hejft [9] and Niedziółka et al. [17] the energetic value of vegetable biomass depends on the kind and condition of the raw material and on its moisture content in the first place. This is, because high contents of water decreases the amount of heat arising during biomass burning, thus decreasing its heating value and increasing pollution emission.

MATERIALS AND METHODS

The experiments were conducted for four kinds of straw (rape, rye, wheat and maize) and for four moisture content levels: 12%, 16%, 20% and 26 %.

The determination of the moisture content of straw was performed using the oven-dry method, according to the procedure described in norm [PN-93/Z-15008/02]. The measurement of the moisture content of the materials was carried out in 5 repetitions and defined by the following formula (1):

$$W = \frac{m_o - m_1}{m_o} \cdot 100 , \qquad (1)$$

where:
W – moisture content of the examined material (%),

m_0 – mass of material sample prior to drying (g),
m_1 – mass of material sample after drying (g).

The determination of the heat of combustion was performed following the procedure described in [PN-ISO 1928]. The heating value was calculated based on combustion heat determined by means of KL-12 Mn. The measurement of combustion heat of the examined materials was carried out in 3 repetitions.

The obtained results were analyzed from the statistical point of view using the SAS Enterprise Guide 5.1. program. The results of the statistical analysis are shown in the variance analysis tables containing appropriate averages along with specification of their impact on important differences between the examined features. Significance level $\alpha = 0.05$ was assumed in all these analyses.

THE RESEARCH RESULTS

Figure 1 presents the mean heating values of the examined kinds of straw depending on their moisture content. While analyzing the obtained research results, it was identified that along with the decrease of the materials' moisture content from 26 to 12%, the highest growth of the heating value occurred in case of the maize straw (ca. 23%), much lower increase occurred for the rape straw (ca. 14%) and the lowest one for the rye straw (11.4%) and the wheat straw (10,6%).

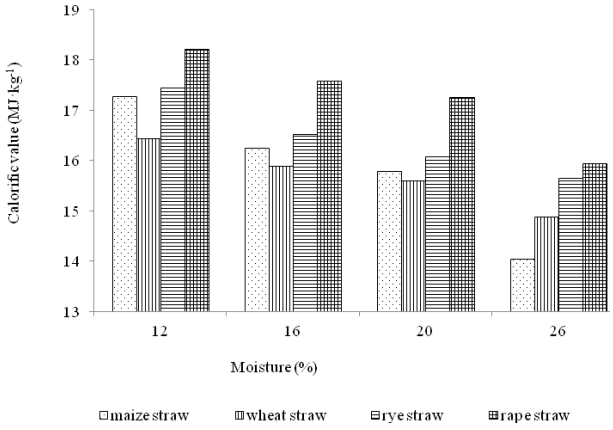

Fig. 1. Average heating values of the investigated straw kinds depending on their moisture content

In order to investigate the influence of the straw kind and moisture content on the heating value, two-way analysis of variance was performed and interactions between factors were investigated. The obtained results are shown in Table 1. The obtained coefficient of determination was R^2 =0.72. Table 1. shows that the heating value of straw largely depends on its kind and the moisture content; on the other hand, no important influence on the heating value could be ascribed to the interaction of the kind and moisture. Thus, we may say these parameters were not strongly dependent on each other.

Table 1. Analysis of variance for the straw heating value depending on the kind of straw and its moisture

Source of variability	df	SS	MS	Value F_0	$P(F > F_0)$
Kind of straw	3	17,79	5,93	9,48	0,0001
Moisture	3	30,34	10,13	16,19	<0,0001
Kind*Moisture	9	3,20	0,36	0,57	0,8120
Error	32	20,02	0,63	-	-
Whole thing	47	71,40	-	-	-

In order to investigate which straw species and moisture content value influences the heating value most, Tukey's test was performed, i.e. pairs of means were compared. The obtained results are shown in Table 2.

Table 2. Simultaneous comparisons of heating value of Tuckey for the examined kinds of straw and moisture

Heating value ($MJ \cdot kg^{-1}$)	Kind of straw			
	Rape	Rye	Maize	Wheat
Average values	$17,239^{A}$	$16,412^{AB}$	$15,826^{B}$	$15,696^{B}$
Moisture	12%	16%	20%	26%
Average values	$17,332^{A}$	$16,549^{AB}$	$16,170^{B}$	$15,122^{C}$

Averages with the same letter do not significantly differ at the significance level of $\alpha = 0,05$

We can conclude from Table 2 that the highest heating value (17.239 $MJ \cdot kg^{-1}$) was obtained for rape straw. However, no significant difference was indicated between the heating values of rape and rye straw. Maize and wheat straw reveal significantly lower heating value than rape straw. There was no significant difference between the heating values of maize and wheat straw.

We can also conclude from Table 2 that moisture content also influences the heating value of straw. The straw of the lowest investigated moisture content (12%) demonstrated the highest heating value. Additionally, significant differences between the straw heating values for 12% moisture content and both 20% and 26% moisture content were obtained. No significant differences were obtained between the straw heating values for 12% and 16% moisture content, nor 16% and 20%. Significantly, the lowest heating value was obtained for 26% moisture content straw.

In sum, we can conclude that the highest heating value was obtained for rape straw, slightly lower value was obtained for rye straw, and significantly lower values were obtained for maize and wheat straw. The heating value decreases with increasing moisture content of straw within the investigated material. This confirms the results obtained by other authors [9, 18].

CONCLUSIONS

The obtained results and their statistical analysis lead to the following conclusions:

1. The experiments showed that both straw species and moisture content significantly influence the straw heating value.
2. The highest heating value (17.24 MJ·kg^{-1}) was obtained for rape straw. However, no significant difference was found between the heating values of rape and rye straw (16.55 MJ·kg^{-1}). Maize and wheat straw demonstrate significantly lower heating value.
3. Moisture content is an important factor influencing the heating value of straw. The highest heating values were obtained for the straw of 12% and 16% moisture content, and no significant difference was found between them. The straw of 26% moisture content demonstrates significantly lower heating value.

REFERENCES

1. **Borkowska H., 2006.:** Pelety ze ślazowca pensylwańskiego na tle normy DIN 51731. Czysta Energia, 6, 22-23.
2. **Denisiuk W., 2006.**: Produkcja roślinna jako źródło surowców energetycznych. Inż. Rol., 5(80), 123-131.
3. **Denisiuk W., 2009.:** Słoma jako paliwo. Inżynieria Rolnicza, 1(110), 83-89.
4. **Dreszer K., Michałek R., Roszkowski A., 2003.:** Energia odnawialna – możliwości jej pozyskiwania i wykorzystania w rolnictwie. Wyd. PTIR, Kraków-Lublin-Warszawa.
5. **Duer I., 1993.:** Możliwości pozyskiwania energii z biomasy roślinnej. Fragm. Agron. 2, 87-93.
6. **Gajewski R., 2011.:** Potencjał rynkowy biomasy z przeznaczeniem na cele energetyczne. Czysta Energia, 1, 22-24.
7. **Grzybek A., 2004.:** Potencjał biomasy możliwej do wykorzystania na produkcję pelet. Czysta Energia, 6, 24-25.
8. **Grzybek A., 2005.**: Wykorzystanie pelet jako paliwa. Czysta Energia, 6, 32.
9. **Hejft R., 1994.:** Słoma jako surowiec energetyczny. Probl. Inż. Rol., 2, 65-71.
10. **Jäger-Waldau A., Szabó M., Monforti-Ferrario F., Bloem H., Huld T., Lacal Arantegui R., 2011.:** Renewable Energy Snapshots. EUR 24954 EN – Joint Research Centre – Institute for Energy and Transport. EUR – Scientific and Technical Research series – ISSN 1018-5593 ISBN 978-92-79-21398-4.
11. **Komorowicz M., Wróblewska H., Pawłowski J., 2009.:** Skład chemiczny i właściwości energetyczne biomasy z wybranych surowców odnawialnych. Ochrona Środowiska i Zasobów Naturalnych, 40, 402-410.
12. **Kubica K., Ściążko M., Raińczak J., 2003.:** Współspalanie biomasy z węglem. Polityka Energetyczna. Wyd. Instytutu GSMiE PAN. Zeszyt specjalny, t. 6, 297-307.
13. **Kulig R., Skonecki S., 2011.:** Wpływ wilgotności na parametry procesu zagęszczania wybranych roślin energetycznych. Acta Agrophysica, 17(2), 335-344.
14. **Liszka M., Majchrzak H. 2005.** Analiza efektów ekologicznych w procesie współspalania węgla i biomasy na przykładzie Elektrowni Opole. Energetyka, 3.
15. **Mani S., Tabil L.G., Sokhansanj S., 2006.:** Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets from grasses. Biomass and Bioenergy, 30(7), 648-654.
16. **Miciuła K., 2011.:** Potencjał biomasy na cele energetyczne. Dostępny: www.bioenergypromotion.w.interia.pl/0115a.pdf., 305-317.
17. **Niedziółka I., Szymanek M., Zuchniarz A., 2006.:** Energetic evaluation of postharvest corn mass for heating purposes. Teka Komisji Motor. i Energ. Rol., t. VI(6A), s. 145-150.
18. **Niedziółka I., Szpryngiel M., Zaklika B., 2012.:** Analiza właściwości fizycznych i mechanicznych peletów wytworzonych z wybranych surowców roślinnych. Autobusy – Technika, Eksploatacja, Systemy Transportowe, 11, 79-86.
19. **Skonecki S., Potręć M., Laskowski J., 2011.:** Właściwości fizyczne i chemiczne odpadów rolniczych. Acta Agrophysica, 18(2), 443-455.
20. **Stolarski M., Szczukowski S., Tworkowski J., Kwiatkowski J., Grzelczyk M., 2005.:** Charakterystyka zrębków oraz peletów (granulatów) z biomasy wierzby i ślazowca jako paliwa. Probl. Inż. Rol., 1(47), 13-22.
21. **Szlachta J., 2001.:** Wykorzystanie słomy (zbożowej i rzepakowej) do ogrzewania budynków mieszkalnych i szklarni. Konferencja FSNT-NOT.
22. **Szpryngiel M., Kraszkiewicz A., Kachel-Jakubowska M., Niedziółka I., 2011.:** Ocena gęstości usypowej i energochłonności produkcji peletów w peleciarce z dwustronną matrycą płaską. Inż. Rol., 6(131), 215-221.
23. **Szwedziak K., 2010.:** Energetyczne wykorzystanie słomy na terenie województwa opolskiego. Inż. Rol., 5(123), 275-277.

WPŁYW RODZAJU I WILGOTNOŚCI SŁOMY NA JEJ WARTOŚĆ OPAŁOWĄ

Streszczenie. Celem pracy było określenie wpływu rodzaju i wilgotności słomy na jej wartość opałową. Badania przeprowadzono dla czterech rodzajach słomy (rzepakowa, żytnia, pszenna i kukurydziana) oraz czterech poziomów ich wilgotności (12, 16, 20 i 26%). Badania wykazały, że najwyższą wartością opałową charakteryzowała się słoma rzepakowa, nieistotnie niższą – słoma żytnia oraz istotnie niższą w porównaniu do słomy rzepakowej – słoma kukurydziana i pszenna. Stwierdzono również, że wraz ze wzrostem wilgotności słomy jej wartość opałowa ulegała obniżeniu.

Słowa kluczowe: słoma, wilgotność, wartość opałowa.