EVALUATION OF FIBROUS PLANT PELLET MOISTURE CONTENT DEPENDENCE ON PRODUCED BIOFUEL QUALITY CHARACTERISTICS

Dionizas Streikus[1], Algirdas Jasinskas[1], Viktorija Zukaite[1], Jiri Soucek[2]
[1]Vytautas Magnus University, Lithuania;
[2]Research Institute of Agricultural Engineering, p.r.i., Czech Republic
dionizasstreikus@gmail.com, algirdas.jasinskas@vdu.lt, mail_viktorijazuk@gmail.com, mail_jiri.soucek@vuzt.cz

Abstract. Investigations of non-traditional herbaceous plants were carried out and physical-mechanical parameters of granules, such as density and resistance to compression, were determined. Investigations were carried out in the fields and laboratories of the Vytautas Magnus University Agriculture Academy (VMU AA) in 2017-2019. In the Institute of Agricultural Engineering and Safety technological-technical means of processing these plants, biofuel pellet production and usage for energy purposes were investigated. In the Lithuanian Energy Institute (LEI), parameters of granule thermal properties, such as the calorific value, elemental composition and ash content, were evaluated. Studies of pellets of unconventional herbaceous plants (fibrous hemp, fibrous nettle) have shown that as the moisture content of pellets increases, their density decreases. Density of the produced 10 ± 2 % moisture biofuel pellets showed that the highest density of pellets were obtained by pressing fiber hemp "Bialobrzeskie" granules – 1263.3 ± 45.1 kg·m^{-3}, and the lowest density was of fibrous nettle granules – 1221.6 ± 32.7 kg·m^{-3}. Density of the pellets is high enough to meet the requirements for granulated biofuels. The research results of the investigated pellet strength (compressive strength) showed that at 10.0 ± 0.1 % moisture content of granules, the maximum critical compressive strength under pressure of fibrous hemp "Bialobrzeskie" granules was 850 N force, and the least resistant fiber hemp "Epsilon 68" granules reached 550 N force. After evaluation of the thermal properties of the fibrous plant pellets, it was found that the prepared biofuel is sufficiently calorific, since its calorific value is close to that of straw and previously our investigated woody plants: the studied fibrous hemp reached 17.3-17.5 MJ·kg^{-1} and fibrous nettle was very similar – 17.2 MJ·kg^{-1}. These parameters meet the standard requirements of the calorific values and other quality characteristics of biofuel pellets.

Keywords: solid biofuel, density, hemp, nettle, mechanical durability.

Introduction

In the world, due to dwindling fuel and wood resources, alternatives to conventional fuels are being sought. In the recent years, progress in the field of energy has been visible: state support for solar panels, wind farms, hydroelectric power stations, biogas power plants. Biomass energy is also unforgettable – forestry waste is no longer emitted, wood chips used for heating, and energy of woody and herbaceous plants are gaining popularity. Due to the harvesting technique for fibrous plants, these plants do not entail significant costs [1-3]. According to the research, fiber crops, such as fiber hemp and fibrous nettle are well adapted to the Lithuanian climatic conditions and have high yield potential – for hemp up to 15 t·ha^{-1} and for nettle up to 8 t·ha^{-1} [4; 5] .

Cultivation of hemp growing for fiber has been legalized in Lithuania since 2014. Widespread uses of this plant, such as biofuels, food, textile, construction materials are leading to an increase in the crop area, which significantly increased in 2014 and reached 1068.39 acres, and in 2016 the area was more than 2 times bigger and reached 2453.84 ha [6].

When converting energy herbaceous plants to biofuels, it is important to know whether the physical-mechanical properties, moisture content, calorific value, ash content of biofuels will allow the production of high-quality biofuels that can replace conventional wood-based biofuels [7-11].

The problem is that energy plants are not used in energy sector. We try to make it much popular, because it is used as fuel. Advantages are the energy independence, less price and work stability, the disadvantage is a bigger land use.

Aim of the presented research: to determine the suitability of unconventional energy crops – fiber hemp and fibrous nettle for the production of granulated biofuel and to investigate the thermal and physical-mechanical properties of biofuel granules.

Materials and methods

The research was carried out at the Vytautas Magnus University Agricultural Academy and the Lithuanian Energy Institute. Granules of fibrous nettle and fibrous hemp "Epsilon 68" and "Bialobzeskie" were selected for testing.

The physico-mechanical properties of the biofuel pellets were determined using the available at the university equipment. The moisture content of biofuel pellets has been studied according to the standard methodology [2]. The experiment is performed with 3 replicates, the determined data are processed statistically and the average moisture content of the pellets is calculated.

Density of the granules was determined by measuring and weighing them, and the density of the granules in dry matter (DM) was also calculated. The strength of the granules (compressive strength) was determined using the Instron 5960 physico-mechanical properties tester. Ready-to-test granules of different moisture content are placed horizontally on a stationary substrate and subjected to a vertical load up to their breaking point. The test data are automatically fixed on a computer and processed for the test result discussion and formulation of conclusions. The test was repeated 5 times with granules of different moisture content of each sort. The average means of data were calculated, and the dependence of the granule compressive strength on the moisture content of granules was analyzed.

The calorific value and ash content of the pellets were determined according to the standard methodology [9]. These studies were performed at the Lithuanian Energy Institute, Laboratory of Thermal Equipment Research and Testing according to ISO 18125: 2017 standard.

Results and discussion

Biometric properties and density of fibrous plant pellets

The biometric properties of fibrous plant pellets – their dimensions, mass and calculated density – are provided in Table 1.

Table 1

Properties of fibrous plant pellets

Plants sort	Diameter d, mm	Length l, mm	Volume V, m^3	Mass m, g	Density ρ, $kg \cdot m^{-3}$
Fibrous hemp "Bialobrzeskie"	6.10 ± 0.01	26.23 ± 0.56	(7.96 ± 0.74) · 10^{-7}	0.57 ± 0.05	1263.3 ± 45.1
Fibrous hemp "Epsilon 68"	6.07 ± 0.07	25.56 ± 1.88	(7.66 ± 0.34) · 10^{-7}	0.67 ± 0.04	1227.1 ± 65.3
Fibrous nettle	5.98 ± 0.05	25.69 ± 0.89	(7.21 ± 0.32) · 10^{-7}	0.89 ± 0.04	1221.6 ± 32.7

Investigation of the pellets with 10.0 ± 2.0 % moisture content revealed that the highest density was in the granules of fibrous hemp "Bialobzeskie" – 1263.3 ± 45.1 $kg \cdot m^{-3}$, and the lowest density was in the granules of fibrous nettle – 1221.6 ± 32.7 $kg \cdot m^{-3}$.

Dependence of compressive resistance of fibrous plant pellets on moisture content

Having performed the research, the received data were processed. After determination of the compression resistance of the granules, it was observed that the compression resistance decreased with increasing the granule moisture (Fig. 1-3). Analogous tendencies were found also in other types of fibrous plant pellets.

The accuracy of the coefficient of correlation R^2 between the moisture content and mechanical strength was 0.889 for fibrous hemp "Bialobrzeskie", 0.850 for fibrous hemp "Epsilon 68" and 0.990 for fibrous nettle.

After evaluation of pellet strength (compressive strength), it was found that at 10.0 ± 0.1 % moisture content of the pellets, the highest critical compressive strength was of fibrous hemp pellets "Bialobrzeskie"– 850 N, and the least resistant pellets were produced of fibrous hemp "Epsilon 68".

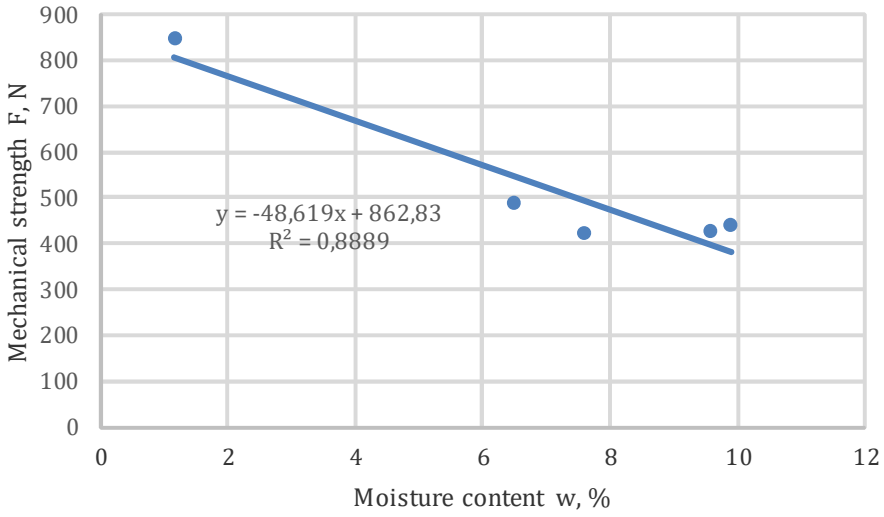

Fig. 1. **Dependence of compressive strength of "Bialobrzeskie" hemp on moisture**

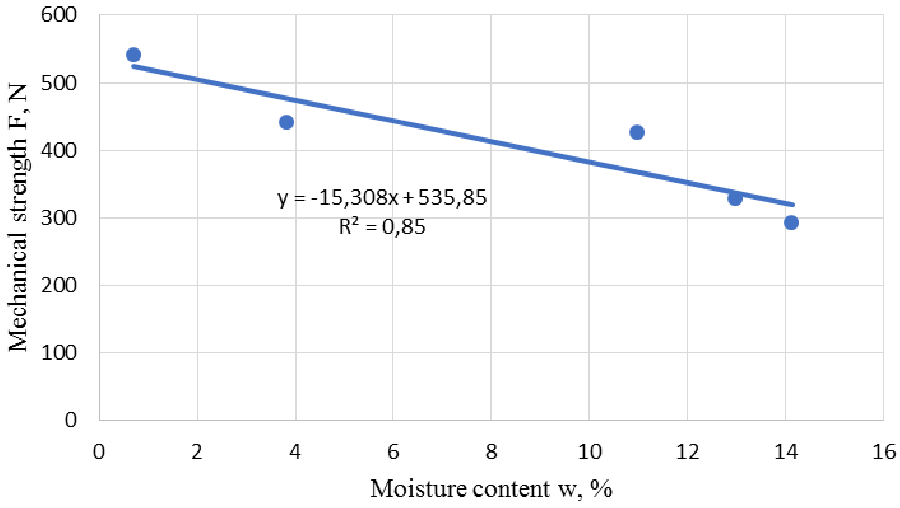

Fig. 2. **Dependence of compressive strength of "Epsilon 68" hemp on moisture**

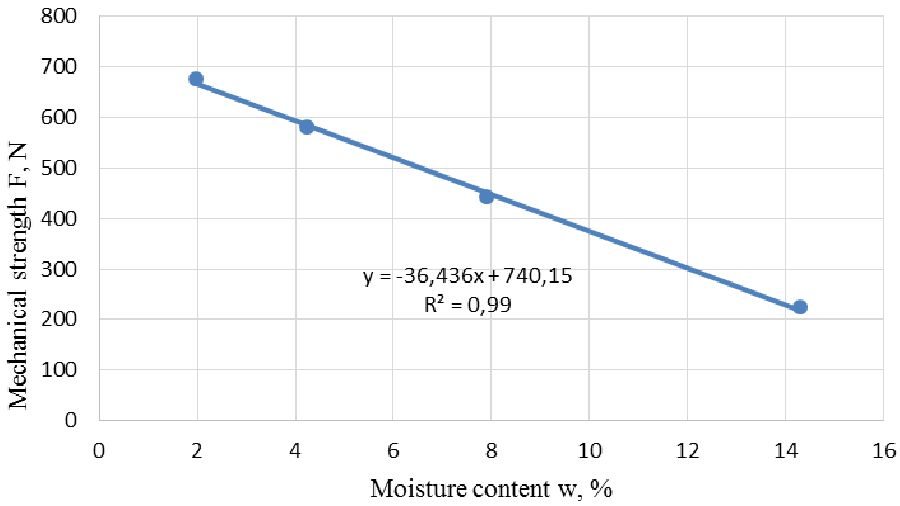

Fig. 3. **Dependence of compressive strength of nettle pellets on moisture**

Calorific value, ash content and elemental composition of pellets

The ash content, calorific value and elemental composition of fibrous plant pellets are shown in Table 2.

Table 2

Resesrch results of the pellet elemental composition, ash content and calorific value

Parameter	Plant sort		
	Fibrous hemp "Bialobrzeskie"	Fibrous hemp "Epsilon 68"	Fibrous nettle
C (carbon) amount, %	46.74 ± 1.09	46.61 ± 1.07	45.91 ± 1.09
H (hydrogen) amount, %	5.16 ± 0.43	5.94 ± 0.43	5.74 ± 0.43
N (nitrogen) amount, %	0.35 ± 0.31	0.29 ± 0.30	0.73 ± 0.31
S (sulphur) amount, %	0.12 ± 0.27	0.09 ± 0.26	0.11 ± 0.27
O (oxygen) amount, %	43.82 ± 0.0	43.52 ± 0.0	41.60 ± 0.0
Cl (chlorine) amount, %	-	-	0.55 ± 0.0
Ash content, %	3.80 ± 0.08	3.55 ± 0.01	5.91 ± 0.03
Moisture content, %	7.52 ± 0.07	6.88 ± 0.07	6.48 ± 0.07
Calorific value, $MJ \cdot kg^{-1}$	17.52 ± 0.35	17.33 ± 0.39	17.16 ± 0.57

From the data obtained in the table, it was observed that the granules of fibrous hemp "Bialobrzeskie" obtained the highest carbon (C) content – 46.74 %, and the least (C) content was found in fibrous nettle – 45.91 %. The highest oxygen (O) content was found in the pellets of fibrous hemp "Bialobrzeskie" (43.82 %) and the lowest – in the pellets of fibrous nettle (41.60 %). The determined nitrogen (N) content ranged from 0.29 % (fibrous hemp) to 0.73 % (fibrous nettle). The moisture content of the produced granules was similar and varied from 7.5 % (fibrous hemp "Bialobrzeskie") to 6.5 % (fibrous nettle).

Another very important quality criterion for pellets is the ash content of the fuel. The more ash, the poorer the fuel. High ash content can reduce the efficiency of the boiler, melting of ash creates slag and the boiler becomes contaminated. The highest ash content was found after burning of fibrous nettle pellets – 5.91 %, and the lowest – after burning of fibrous hemp "Bialobrzeskie" pellets – 3.55 %.

Based on the results of the pellet calorific value presented in Table 2, it can be stated that the prepared biofuel pellets are sufficiently calorific, because their calorific value is close to the calorific value of straw and woody plants: the fiber hemp calorific value was 17.52 $MJ \cdot kg^{-1}$. These parameters satisfy calorific value standards of vegetable pellets.

Other scientists have also studied fibrous plant pressed biofuel and its various properties. A.Kakitis, I.Nulle and D.Ancans researched fibrous hemp Bialobrzeskie, Futura 75 and Santhica 27 briquette properties – density (1185 $kg \cdot m^{-3}$) and mechanical strength (101.28-122.37 $N \cdot mm^{-1}$) [12]. L.Poiša and A.Adamovičs researched fibrous hemp "Bialobrzeskie" properties [13]. The calorific value reached Q = 17.76-18.98 $MJ \cdot kg^{-1}$, ash content 1.5-2.7 %.

Conclusions

1. After determination of the density of 10 ± 2 % moisture content of biofuel pellets, it was found that the pellets of fibrous hemp "Bialobrzeskie" have the highest density – 1263.3 ± 45.1 $kg \cdot m^{-3}$, and the lowest density was of pellets of fibrous nettle – 1221.6 ± 32.7 $kg \cdot m^{-3}$.
2. Based on the pellet strength, it was found that at a moisture content of 10.0 ± 0.1 %, the maximum critical compressive strength is that of the pellets of fibrous hemp "Bialobrzeskie" – 850 N force, and the lowest compressive strength (550 N force) is of pellets of fibrous hemp"Epsilon 68". It has been found that with the increasing moisture content of fibrous plant pellets their compression resistance decreases.
3. Having determined the thermal properties of the fibrous plant pellets, it has been shown that the prepared biofuel is sufficiently calorific, because its calorific value is close to that of straw and woody plants: the calorific value of fibrous hemp ranged from 17.33 to 17.52 $MJ \cdot kg^{-1}$. These and

other indicators of quality of the fibrous plant pellets meet the quality requirements raised for pellets standards.

Acknowledgements

The presented research results were obtained within the framework of the long term program of Plant biopotential and quality multifunctional practice. Also there are presented results of the project of long time development of the Research Institute of Agricultural Engineering p.r.i. No. RO0618 (Prague, Czech Republic).

References

[1] Alternative energy sources usage in Alytus region Druskininkai municipality potential study. Report. 2013. (In Lithuanian) [online] [2019-02-18]. Available at: www.lietuvosregionai.lt/lt/9/news/alytaus-regiono-naujienos/parengtos-alytaus-regiono-atsinaujinanciu-energijos-istekliu-panaudojimo-ir-turizmo-pletros-galimybiu-studiju-aplinkos-analizes-338.html

[2] Jasinskas A., Streikus D., Vonžodas T. Fibrous hemp (Felina 32, USO 31, Finola) and fibrous nettle processing and usage of pressed biofuel for energy purposes. Renewable energy, vol. 149, 2020, pp.11-21.

[3] Streikus D., Jasinskas A., Šarauskis E., Romaneckas K., Marks M. Technological-technical and environmental evaluation of herbaceous plants usage for the production and burning of granulated biofuel. Polish Journal of Environmental Studies, 2020, pp. 1-2.

[4] Šateikis I. Potential of plant biomass cultivation and use for solid fuels and priority of research the present problems. Žemės Ūkio Inžinerija, Mokslo Darbai, vol. 38.3, 2006, pp. 5-21.

[5] Maročkienė N. Artichoke (Heliantus tuberosus L.) morphological index and knobs productivity assessment. Mokslo darbai. Sodininkystė ir daržininkystė, vol. 26.1, 2007, pp. 102-107.

[6] Lithuanian Agriculture Ministry. Fibrous hemp in Lithuania – more popular. 2017. (In Lithuanian) [online] [2019-02-18] Available at: https://zum.lrv.lt/lt/naujienos/pluostines-kanapes-lietuvoje-vis-populiaresnes .

[7] Šlepikas O., Čereška A. Biofuel drying process efficiency research. Science: Future of Lithuania, 2013, pp. 5-6.

[8] Streikus D., Jasinskas A., Arak M., Jotautienė E., Mieldažys R., Čekanauskas S., Jankauskienė Z. Investigations of fibre plants preparation and utilization of solid biofuels. Agronomy research, vol. 14(1), 2016, pp. 259-268.

[9] ISO, E. N. 18125. Solid Biofuels – Determination of Calorific Value, 2017.

[10] Sippula O., Lamberg H., Leskinen J., Tissari J., Jokiniemi J. Emissions and ash behavior in a 500 kW pellet boiler operated with various blends of woody biomass and peat. Fuel, vol. 202, 2017, pp. 144.

[11] Malatak J., Passian L. Heat-emission analysis of small combustion equipments for biomass, Research in agricultural engineering, vol. 57, 2011, pp. 37–50.

[12] Kakitis A., Nulle I., Ancans D. Mechanical properties of composite biomass briquettes. Environmental. Technology. Resources. Proceedings of the 8th international scientific and practical conference, vol. 1, 2011, pp. 175.

[13] Poiša L., Adamovičs A. Evaluate of hemp (Cannabis sativa L.) quality parameters for bioenergy production. Engineering for Rural Development, Proceedings of the 10th international scientific conference, Jelgava. 2011, pp. 358.