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## BRIQUETTING WASTE MATERIAL IN A PROTOTYPE PELLETIZING AND BRIQUETTING ARRANGEMENT<sup>1</sup>

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### ABSTRACT

The objective of the paper was to determine usefulness of a new, prototype pelletizing and briquetting device for the process of briquetting waste vegetal material. During research the impact of potato pulp content (15, 20 and 25%) in the mixture with buckwheat husk and the mass intensity of raw material flow (100, 150 and 200 kg·h<sup>-1</sup>) on the demand of a device for power and kinetic strength of the obtained briquette were determined. Tests on briquetting were carried out with the use of a flat briquetting matrix with a diameter of meshes of 28 mm and the length of 80 mm cooperating with the system of three densifying rolls, which move with the speed of 120 rot·min<sup>-1</sup> and with the fissure between the rolls and the matrix equal to 0.4 mm. The quality of briquettes was assessed with the use of a rotating tester according to recommendations of standards GOST-18691-73 and ASAE S.269-1A. Based on the research which was carried out, a significant impact of the mass intensity of raw material flow and the percentage share of potato pulp in the compacted mixture for the power demand and kinetic strength of the obtained briquette was found.

## Introduction

In the process of briquetting, loose (crumbled) vegetal material is compacted under external and internal force and the obtained product reaches a determined permanent geometric form. Most frequently it is in the form of a cylinder with a diameter of 20÷100 mm and length of 30÷500 mm. The product (briquette) obtained in the process should have appropriate mechanical strength so that during transportation or storing it does not crumble. In case of fuel briquettes made of plant material, their higher strength, which is the most frequently related to their higher density, results in their better combustion kinetics.

According to many authors (Hejft, 1995; Hejft and Demianiuk, 1999) vegetal waste in the form of briquettes have many advantages therefore they can be used e.g. for combustion in many types of furnaces, kinetics of their combustion is similar to combustion of wood pieces (logs), several times higher density of briquettes in comparison to chips and sawdust

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significantly decreases the area of their storing and the costs of transportation, combustion of briquettes is safe and brings no risk of explosion, briquettes may be exported as organic fuel with prices higher than coal etc.

Most frequently, wood material waste average in size (chips) and small (sawdust, dust left after grinding wood) are processed into fuel briquette (Hejft, 2000). However, in the recent years development of briquetting technology of vegetal waste useful, took place. Moreover, other waste vegetal materials are used for production of briquettes. These are: straw briquetted with a rolling method (Adamczyk, 2010; Fiszer, 2008), fodder maize (Niedziółka et al., 2008), grasses (Karunanithy et al., 2012), waste from production of bananas (Wilaipon, 2007; Sellin et al., 2013), rice straw (Chou et al., 2009) or rapeseed straw, wheat straw, meadow straw and Virginia mallow stem (Niedziółka et al., 2011).

According to Demianiuk (2003) on account of a varied "susceptibility" to compaction, some materials should be mixed with other vegetal material or gluing material (most preferably organic one) should be used. This is confirmed by Oladeji's (2010) research, who briquetted mixtures of maize cob waste and rice husk or research carried out by Yaman and co-authors (Yaman et al., 2000), who compacted mixtures of olive oil refuse after production and paper mill waste.

There are such waste materials, in case of which production of fuel briquettes is non-profitable. Thus, for new vegetal material subjected to briquetting, tests should be carried out in order to determine its susceptibility to compaction, determination of optimal parameters of the compaction process, which will allow obtaining a product with good quality and will answer the question whether the compaction process is economically profitable.

## **Objective of the paper**

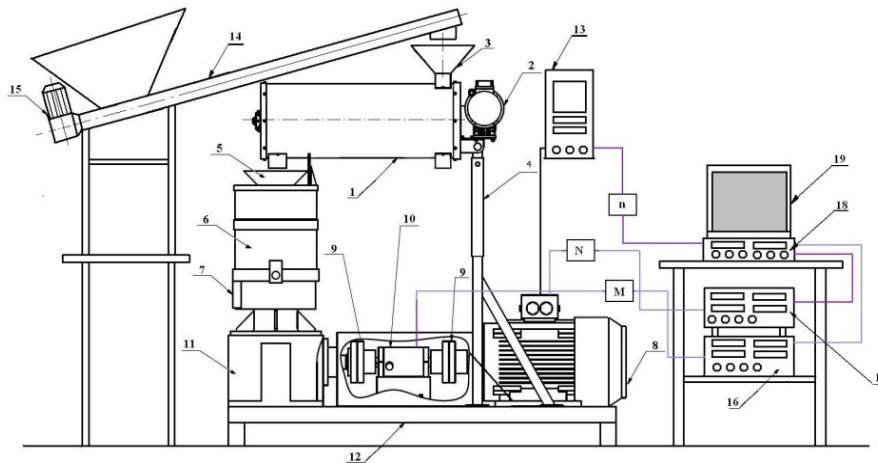
The objective of the paper was to carry out initial evaluation of the usefulness of the new, prototype pelletizing and briquetting device for performance of the briquetting process of waste vegetal material or determination of the impact of the potato pulp content in the mixture with buckwheat husk and mass intensification of raw material flow on the power demand of the prototype pelletizing and briquetting device and on the kinetic strength of the obtained briquette.

## **Methodology of research**

A mixture of buckwheat husk and potato pulp constituted the research material subjected to the pelletizing process in the working system of the new, prototype pelletizing and briquetting device.

Tests with regard to the briquetting process were carried out on the prototype pelletizing and briquetting device (fig. 1) with the use of a flat matrix (fig.2) with a diameter of meshes of 28 mm and length of 80 mm cooperating with the system of three compacting rolls.

a)



b)



Figure 1. Test rigs with new prototype densifying-briquetting device with a flat immovable matrix: a) scheme of test rigs: 1 – mixing–densifying–dosing system, 2 – drive of mixing–densifying–dosing drive (electric engine connected to reducer), 3 – feed of raw material to mixing–densifying–dosing system, 4 – mounting frame for mixing–densifying–dosing system, 5 – batch of initially compacted raw material to working system of pelletizer, 6 – working system of pelletizer, 7 – discharge of pellets from working system, 8 – drive of pelletizer (electric engine), 9 – clutch, 10 – measuring torque Mi20, 11 – toothed gear, 12 – base, 13 – frequency converter, 14 – batcher, 15 – drive of batcher (electric engine connected to reducer), 16 – index of rotational moment and force WT-1, 17 – device for measuring active power METROL KWS 1083, 18 – recorder Spider 8, 19 – PC computer b) view of test rigs

Innovativeness of a device is related to a new solution of a dividing material device to the working system of a pelletizer, with introduction in the mixing-densifying-dosing device to the working system of a pelletizer and with the use of a densifying-briquetting matrix.



*Figure 2. Briquetting matrix with diameter of meshes of 28 mm and length of meshes (sleeves) 80 mm*

Drive of the pelletizer 6 is composed of the electric engine 8 from which torque was transferred to the pelletizer shaft 6 through the system of two clutches 9 (between which the measuring torque 10 is mounted) through the conic toothed gear 11. For regulation of torque of the pelletizer shaft 6 the frequency converter 13 coupled with the electric engine 8 was used.

Feeding the compacted raw material to the working system of the pelletizer 6 was ensured by the use of the screw batcher 14, the drive of which 15 is made of the electric engine combined with a reducer. The screw conveyor 14 is also equipped with a frequency converter, which enables the change of the fed raw material to the working system of the pelletizer 6. From the screw conveyor, raw material gets through the feed 3 into the mixing-densifying-dosing system 1. The driveline of the mixing-densifying-dosing device 1 consists of the electric engine 2 from which the drive is transferred through the chain transmission onto the shaft of the mixing-densifying-dosing device 1. From the mixing-densifying-dosing device 1 raw material gets to the working system of the pelletizer 6.

The test rig was equipped with a universal measuring device for measurement of the power demand of the device 17 in the indicating device of the torque and force 16 (WT-1 type) and the recorder 15 clutched with a computer 19. Signals from the measuring tool of the power demand of the device 17, from the indicator of torque and force 16 were transmitted to the recorder 18 in the form of binary flies, which were subjected to further processing in Statistica 10.0 PL.

During the research, the impact of the potato pulp content (15, 20 and 25%) in the mixture with buckwheat husk and the mass intensity of raw material flow ( $100 \text{ kg}\cdot\text{h}^{-1}$ ,  $150 \text{ kg}\cdot\text{h}^{-1}$  and  $200 \text{ kg}\cdot\text{h}^{-1}$ ) on the demand of a device for power and for the kinetic strength of the obtained briquette were determined. Tests were carried out at the rotational speed of compacting shafts equal to  $120 \text{ rot}\cdot\text{min}^{-1}$  and at the fissure between the shafts and the matrix of 0.4 mm.

The quality of briquettes was assessed at the test rigs for measurement of the kinetic strength with the use of a rotating tester according to the recommendations of standards GOST-18691-73 and ASAE S.269-1A. During the test 10 randomly selected briquettes with a similar mass were fed to the chamber ( $\pm 10\%$ ). The test was carried out within three minutes with the velocity of  $13 \text{ rot}\cdot\text{min}^{-1}$ . Relation of the mass of briquettes after the test to the mass of briquettes before the test (expressed in %) determined the kinetic strength of briquettes.

Moisture of the mixture components and mixtures of the tested waste were determined according to PN-EN 14774-1:2010 with the use of a moisture meter WPE 300S, determining each time moisture of five samples with mass of 5 g, which were dried in the temperature of  $105^\circ\text{C}$  to the moment a fixed mass was obtained. Average value from the obtained determinations was assumed as the final result of moisture.

## Results of the research

Table 1 presents the research results of the compaction process of the mixture of buckwheat husk with potato pulp on the new, prototype densifying-briquetting device with a flat, immovable briquetting matrix.

Table 1

*Research results of compaction process of mixture of buckwheat husk with potato pulp on new prototype densifying-briquetting device with the use of a briquetting matrix*

No. of mea- surement	Independent variables		Dependent variables		
	$x_1 = z_w$ (%)	$x_2 = Q_m$ ( $\text{kg}\cdot\text{h}^{-1}$ )	Power demand of device $N_g$ (kW)	Unit energy consumption of process $E_j$ ( $\text{kWh}\cdot\text{t}^{-1}$ )	Kinetic strength of briquette $P_{dx}$ (%)
1	15	100	6.01	60.10	94.50
2	15	150	8.21	54.73	93.95
3	15	200	11.37	56.85	93.01
4	20	100	5.01	50.10	92.10
5	20	150	7.89	52.60	92.10
6	20	200	8.69	43.45	89.82
7	25	100	3.95	39.50	83.40
8	25	150	4.93	32.87	81.60
9	25	200	5.19	25.95	77.60

$z_w$  – content of potato pulp in mixture;  $Q_m$  – mass intensity of raw material flow

Figure 3 presents a graphic interpretation of the obtained results of research on the impact of the potato pulp content in the mixture with buckwheat husk and mass intensity of raw material flow on the power demand of the device during compaction of the mixture of buckwheat husk and potato pulp with the use of a briquetting matrix.

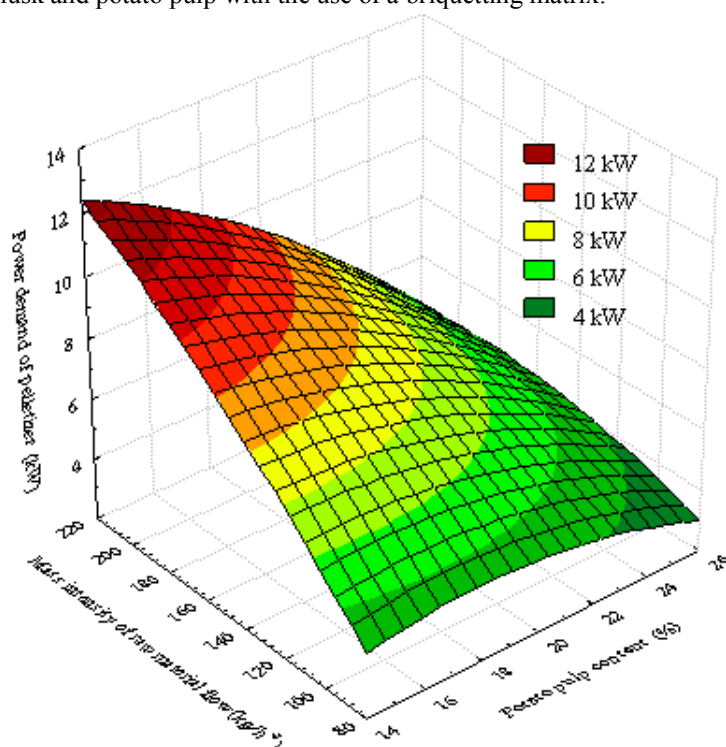


Figure 3. Impact of the potato pulp content in the mixture of buckwheat husk and mass intensity of raw material flow on power demand of pelletizer

Based on the research (fig. 3 and table 1) it was found out that increase of the mass intensity of raw material flow from 100 to 200 kg·h<sup>-1</sup> causes the increase of the power demand of the engine which drives the device during compaction process of the mixture of buckwheat husk and potato pulp. Whereas increase of the potato pulp content from 15 to 25% in the mixture with buckwheat husk caused decrease of the power demand value of the device. For example, the increase of the mass intensity of raw material flow from 100 to 200 kg·h<sup>-1</sup>, at 15% of the potato pulp content in the mixture with buckwheat husk causes the growth of power demand of the engine which drives the device by approx. 89% (from 6.01 to 11.37 kW), at 20% of the pulp content in the mixture with buckwheat husk results in the growth on the power demand by approx. 73% and at the 25% pulp content in the mixture with buckwheat husk – growth of demand was approx. 31%.

The obtained decrease of power demand of the pelletizer results mainly from a considerable growth of mixture moisture caused by the increase of the potato pulp content from 15 to 25%. Moisture of the compacted mixture increased from 18.63% (at 15% pulp con-

tent in the compacted mixture) to 26.23 % (at 25% of the pulp content in the compacted mixture). Increase of the pulp content in the compacted mixture caused formation of higher amounts of binder (in the form of viscous liquid from starch and moisture) during pelletizing. The growing content of viscous liquid caused the effect of "smearing" of the surface of meshes in the matrix of a pelletizer and decrease of the pressing resistance. Reduction of pressing resistance allowed as a consequence decrease of the value of power demand of a pelletizer. It is confirmed by other tests carried out for the mixture of oat bran and potato pulp (Obidziński and Hejft, 2013).

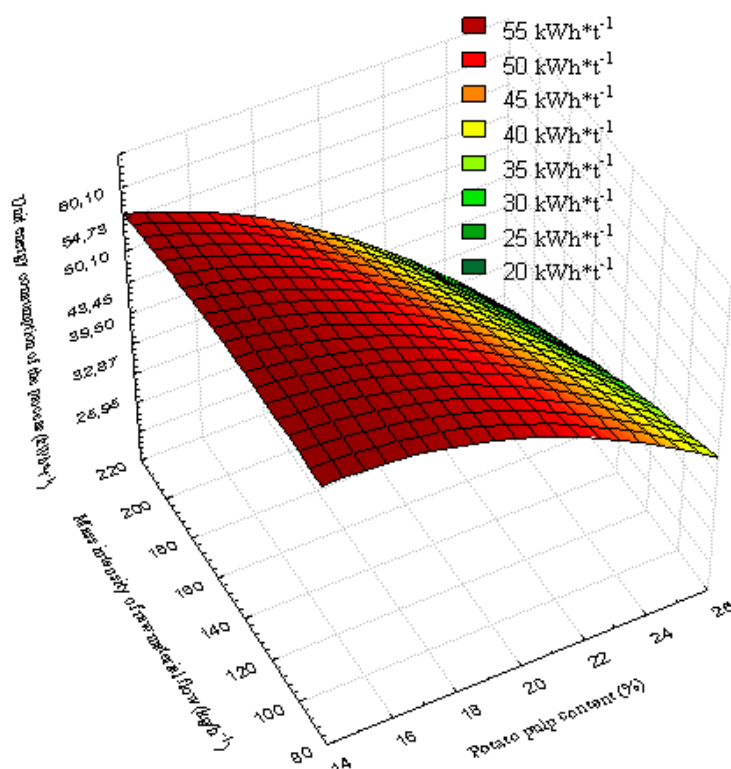


Figure 4. Impact of potato pulp content in mixture of buckwheat husk and mass intensity of raw material flow on the unit energy consumption of compaction process

The research, which was carried out (fig. 4 and table 1) allow stating that the increase of both mass intensity of flow of raw material from 100 to 200 kg·h<sup>-1</sup>, as well as the increase of the potato pulp content from 15 to 25% in the mixture with buckwheat husk causes also decrease of the unit energy consumption of the compaction process.

Figure 5 presents results of research on the impact of the potato pulp content in the mixture with buckwheat husk and mass intensity of raw material flow on the kinetic strength of briquette obtained during compaction of the mixture of buckwheat husk and potato pulp with the use of a briquetting matrix.



Results of the research (fig. 5 and table 1) allow stating that both the increase of mass intensity of flow of raw material from 100 to 200 kg·h<sup>-1</sup>, as well as the increase of the potato pulp content from 15 to 25% in the mixture with buckwheat husk causes also decrease of the kinetic strength of briquette. For instance, the increase of the mass intensity of raw material flow from 100 to 200 kg·h<sup>-1</sup> (at the potato pulp content of 15% in the mixture with buckwheat husk) caused decrease of the kinetic strength of briquette from 94.5% to 93.01. Decrease was higher than the potato pulp content which was 25% in the mixture with buckwheat husk because the kinetic strength dropped from 83.4 to 77.6%.

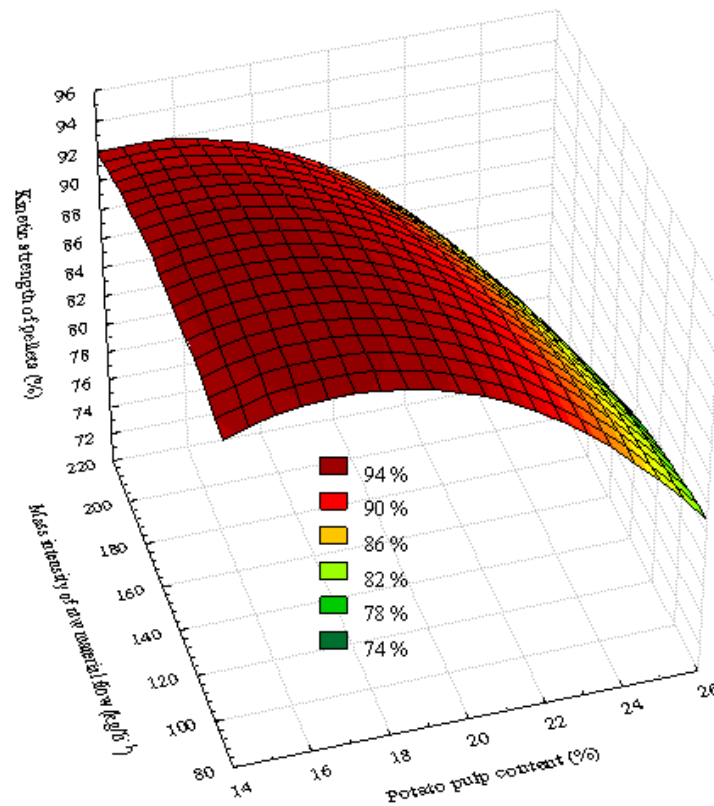


Figure 5. Impact of potato pulp content in mixture of buckwheat husk and mass intensity of raw material flow on kinetic strength

Based on the research which was carried out, it may be stated that the potato pulp addition up to approx. 20% to buckwheat husk allows obtaining briquette of a satisfactory quality.



## Conclusions

1. The research which was carried out confirmed that the new, prototype pelletizing – briquetting device was useful for the process of briquetting waste vegetal material.
2. Increase of the mass intensity of flow of raw material from 100 to 200 kg·h<sup>-1</sup> caused the increase of the power demand of the engine which drives the device during the compaction process of the mixture of buckwheat husk and potato pulp even by approx. 89% (at 15% of the potato pulp content in the mixture with buckwheat husk from 6.01 to 11.37 kW) whereas the decrease of the content of potato pulp from 15 to 25% in the mixture with buckwheat husk caused the decrease of the value of power demand of the device to approx. 35% (from 6.01 to 3.95 kW at the mass intensity of flow of 100 kg·h<sup>-1</sup>).
3. The increase of the mass intensity of flow of raw material from 100 to 200 kg·h<sup>-1</sup>, as well as the increase of the potato pulp content from 15 to 25% in the mixture with buckwheat husk causes also decrease of the unit energy consumption of the compaction process.
4. The increase of the mass intensity of flow of raw material from 100 to 200 kg·h<sup>-1</sup>, as well as the increase of the potato pulp content from 15 to 25% in the mixture with buckwheat husk causes also a slight decrease of the kinetic strength of briquette obtained from the mixture of buckwheat husk and potato pulp.

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## **BRYKIETOWANIE MATERIAŁÓW ODPADOWYCH W PROTOTYPOWYM UKŁADZIE GRANULUJĄCO-BRYKIETUJĄCYM**

**Streszczenie.** Celem pracy było określenie przydatności nowego, prototypowego urządzenia granulująco-brykietującego do realizacji procesu brykietowania odpadowych materiałów roślinnych. W trakcie badań określano wpływ zawartości wycierki ziemniaczanej (15, 20 i 25%) w mieszaninie z łuską gryki i masowego natężenia przepływu surowca (100, 150 i 200 kg·h<sup>-1</sup>) na zapotrzebowanie urządzenia na moc oraz na wytrzymałość kinetyczną otrzymanego brykietu. Badania brykietowania przeprowadzono z wykorzystaniem płaskiej matrycy brykietującej o średnicy otworów 28 mm i długości 80 mm współpracującej z układem trzech rolek zagęszczających, poruszających się z prędkością 120 obr·min<sup>-1</sup> oraz przy szczelinie między rolkami a matrycą równej 0,4 mm. Jakość brykietów oceniono z wykorzystaniem testera obrotowego, zgodnie z zaleceniami norm GOST-18691-73 oraz ASAE S.269-1A. Na podstawie przeprowadzonych badań stwierdzono istotny wpływ masowego natężenia przepływu surowca oraz udziału procentowego wycierki ziemniaczanej w zagęszczanej mieszaninie na zapotrzebowanie na moc oraz wytrzymałość kinetyczną otrzymanego brykietu.

**Słowa kluczowe:** brykietowanie, odpady roślinne, łuska gryki, wycierka ziemniaczana