INFLUENCE OF DEGREE OF FRAGMENTATION ON CHOSEN QUALITY PARAMETERS OF BRIQUETTE MADE FROM BIOMASS OF CUP PLANT *SILPHIUM PERFOLIATUM* L.

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Abstract. Energy plant species are plants characterized by high annual growth, resistance to disease and pests, small habitat requirements and adaptation to the Polish climatic conditions. A new species, characterized by high values of pro energetic attributes is cup plant *Silphium perfoliatum* L. The aim of the research was to determine the influence of the material fragmentation degree on the selected quality parameters of briquette from cup plant biomass. Briquetting was conducted at the pressure of agglomeration: 27 MPa, 37 MPa, 47 MPa. The research material was cup plant shoots pre-chipped to the theoretical length L = 10 mm and then milled into a hammer mill using a sieve with the diameter of holes: ø10 mm (S10) and ø6 mm (S6). The obtained briquette quality was assessed according to the guidelines included in. Accordance with these requirements determined the specific density of the briquette. Further the durability of the obtained briquettes according to was determined. It has been shown that the greater degree of material fragmentation causes an increase in the investigated quality parameters but the briquette obtained from the chipped raw material is characterized by allowed standard quality, so in the cup plant briquetting process we can skip the grinding stage.

Keywords: cup plant, biomass, solid biofuels quality, briquetting.

Introduction

In Poland, the greatest hopes are still associated with the use of biomass as a primary source of renewable energy. Therefore, energy plantations should be the main source of biomass for the production of solid biofuels such as bales, wood chips, pellets and briquettes. This will ensure a certain amount of biomass with uniform quality, required in the processes of processing and combustion.

Willow *Salix viminalis L.* is considered as the most popular energy plant, which different varieties and clones are grown on perennial plantations. However, water and soil requirements of this plant determine that it cannot be grown all over potentially available for energy crops acreage. The Polish territory is characterized by a great diversity of soil conditions, so prospective growers must have to their disposal a wide range of plant species in order to adapt the type of crop to the soil-water characteristics of the owned habitat [1-5]. This approach to energy crops will allow producing the maximum yield of biomass while minimizing the expenditures on the establishment and operation of crops.

The plants characterized by high annual growth, resistance to disease and pests, small habitat requirements and adaptation to the Polish climatic conditions are considered to be potential energetic species used to produce biofuels.

The species like this can be cup plant, which until now has been used as a forage plant, giving honey and curative. However, due to pro-energetic properties it can serve as a source of biomass for energy purposes [6; 7]. However, there is lack of research on the issues of briquetting of milled cup plant biomass and the quality of the obtained briquettes.

The aim of the study was to determine the effect of the degree of fineness material on the selected quality parameters of briquette from cup plant biomass.

Materials and methods

Cup plant *Silphium perfoliatum,* also known as *sylfia*, is a large, acervate perennial of the aster family (Asteraceae) as well as sunflower and topinambour, the species originating from North America, which is a component of prairie vegetation. It occurs in large areas of Canada and the United States. In the XVIII century it was brought to Europe because of its decorative values and used in naturalistic plantings in parks and gardens. In the former Soviet Union it was grown for feeding. A similar trend in the use cup plant is propagated in Belarus and Ukraine [8], however, in the light of different researches, the high content of phenolic acids reduces the possibility of using them for this purpose [9; 10]. However, the high content of saponin compounds in leaves, inflorescences and rhizomes is a valuable raw material for the pharmaceutical industry [11]. This plant is also valuable, giving honey species. Its performance of honey is 550 kg·ha^{-1} [12], and pollen 200-300 kg·ha^{-1} [13]. In recent years, due to the low nutritional requirements it can be used as a pioneer plant for reclamation of degraded land. Due to the high yield – 15-19 t·ha^{-1} of dry weight [5], this plant is considered as energy plant. Energetic plantations should be assumed in the autumn (X-XI), by sowing seeds in rows with a pitch of 100 cm [6].

The morphology of the species is as follows (Fig. 1): plant with a nude quadrangular stem, reaching the height of 2.5-3 m. In the first year of growth it produces only a rosette of leaves, the generative shoots grow in subsequent years. The number of shoots (10-25) increases with age. The stems made up of 8-12 internodes about the length of 20-30 cm are filled with spongy core. The leaves are triangular or oval-ovate to 40cm long, with a serrated edge, covered with rough hairs and arranged in pairs along the stem. The lower leaves with winged petioles, the upper leaves are slightly shorter, sitting and covering the stem. Yellow flowers with a diameter of 5-7.5 cm are gathered in loose cymes. Blooming from July to September. The seeds are gray-brown achenes. An advantage of the species is high frost resistance (can withstand temperature drops below -25 ºC).

Foto: M. Wróbel

Fig. 1. **Cup plant *Silphium perfoliatum* L.:** 1 – generative shoot; 2 - flower bud; 3 – flower; 4 – fructification; 5 – seeds; 6 – cross section of shoot

Briquetting was conducted at compaction pressure: 27 MPa, 37 MPa, 47 MPa, cup plant shoots were the research material, derived from experimental plantations, pre-shredded in a straw cutter to the theoretical length 10 mm (L10) and then ground into a beater mill using a sieve with a diameter of holes: ø10 mm (S10) and ø6 mm (S6). Humidity of the briquetted material was set at 12 %.

Granulometric composition measurement of the material was performed on a shaker LPzE-4e Morek Multiserw equipped with a set of sieves with round holes in the diameter of 45, 16, 8 and 3.15 mm and a braided screen with square holes of 2,8; 2; 1,4; 1; 0; 5 and 0,25 mm (according to the standards [14] and [15].

The resulting briquette was assessed of quality according to the guidelines set in standards [16]. In accordance with the requirements in norm, a specific density of briquettes was set by using a kit for determining the specific density – RADWAG - WPS 510/C/1.

Further the mechanical durability of the obtained briquettes was specified. The measurement was carried out in accordance with [17]. Samples of 2 kg (± 0.1 kg) were placed in a tester drum equipped with a special shelf accelerating the process of destruction of the briquettes. In accordance with the guidelines of norm, the drum was rotating at 21 $r \cdot min^{-1}$, and the duration of the test was 5 min. After the end of the test the briquettes were screened through a sieve with a hole diameter of 35 mm. The material remaining on the sieve was weighed on a laboratory scale with an accuracy of 0.1 g, and the durability of the briquette DU (mechanical durability) was calculated from the formula (1):

$$DU = \frac{m_A}{m_E} \cdot 100\% \tag{1}$$

where DU – mechanical durability of briquette, %;
m_A – mass of the sample after the test, g;
m_E – mass of the sample before the test, g.

Mechanical durability of briquettes is defined as the immunity to external dynamic factors which are causing damage. It is the one of the most important features determining the easiness of transport, storage and using of the biofuel. Although the current normative regulations [16] do not require mandatory labeling of durability, however, it was included in this study because it is important, especially for individual customers.

Results and discussion

The first stage of the study concerned the measurement of the grain size distribution of the research material. Table 1 shows the percentage of the mass of the individual fractions. As it can be seen, in the case of a theoretical chaff length of 10mm (L10), the largest group is the fraction remaining on the sieve mesh diameter 3.15 mm (67.92 %), while the fraction passing through the sieve of 19.8 %. Geometrical characteristics of the milled material (S10 and S6) are shown in the aforementioned Table 1. It was observed that the grain size distributions of these materials are similar and are characterized by the dominant fraction remained on the screen ø15mm (35.25 % of the material S10 and 47.92 % for the material S6). In both cases, most of the particles have the size less than 2mm. The difference between these materials can be observed for the remaining fraction of the 3.15 mm sieve, which participated in the first case, (S10) is up 14.58 %, and in the second case (S6) it is negligible (0.47 %).

Table 1

Grain size distribution of particulate material in the straw cutter and mill at 12 % humidity

Material after chaffing	Diameters of sieve shaker, mm				
	45	16	8	3,14	<3,14
	Percentage share				
L10	-	1.7	11.74	66.76	19.8

Material after milling	Diameters of sieve shaker. mm								
	8	3.2	2.8	2	1.4	1	0.5	0.25	Dust
	Percentage share								
S10	-	14.58	0.25	2.63	16.02	11.41	35.27	12.5	7.34
S6	-	0.47	-	1.38	15.06	11.9	47.92	14.66	8.61

The material described above, after determining the humidity of 12 %, has been subjected to the process of briquetting at the pressure of 27, 37 and 47 MPa. The product obtained was evaluated in terms of quality characteristics, such as mechanical durability and specific density. The obtained values of the above parameters are shown in Table 2.

In the case of density of briquettes for all research variants, the obtained lowest class DE 0.8 – according to [16]. The obtained values are from 836.5 kg·m^{-3} to 989.9 kg·m^{-3}. The increase in density of the obtained briquettes was due to both: increase of the compaction pressure and the degree of fragmentation of the material. It must therefore be concluded that briquetting of cup plant biomass at the pressure at least 27 MPa allows to obtain briquettes with satisfying quality standards for density.

A similar correlation was observed in the case of mechanical durability of the obtained briquettes. The lowest durability (80.2 %) was characterized by the briquettes from chopped straw of cup plant (L10) briquetted at the compaction pressure 27 MPa, the highest durability (95.04 %) was observed for the material with the highest degree of fragmentation (S6) compacted under the compaction pressure 47 MPa.

Table 2

Quality parameters of briquettes with humidity of 12 %

Quality parameter		Particulate material								
		L10			S10			S6		
		Pressure, MPa								
		27	37	47	27	37	47	27	37	47
Mechanical durability, %	Mean	80.2	88.14	93.09	89.7	91.53	94.97	92.51	93.06	95.04
	Std deviation	0.95	0.9	0.35	0.34	0.48	0.34	0.33	0.32	0.67
Specific density, kg·m^{-3}	Mean	836.5	890.3	922.3	885.8	915.6	982.1	920.2	941.8	989.9
	Std deviation	13.56	17.74	18.5	12.46	15.04	11.7	11.05	11.28	8.15

Conclusions

The results of the qualitative assessment of the obtained briquettes showed that:

1. Cup plant biomass is a suitable raw material for the production of compact solid biofuels (briquettes).
2. It has been shown that the greater degree of fragmentation of the material increases the quality of the studied parameters.
3. In the case of density of briquettes for all research variants the lowest quality class obtained was DE 0.8. The range of the obtained values was 836.5 kg·m^{-3} to 989.9 kg·m^{-3}.
4. Briquettes obtained from the raw material from straw cutter (L10) are characterized by the quality allowed by the standard (mechanical durability – 93.09%, specific density – 922.7 kg·m^{-3}).
5. Taking into account the optimization of the energetic expenditure incurred in the production of briquettes from cup plant, a variant of production without a very energetic milling process can be taken into account, due to the fact that the quality parameters of biomass briquettes made from milled biomass is slightly higher than the parameters of briquettes from chaff length of 10mm.

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