PRESSURE AGGLOMERATION OF BIOMASS WITH ADDITION OF CALCIUM CARBONATE

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Abstract. According to the biomass physical properties, including a low density, it is commonly converted into form of pellets or briquettes, improving the characteristics of the solid fuel. Formed biomass has a higher calorific value and a lower moisture content and that purpose could be served by natural binders or special additives. Calcium carbonate binds water from the biomass and allows to agglomerate materials with a higher moisture content without a necessity of drying. The aim of the study was to determine the influence of calcium carbonate on the physical properties of the obtained pellets from hay and straw. The biomass and pellets without and with the addition of 10 % of calcium carbonate were examined. The studies were performed according to standards. The scope of research included tests of bulk and specific density, durability and gross calorific value. It was found that addition of calcium carbonate generally increased the durability of pellets, above 97 % and the durability was positively correlated with the pellet bulk density. The addition of calcium carbonate significantly increased the density of the pellets by 26 %, but the dynamic of changes was varied for different types of biomass. Calcium carbonate slightly decreased the gross calorific value but the addition of calcium carbonate in the production process significantly increased the effectiveness of the agglomeration process and allowed for agglomerating the raw materials with a higher moisture content than ever before.

Keywords: biomass, calcium carbonate, pressure agglomeration.

Introduction

Biomass is commonly converted in the pressure agglomeration process into form of pellets or briquettes because of its physical properties, such as a low density. The selection of the proper type of biomass, its fragmentation, conditioning process, addition of special binders and the valid process of agglomeration allow to obtain pellets with high quality in respect of their durability. Produced agglomerates have better, improved characteristics, compared with a raw material. The raw material, especially of a high moisture content has strengthened influence between the particles what worsens the material mechanical properties [1] and causes an adverse influence on the pressure agglomeration process [2]. Moreover, biomass is a hygroscopic material and is characterized by a high susceptibility on the absorption of the moisture from the air. This leads to crushing and expansion of the pellets during storage [3]. Furthermore, this parameter has a great importance for the calorific value. However, after crossing a border of the moisture content it permeates through capillaries and pores to the particle interior [4]. To avoid this and improve the pellets properties it is possible to add some natural binders to the material. On the basis of the state of the issue it can be stated that additives increase the quality and environmental performance of the pellets [5]. Applied binders increase the pellets durability [6], strengthen [7] and decrease the energy efficiency of the pressure agglomeration process [8]. Additionally, the formed biomass has a higher calorific value and a lower moisture content and that purpose could be served by natural binders or special additives. One of them is calcium carbonate. The molecules of calcium carbonate create special clusters and after that they connect with themselves randomly to bigger aggregations [9]. That indicates that calcium carbonate has an ability to linking with other particles and make the bonds with them very durable. Except that, calcium carbonate binds water from the biomass [10] and allows to agglomerate materials with a higher moisture content without necessity of drying.

Knowledge of the fundamental compaction properties of different biomass species, bulk densities and sizes is essential to optimize densification processes [11-13]. The properties of the obtained pellets are important due to their quality and usefulness to combustion.

The aim of the study was to determine the influence of calcium carbonate on the physical properties of the obtained pellets from hay and straw biomass.

Materials and methods

The pellets for tests were produced in the production facility named “Polish Energy Partners – Biomasa Energetyczna Wschód Sp. z o.o.” in Zamość (in Poland). The pellets were produced on the technological line equipped with a system of adding calcium carbonate $CaCO_3$ to decrease the moisture content in the raw material. That binder was stored in the special container and was gravitationally added to the screw conveyor and then through a dozer to the conditioner. The supplied material was mixed with a binder – 10 % of calcium carbonate, and after that it was agglomerated in the granulating unit chamber consisting of a ring die with 6 mm holes and the pressure rollers into form of pellets in the comparable conditions. The obtained pellets were cooled to the temperature of 6-10 ºC and were stored. For the tests the biomass from hay and straw with the moisture content of 15.45 ± 0.12 % and 16.52 ± 0.17 %, respectively, was used. The mean geometric value of the particles was 3.12 mm for hay and 2.72 mm for straw. Whereas, for further tests, the obtained pellets from hay and straw with the moisture content of 9.44 ± 0.09 % and 10.58 ± 0.10 %, respectively, were used [14].

The scope of the research included determination of the parameters involved with physical properties of random chosen samples of biomass and pellets: bulk and specific density, durability, strength and gross calorific value. All tests were performed according to standards. The bulk density of the plant materials was measured according to the ASAE S269.4 standard [15]. The durability of the obtained pellets was determined for five samples of 500 g of pellets from hay and straw [16] and the durability coefficient was calculated. The heating value was measured using the standard KL-10 calorimeter. The milled sample of 1 g of the material was weighted with accuracy of 0.0001 g on the electronic scale RADWAG WPA 40/160/C/1 and combusted. Each trial was repeated five times.

Results and discussion

In the pressure agglomeration process, the properties of the formed biomass were improved through addition of calcium carbonate as a binder. The part of these properties, such as the particle size distribution and strength were described in previous research papers [17]. The density of the obtained pellets from hay and straw is consistent with the biomass bulk density (Fig. 1). The bulk density of straw was higher than hay and was more homogenous. The addition of 10 % of calcium carbonate had a significant influence on the pellets specific density and there was no clear increase in the pellets bulk density through addition of a binder. The bulk density of the pellets from hay and straw without addition of calcium carbonate was similar, because the values of that parameter were 544 $kg \cdot m^{-3}$ and 545 $kg \cdot m^{-3}$, respectively. The addition of calcium carbonate caused increase of the bulk density of the pellets from straw from 545 $kg \cdot m^{-3}$ to 616 $kg \cdot m^{-3}$, by 13 %. The pellets bulk density was conversely dependent on the biomass moisture content what is involved with worse susceptibility of the moist material on the compaction. On the other hand, logically, it was positively correlated with the particle dimensions.

The rating of the density of the pellets produced from hay and straw without addition of calcium carbonate creates the values of 763 $kg \cdot m^{-3}$ and 1056 $kg \cdot m^{-3}$, respectively, what is consistent with the bulk density of the biomass. Generally, the addition of 10 % of calcium carbonate to shredded biomass significantly increased the density of the pellets by 26 %, but the dynamic of the changes was varied for different types of biomass. From the state of the issue results that a moisture content of the raw material also significantly effects on the pellet density. According to Gustafson and Kjelgaard [18], who studied the agglomeration of hay in the range of 28-44 % moisture content it could be stated that the density of the pellets decreased while the moisture content increased. The addition of 10 % of calcium carbonate caused the moisture content decrease. The percentage increase of the specific density of the pellets with an addition of the binder was 47 % for hay and only 9 % for straw. It was determined by the ability and ease of an adhesion of calcium carbonate to the external surfaces of the soft particles of hay. However, calcium carbonate was not adhered so much to the harder particles of straw and the part of the powder was not linked with the straw particles. It could result from roughness of the plant material surface and from the ability of an adhesive influence between the biomass and the calcium carbonate particles. The relation and explanation of that phenomenon could be an object of separate research considerations in the future.

The durability determines the pellets quality. The pellets from straw meet the standards of the agglomerate durability, both, without or with the binder, of values 97.37 % and 98.82 %, respectively (Table 1). The durability of the pellets from hay is slightly lower, due to the biomass physical properties, what is consistent with other biomass durability studies [19]. The addition of calcium carbonate to the raw material from hay and straw in a similar way contributed to increase the pellets durability, by 1.18 % and 1.45 %, respectively. The pellet durability is positively correlated with the biomass bulk density and inversely correlated with the pellet bulk density and has a positive trend with the pellet specific density.

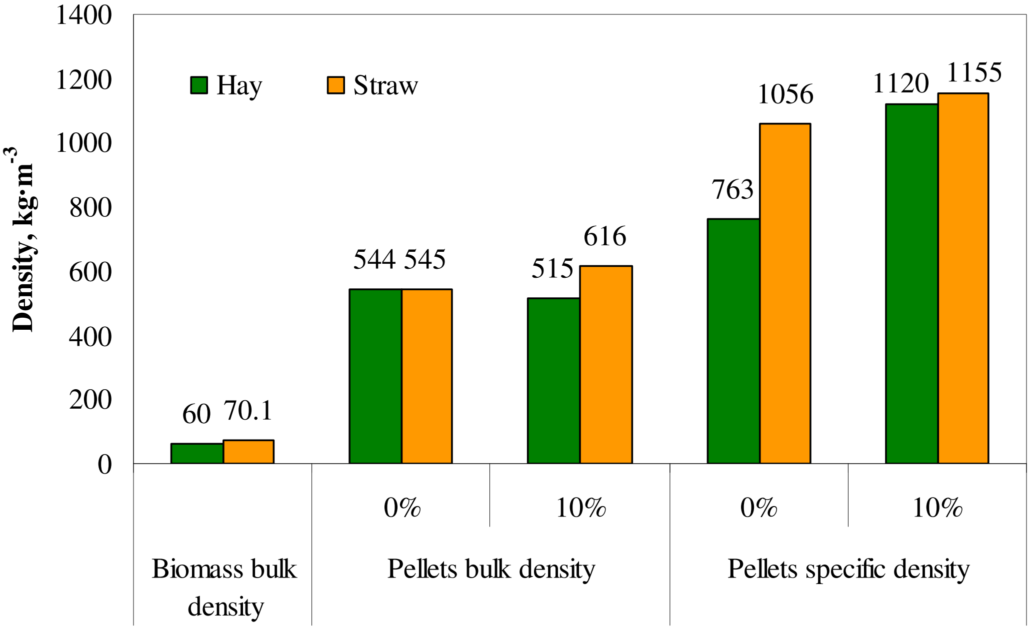

Fig. 1. **Density of biomass and pellets from hay and straw with or without addition of calcium carbonate**

As it can be seen from Table 2, the gross calorific value of the pellets from biomass without the addition of a binder was slightly higher, by 4 %, than with the addition of calcium carbonate and it was 17.01 $MJ \cdot kg^{-1}$ and 16.41 $MJ \cdot kg^{-1}$, respectively. For straw and hay, the addition of that binder caused similar decrease of that parameter, on average by 7 %. Based on the literature analysis, it could be stated that the addition of that mineral compound should lead to decrease of the calorific value, because calcium carbonate is an organic substance and its presence in the fuel or in the material increases the carbon content, which is already on the highest degree of oxidation. Moreover, during the combustion process, calcium carbonate takes a part of the heat on the decomposition of carbonate to the mixture of calcium oxide and carbon dioxide [20] and leads to decrease the amount of nitrogen oxides. Furthermore, the addition of calcium carbonate contributes to increase the melting temperature of ash, thereby limits the risk of slag formation on the furnace grates [21].

Table 1

Mean values of durability *DU*, their standard deviations SD and 95 % confidence intervals of the pellets from hay and straw with and without addition of calcium carbonate

Material	Binder, %	Durability *DU*, %	SD *DU*, %	–95 % *DU*, %	+95 % *DU*, %
Hay		96.05	0.10	95.84	96.26
Straw		98.10	0.10	97.89	98.30
	0	96.42	0.08	96.28	97.62
	10	97.73	0.08	95.80	97.93
Hay	0	95.46	0.15	95.16	95.76
Hay	10	96.64	0.15	96.34	96.94
Straw	0	97.37	0.13	97.10	97.65
Straw	10	98.82	0.15	98.52	99.12

All of these parameters describe calcium carbonate as a proper binder in the agglomeration process, improving the pellets physical properties. In the case to compensate its disadvantages, such as slight decrease of a gross calorific value and increase of wear of pelletizing equipment, other types of binders could be proposed to mix with calcium carbonate, and in consequence improving the bonds durability and pellets calorific value.

Table 2

Mean values of a gross calorific value *Q*, their standard deviations SD and 95 % confidence intervals of the pellets from hay and straw with and without addition of calcium carbonate

Material	Binder, %	Calorific value *Q*, $MJ\cdot kg^{-1}$	SD *Q*, $MJ\cdot kg^{-1}$	–95 % *Q*, $MJ\cdot kg^{-1}$	+95 % *Q*, $MJ\cdot kg^{-1}$
Hay		16.05	0.07	15.89	16.21
Straw		17.58	0.07	17.42	17.73
	0	17.38	0.06	16.58	17.43
	10	16.25	0.06	16.08	16.74
Hay	0	16.60	0.10	16.38	16.82
Hay	10	15.50	0.10	15.28	15.72
Straw	0	18.15	0.10	17.93	18.37
Straw	10	17.00	0.10	16.78	17.22

Conclusions

1. The addition of calcium carbonate increased the durability of the pellets, above 97 % and the durability was positively correlated with the pellet bulk density.
2. The addition of calcium carbonate significantly increased the density of the pellets by 26 %, but the dynamic of the changes was varied for hay and straw.
3. Calcium carbonate slightly decreased the gross calorific value but the addition of calcium carbonate in the production process significantly increased the effectiveness of the agglomeration process and allowed for agglomerating the raw materials with a higher moisture content than ever before.

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