EXPERIMENTAL RESEARCH ON THE PROCESS OF PELLETING SALIX VIMINALIS DEPENDING ON HUMIDITY AND GRANULATION

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Abstract. Materials that have a lignocellulosic structure (wood, straw, sawdust, tree bark, etc.) represent important energy resources. Their main disadvantage is represented by the fact that they have very low density, which leads to difficulties in the process of handling, transport, storage, and in consequence they have increased the production costs. These drawbacks can be improved by compacting (densifying) the material at very high pressures, thus obtaining solid biofuels with a uniform structure, such as pellets. The paper presents a series of experimental research conducted on the process of compacting wood biomass from *Salix viminalis*, in the form of pellets, using an experimental installation, following two of the parameters with the highest influence on the pelleting process: humidity and granulation of the raw material.

Keywords: biomass, densification, pellets, humidity, granulation, solid fuels.

Introduction

Biomass, considered as an energy resource, is fundamentally different from other non-fossil energy sources. It generates energy and by-products similar to those of fossil resources. Biomass also has a very important utilization as source of food and as raw materials for industrial uses that should be properly correlated with the use for energy purposes, and with complying with the principles of sustainability [1; 2].

One of the major limitations of biomass for energy purposes is its low bulk density, typically ranging from 80-100 $kg \cdot m^{-3}$ for agricultural straw and grasses and 150-200 $kg \cdot m^{-3}$ for woody biomass, like wood chips. The low bulk densities of biomass often make the material difficult to store, transport, and use. Low bulk density also presents challenges for technologies such as coal co firing, because the bulk density difference causes difficulties in feeding the fuel into the boiler and reduces burning efficiencies [3-6].

Energy associated to forestry biomass could be very profitable for the new industries, because all cellulosic matter that is abandoned today (branches, tree bark, trunks, logs) will be transformed in energetic products. The use of forestry biomass in energy purposes leads to the production of solid fuels that could replace a good part of the current consumption of oil, once the technologies for energetic conversion will prove to be effective [7; 8].

Densification is one promising option for overcoming these limitations. During densification, biomass is mechanically compressed increasing its density about ten fold. Commercially, densification of biomass is performed using pellet mills, other extrusion processes, briquetting presses, or roller presses in order to help overcome feeding, storing, handling, and transport problems [5].

The pelletizing process represents a real possibility for wood densification. Pellets represent a fuel that is made from waste from wood processing, (sawdust, shavings, wood chips, crop residues or energy crops). In general, pressed pellets have a cylindrical shape with a diameter of 6-8 mm and a length of 20-40 mm. It is an entirely non pollutant fuel, because by burning it no harmful emissions are released into the atmosphere. The mass of 1 m^3 of pellets is approximately 650-700 kg and produces approximately 3.250 kWh of energy. The process of manufacturing pellets is not complicated, but it is still complex [3; 4].

For a large scale densification process (Fig. 1), the raw material (sawdust, tree bark, straw, etc.) is dried and then introduced in the grinder, where it is grinded until it reaches the desired sizes (preferably maximum 6 mm). The material resulted is then stored until it reaches the refinement stage. After refinement it is stored again until it is introduced in the pelleting process. Before being densified, the material can be conditioned (by steam treatment, torrefaction, etc.). The actual pelleting process begins, when the material is introduced in the pelleting machine, where the material in pressed in the form of cylindrical granules. The compression causes friction between the particles, producing heat, which melts the lignin in the wood. Lignin glues the material particles forming hard, densified particles.

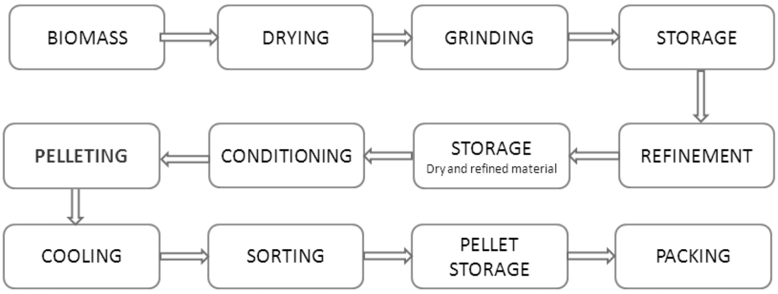

Fig. 1. **Process of obtaining pellets from biomass**

Densification comprises two stages:

- Compacting the biomass material under pressure in order to reduce its volume and eliminate the spaces between the particles;
- The lignin in the biomass activated due to the increased temperature (that appears due to the friction between the material and the die) acts like a binder and glues the biomass particles without requiring any other artificial or natural binder.

Materials and methods

For production of pellets, sawdust (Fig. 2) obtained from energy willow (*Salix viminalis*) was used. The sawdust was obtained by grinding willow wood chips in a hammer mill. Three particle dimensions were used: < 3 mm, < 5 mm and <6 mm. The initial moisture content of the sawdust was verified using a MEMMERT-UFE 500 oven with temperature control, its value being 11.25 and that value represented the first humidity content used for producing pellets, combined with two other humidity values – 9.5 and 14, obtained by drying the sawdust (for the lowest value) and by steam treatment (for the higher value).

a) b) c)

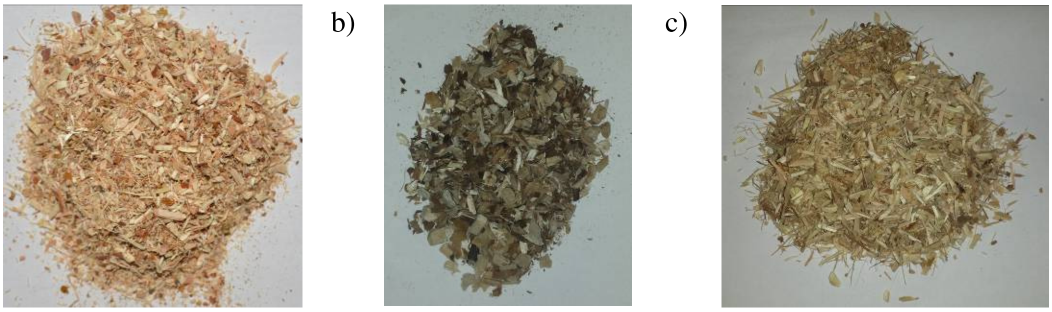

Fig. 2. **Energy willow sawdust:** a – < 3 mm; b – < 5 mm; c – < 6 mm

The pellets were produced using an experimental pelleting installation, represented by a force machine with a maximum capacity of 100 kN. The experimental installation is connected to a computer, and through specialized software program it is possible to vary the forward speed of the piston and it also offers the possibility to save the data while performing the tests. The machine was equipped with a special device (Fig. 3a) for obtaining pellets. The device can be equipped with two different dies, with diameters of 6 mm (Fig. 3b) and respectively 8 mm (Fig. 3c). For the test conducted in this research, only the 6 mm die was used.

The steps for producing pellets using the installation for compressing biomass at reduced scale are the following ones:

- installation is connected to the computer;
- piston of the device for forming pellets is attached to the force machine;
- pressing chamber is placed on the special support;
- grinded material is introduced in the pressing chamber of the device for forming pellets;
- piston is introduced in the chamber and the process is started;
- pellets from one test exit the die and are collected in a special box;
- after pellets exit the die channels, the installation is stopped and the recorded data are processed.

a)

b)

c)

Fig. 3. **Device for compressing biomass at low scale:** a – device ready to be fitted to the force machine; b – 6 mm die; c – 8 mm die

The tests were conducted for each humidity and for each granulation, resulting in a total of 6 tests performed for these two parameters of the raw material used – in this case *Salix viminalis*. Taking into account that willow is a woody form of biomass and that it has a high content of lignin, no additives were added, being considered that this type of raw material does not need any types of binders in order to produce good quality product. From each test, 5 pellets were collected and analyzed, summing the results for each one and obtaining the average for a certain type of humidity/granulation.

All experiments were conducted in the same conditions in terms of environment temperature and air humidity. For the tests conducted in order to observe the influence of humidity on the process, the granulation of the material used was the same in all cases – < 3 mm. For the tests conducted in order to observe the influence of material granulation on the process, the humidity of the material used was the same in all cases – 11.25 %.

Results and discussion

From the visual analysis of the pellets it was found that the pellets obtained from material granulation of < 3 mm had the best quality in terms of the length and surface characteristics. The pellets from material granulations of < 5 mm and < 6 mm decreased considerably in length and presented severe cracks due to the high number of large particles in the material, which represent the main rupture points and pose serious issues for handling and storage operations.

Also, it was found that the pellets produced from the highest material granulation produced the most dust during after production and during handling, indicating that they are not suitable for long term storage. Also, the same types of pellets showed the most cracks and the most uneven surface.

In Fig. 4 the samples of the pellets obtained from the tests using the experimental installation, after they were left to dry for 48 hours, are shown.

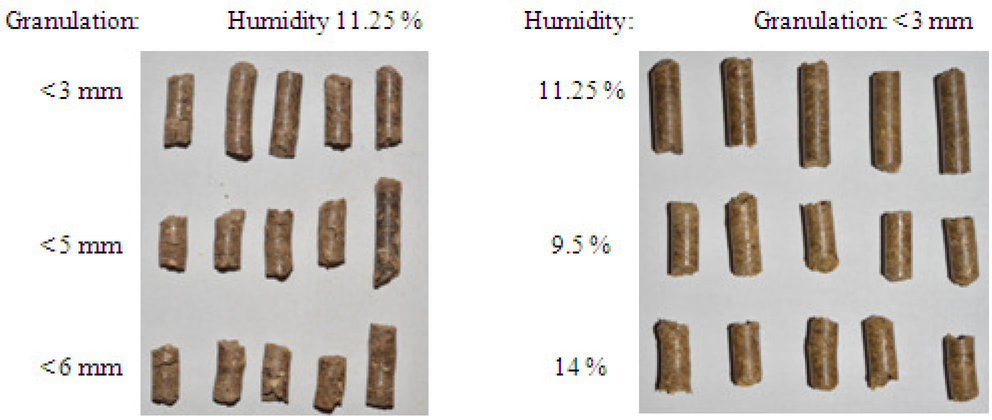

Fig. 4. **Samples of pellets obtained during experiments**

The first samples to be analyzed were those taken from the test concerning the humidity. They were visually analyzed and weighed (using a Shimadzu W 220 special precision weighing equipment) and also their final humidity and the ash content were calculated using a MEMMERT-UFE 500 oven with temperature control and respectively, a CAL 2k Calorimeter. The results from the analysis are shown in Table 1.

Table 1

Analysis of the pellets obtained from the tests concerning humidity

Sample	Granulation	Initial humidity, %	Final humidity, %	Calorific power, $MJ \cdot kg^{-1}$	Ash content, %
1	< 3 mm	9.00	8.92	Average 17140	Average 2.46
2			8.90		
3			9.01		
4			8.84		
5			8.98		
6		11.25	9.81	Average 17090	Average 2.49
7			10.02		
8			9.95		
9			10.14		
10			10.04		
11		14.00	11.48	Average 17020	Average 2.52
12			11.48		
13			11.56		
14			11.62		
15			11.57		

The highest humidity resulted for the initial humidity of 14 %, but that also represented the biggest decrease in humidity for all samples analyzed.

A humidity of 14 % was found to be too high for this type of material, causing the pellets to break more easily.

In Table 2 are shown the results from analyzing the samples from the tests concerning granulation of the material used.

Table 2

Analysis of the pellets obtained from the tests concerning material granulation

Sample	Initial humidity, %	Material granulation	Sample humidity, %	Calorific power, $MJ \cdot kg^{-1}$	Ash content, %
1	11.25	< 3 mm	11.01	Average 17130	Average 2.46
2			10.96		
3			11.04		
4			10.98		
5			10.85		
6		< 5 mm	10.84	Average 17170	Average 2.47
7			10.81		
8			10.88		
9			11.00		
10			10.78		
11		< 6 mm	10.80	Average 17120	Average 2.51
12			10.82		
13			10.77		
14			10.77		
15			10.74		

Conclusions

The present work examined the effects of the humidity and particle size on the final humidity and combustion properties of biomass pellets. It was found that:

1. Material granulation and humidity did not significantly affect the calorific power and ash content for the pellets obtained, the variations of these parameters having low values, indicating that the pellets maintain the characteristics of the raw material used (*Salix viminalis*).
2. For the conditions used during these tests, it was found that the best final product in terms of the humidity, length, surface characteristics, calorific power and ash content combined are obtained using raw material at granulation of < 3 mm and humidity of 9 %.

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