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EXPERIMENTAL RESEARCH ON OBTAINING BIOMASS TABLETS

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Abstract: Renewable energy technologies have the great advantage of using inexhaustible, low–polluting resources with an insignificant contribution to climate change. In addition, their use reduces dependence on conventional resources that will be depleted in the not–too–distant future. Solid biofuels are produced from biomass materials, especially wood, and are new fuels that meet the new requirements of using "clean" and regenerative energy. The paper presents a series of experimental research for obtaining biomass tablets using specially designed equipment, which are a viable solution for the recovery of lignocellulosic waste from vineyards and orchards and beyond.
Keywords: biomass, lignocellulosic waste, agricultural waste, tableting, solid biofuels

INTRODUCTION

Agricultural activity is a source of greenhouse gases (GHGs), but also an absorber, especially by storing carbon dioxide in soil organic matter and biomass (INMA Bucharest, 2008; Golub et al., 2020; Kukharets et al., 2020).

In terms of emissions absorption, agriculture and forestry, unlike other economic sectors, have the ability to fix carbon in the atmosphere through the process of photosynthesis and sequester it in soil and biomass. In particular, pastures, wetlands and forests have the ability to fix carbon in large quantities. On the other hand, carbon stocks may be lost, for example as a result of land use change (deforestation, pasture ploughing, wetland drainage, etc.) or as a result of extreme weather events (storms, fires, etc.), which leads to the rapid release of carbon stored in the atmosphere in the form of CO_2 (Matache et al., 2011, Capareda S.C., 2014).

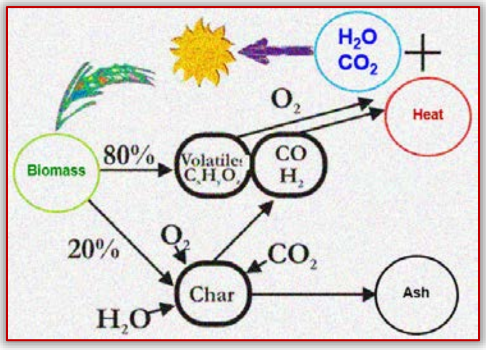

Figure 1 – Biomass combustion diagram and closed carbon circuit (Gurau L., 2016)

Biomass produced in agriculture and forestry and used for energy (energy from renewable sources) or as a raw material (biomaterials, plant chemistry) is another way to increase carbon sequestration (INMA Bucharest, 2008; Tumuluru et al., 2010, Voicea et al., 2014; Vladut et al., 2010).

The most efficient mechanism for capturing solar energy on a large scale is biomass growth. The total amount of carbon in biomass can produce 110 times more energy than human energy needs (Milko et al., 2020).

During the period of cheap oil, which ended in the 1970s, biomass as an energy resource was secondary. Currently, biomass is considered one of the main sources of renewable energy of the future, due to its great potential and the various related positive effects on social and environmental issues (Tabil & Kashanienejad, 2011).

The energy content of biomass can be used by direct combustion or by chemical conversion into fuels, followed by combustion. Biomass has a very important role in fixing carbon dioxide in the atmosphere, the ambient air with an average concentration of 350 ppm (parts per million) carbon dioxide is also an important reserve (Romania's Energy Strategy 2019–2030; Ungureanu et al., 2018; Voicea et al., 2015).

In all European countries, various lignocellulosic biomasses have started to be used to produce renewable energy (European Commission, 2005). Out of these, we can mention agricultural residues (straw, straw containing manure) or fractions of solid municipal waste available in large quantities, but little of this potential is currently used. Not all wastes have an adequate content for their treatment with the help of available techniques for transforming lignocellulosic biomass into renewable energy such as anaerobic digestion, ethanol production or thermal recovery (European Commission, 2005).

Forest waste includes unusable waste, dry trees, trees that do not meet commercial standards, and other trees that cannot be marketed and must be cut down to clear the forest. Some species of energy plants also belong to the category of woody biomass, these being for example fast–growing trees (Vladut et al., 2012).

In order to increase the density of biomass and to allow the automation of the combustion process, it is currently used to transform biomass into pellets, briquettes of tablets.

The paper presents an experimental research on obtaining tablets from biomass residues using a specially designed tableting equipment, this being a solution for the recovery of lignocellulosic waste.

MATERIALS AND METHODS

In the current climate and environmental context, it is desired to obtain energy from green fuels by energy recovery of biomass and biofuels and also increase the quality of the environment, thus meeting the requirements of the European Union, the use of biomass for energy purposes. Among the objectives achievable after conducting research and implementing the results, there are: promoting clean energy technologies; obtaining additional energy resources, different from the traditional ones; adoption of environmental protection measures; management and recovery of ligno–cellulosic residues from horticultural exploitations in biofuels with energy values.

The experimental model of ligno–cellulosic waste tableting equipment – TDL (figure 2), is composed of a compaction die, a compaction assembly with hydraulic compaction cylinder that presses the biomass, forcing it to reduce its volume, a feed hopper with auger that feeds the die biomass material, a die closing plate, a hydraulic cylinder for emptying the die by moving the plate in the closed–open position, a hydraulic group which powers and actuates the 2 cylinders, fitted with hydraulic distributors, 5 proximity sensors that allow to control the movement of the cylinders during the compaction process and an automation box where the control of the whole system is done.

Figure 2 – Experimental model of lignocellulosic waste tableting equipment

The experimental model of ligno–cellulosic waste tableting equipment is designed to obtain compacted solid biofuel – tablets that can be used both as a biofuel for heating and as a material for the production of smoke and heat for protection during late spring frosts / hoars.

The mass of material is introduced into the feed hopper of the equipment, and from here, it is taken up by the transportation auger and reaches the tableting die, where it is compressed by the piston connected to the hydraulic installation, thus forming the tablets. The evacuation of the tablets takes place at the bottom of the equipment, immediately below the die, by pushing it outwards by the evacuation piston.

The material used for obtaining compacted tablets was represented by woody biomass: sawdust (figure 3) and mixture of sawdust and agricultural vegetable residues (figure 4).

The following methodology was used for obtaining tablets with the equipment:

≡ the biomass materials used as raw material were crushed to the desired dimensions;
≡ the initial moisture of the raw material was determined by means of the drying oven and the thermobalance and the material was brought to the desired moisture by drying or spraying with water;
≡ the mass required for each batch was measured using a balance;
≡ the mass of material was homogenized;
≡ the actual process of obtaining the tablets was performed using the tableting equipment (figure 5).

Figure 3 – Sawdust used for obtaining tablets

Figure 4 – Biomass mix used for obtaining tablets

A total amount of 5 kg of material (introduced into the feed hopper) was used for each material batch (sawdust or sawdust and agricultural residues mix).

Figure 5 – Aspects from experiments

RESULTS

After conducting the tableting process, tablet samples were collected (figure 6) to be analysed.

During and after conducting the experiments, a series of very important parameters in the production process were monitored for each sample: tableting time, tablet length and diameter, calorific value, ash content, moisture, tablet density, volatile matters content.

Figure 6 – Pellet samples obtained using the tableting equipment

Table 1. Compaction time per tablet

Sample 1	Sample 2	Sample 3	Average
Time [seconds]			
30	31	27	29.33

To determine the length and diameter of the tablets, tablets were randomly selected and were measured in order to determine their length and diameter, the results being shown in Table 2.

Table 2. Biomass tablet length

Sample		Length [mm]	Diameter [mm]
Sawdust	1.	44	120
	2.	46	120
	3.	43	121
	Average	44.33	120.33
Sawdust and agricultural residues mix	1.	41	124
	2.	40	126
	3.	38	128
	Average	39.66	126

From table 2 it can be seen that tablets obtained using a mix of sawdust and agricultural residues (cereal straws) had a smaller length, meaning that the initial material had more spaces between particles, but they had higher diameter, meaning that they started to expand after existing the compaction die.

The calorific value of tablets was determined using a CAL3K–U Oxygen Bomb Calorimeter System, according to the method described in the standard SR EN 18125: 2017 – Solid biofuels. Determination of calorific value. The ash and volatile matter content were determined using a calcination furnace, according to the method described in standards SR EN ISO 18122:2015 – Solid biofuels – Determination of ash content, respectively SR EN ISO 18123:2015 – Solid biofuels – Determination of the content of volatile matter.

Moisture content was determined by drying tablet samples in a drying oven according to the method described in standard ISO 18134–1:2015 – Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method. The results of the determinations are given in Table 3.

From table 4, it can be seen that tablets obtained from the mixture of sawdust and agricultural residues registered smaller unit densities, due to the fact that they started expanding after they exited the die.

Table 3. Calorific value, ash, volatile matters and moisture content of tablets obtained

Samples		Calorific value [MJ/kg]	Ash content [%]	Volatile matter content [%]	Moisture content [%]
Sawdust	1.	16.41	6.53	71.84	8.25
	2.	16.13	6.78	72.19	8.46
	Average	16.27	6.655	72.59	8.36
Sawdust + agricultural residues mix	1.	14.22	7.41	72.21	9.54
	2.	14.16	7.52	75.21	9.73
	Average	14.19	7.465	75.08	9.64

To determine the tablets' unit density, the formula $\rho = m / v$ was used, where ρ is the unit density, m is the mass of the tablet and v is the volume of the tablet. The results are shown in Table 4.

Table 4. Unit density of the tablets obtained

Sample		Unit density [kg/m^3]
Sawdust	1.	441.21
	2.	434.82
	3.	436.47
	Average	437.50
Sawdust + agricultural residues mix	1.	389.52
	2.	387.15
	3.	391.73
	Average	389.47

CONCLUSIONS

Romania has sufficient biomass resources to obtain solid biofuels at small scale or at an industrial level, the raw material being generally agricultural and forestry residues that are available in all regions and to any category of population. Biomass compaction is one of the easiest and overall affordable ways to convert biomass into biofuels that are also possible to burn in already existing wood burners.

Tablets represent an affordable way to compress biomass, tableting equipment having simpler construction than pelletizers or briquetting machines, translated into easier and less resource consuming maintenance. Biomass tablets obtained from sawdust and sawdust + agricultural residues mix have good quality in terms of moisture, calorific value, volatile matter content. Tablets obtained from the sawdust and agricultural residues mix have lower densities, but they can still be successfully used as solid biofuel and have the advantage that they can also be used as smoke / heat material in burners for orchards / vineyards protection.

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