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RECOVERY OF LIGNOCELLULOSIC WASTE FROM HORTICULTURE BY TABLETING

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Abstract: The benefits of biofuels compared to traditional fuels include greater energy security, lower environmental impact, financial savings and socio-economic issues related to the rural sector. The concept of sustainable development embodies the idea of interconnectivity and balance between economic, social and environmental concerns. The use of renewable energy is an efficient way to ensure a cleaner energy supply. Romania has the capacity to produce energy from a multitude of sources, biomass being one of the most abundant and easy to use. Lignocellulosic waste represents an important biomass source that can be easily transformed in solid biofuels, thus eliminating losses and contributing to environmental protections. The paper presents a solution for lignocellulosic waste recovery, by transforming it into tablets using a specially designed equipment.
Keywords: biomass, lignocellulosic waste, tableting

INTRODUCTION

In all European countries, various lignocellulosic biomass have started to be used to produce renewable energy (Danciu et al, 2010; Ungureanu et al., 2016b; Vlăduţ et al., 2012; Voicea et al., 2014a). 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 using available techniques for transforming lignocellulosic biomass into renewable energy such as anaerobic digestion, ethanol production or heat recovery (European Commission – EUR 21350 – Biomass, 2005).

The most important categories of lignocellulosic materials are:

- wood and wood waste;
- stems of non-woody plants (annual or perennial); this includes agricultural cellulosic waste such as: cereal straw and stems from different crops as well as those from the processing of technical plants (textile plants, tobacco stems), spontaneously growing plant stems;
- fractions from municipal waste such as paper waste [td]. Lignocellulosic agricultural waste is a resource with high global availability and low price, resulting from the harvesting of cereals and some technical plants (quantities that can be collected depending on the type of crop: wheat straw: 1.4-2.5 t / ha; corn stalks: 4-6.5 t / ha; sunflower stems 1.9-5.0 t / ha; rapeseed stems 1.7-3.5 t / ha, (Marcu A., 2008).

Wood waste from the paper and woodworking industry is usually clean and can be used as fuel for various biomass-based energy systems. Forest waste includes unusable waste, dry trees, trees that do not meet commercial standards and other trees that cannot be traded and must be cut down to clear the forest.

Some species of energy plants are also part of the woody biomass category, such as fast-growing trees. The harvesting period of such plants varies between 3 and 10 years depending on the tree species.

Agricultural biomass is appreciably more abundant than woody biomass. Within it, the most commonly used types for energy purposes are: straw; corn stalks and cobs; grapevine canes; flax and hemp stalks; agricultural plants; sunflower and soybeans; biomass from fruits and seeds (Ungureanu et al., 2016a).

Straws have good energy characteristics, so they are acceptable for use in energy purposes. For example, corn can generate more than three times as much waste as all forms of wood waste. Sometimes large amounts of chlorine, especially in coastal areas grown with corn, can lead to corrosion of heat recovery plants (Ungureanu et al., 2018; Vlăduţ et al., 2011; Voicea et al., 2014b).

The paper presents a solution for the recovery of lignocellulosic waste, as an important part biomass, using a specially designed tableting equipment.

MATERIALS AND METHODS

Table 1 shows the energy potential by types of agricultural biomass available in Romania.

Table 1. Energy potential by types of agricultural biomass (https://ec.europa.eu/transparency/)

Biomass type	Available energy potential	
	TJ	toe*
Straws	30841	736580
Corn – stalks + cobs	177870	4248150
Sunflower – stalks, head, husks	55346	1321830
Flax and hemp stalks	92	2190
Grapevine canes	2688	64190
Total	266835	6372940

*tonne of oil equivalent

The main types of biomass conversion processes can be classified into four groups (Romania's 2018-2030 energy strategy, 2018):

≡ physical (grinding, separation, drying, briquetting, pelletizing, etc.);
≡ biological-biochemical (fermentation: anaerobic, aerobic, alcoholic);
≡ thermal (combustion, pyrolysis, gasification, hydrogenation);
≡ chemical (they initially use biological and biochemical processes which are then supplemented with chemical syntheses; for example, the synthesis of biodiesel).

Biofuels can be obtained in various forms, and they are beneficial for the environment, because they add much less harmful emissions into the atmosphere (they also contain oxygen in their chemical structure with beneficial effects for combustion and flue gas emissions) and uses various agricultural wastes as a resource.

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. Used in the thermal energy system, biomass-type substances must meet the requirements of thermochemical conversion technologies (combustion or gasification), food and flow maintenance, in conditions of optimal energy efficiency with minimal impact on the environment. Biomass through its components (agricultural, forestry) varies in type, shape and presentation and does not does not meet the requirements of energy efficient installations. Thus, additional processing is required to improve the thermo-physical characteristics such as:

≡ increase of calorific value;
≡ increasing the specific mass;
≡ achieving optimal transport and supply dimensions.

In order to increase the density of solid fuels in biomass and to allow the automation of the combustion process, biomass is usually transformed into pellets, briquettes or tablets.

The specific characteristics of combustion products, briquettes, wood pellets are comparable in relation to thermal performance (calorific value), the differences in volume, density and final moisture being influenced by dimensional factors, moisture on pressing and compaction requirements of these combustible products (Table 2).

Mechanical, thermal and agglomeration processing of biomass, bringing it to the optimum particle size and moisture density, in solid combustion products – tablets, briquettes, pellets - has multiple advantages:

≡ the products obtained have superior energy properties, compared to biomass;
≡ tablets, briquettes and pellets produce, through combustion, reduced pollutant emissions and ash in smaller quantities, with a weight of 1 ÷ 2% of the amount of composite material subjected to combustion;
≡ widens the field of use, for private households, communal, urban and administrative thermal power plants;
≡ requires storage spaces under the storage requirements of natural biomass product (firewood, remains and sawdust from wood manufacturing);
≡ reduces the transport fleet, handling of the energy process;
≡ optimizes the combustion process;
≡ increases the calorific value of biomass.

a)

b)

c)

Figure 1 . Examples of solid biofuels from biomass [13, 14]; a – pellets; b – briquettes; c - tablets

Table 2. Calorific performance of briquettes, pellets compared to wood

Biomass products	Calorific value [kcal/kg]	Calorific ratio compared to wood [%]
Masive wood	4500 ÷ 5000	100
Wood tablets and briquettes	4000 ÷ 5000	100
Wood pellets	4000 ÷ 4800	96
Resinous bark	4500 ÷ 5250	105
Straw tablets and briquettes	4500 ÷ 4750	95
Reed tablets and briquettes	4300 ÷ 4500	90

The processing of biomass, which appeared to be necessary for energy, economic, ecological and social requirements, transforms products with low value and use into new products with high energy value.

RESULTS

Biomass tableting consists in subjecting biomass materials to high pressures in a closed die for a short period of time and then evacuating it by opening the closed end of the die.

The design of the tableting equipment for the recovery of lignocellulosic waste from horticulture involved the design of a system that would allow the recovery of lignocellulosic waste resulting mainly from orachards and viticulture, namely tree branches, vines resulting from spring pruning and falling leaves at the end of the vegetation period, thus transforming a series of waste into raw materials and finally obtaining a value-added product, which has no negative effects on the environment, and can be considered a "green" product.

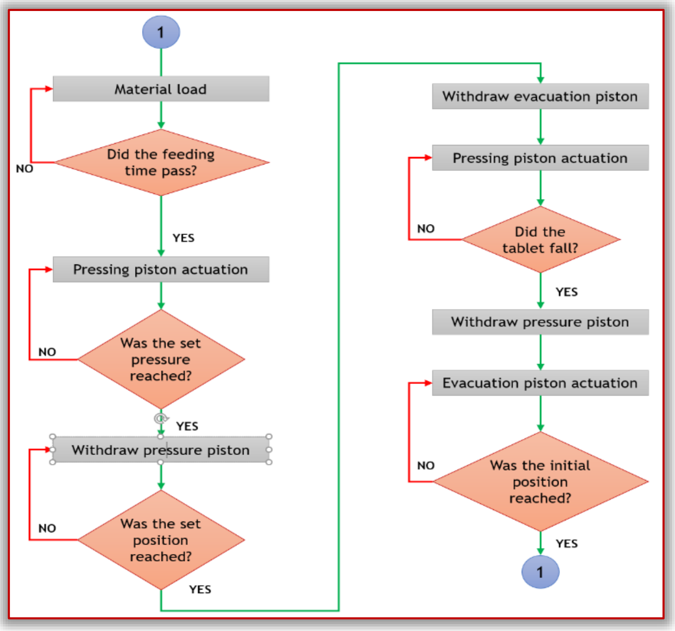

Figure 2. Operating diagram of the experimental model of lignocellulosic waste tableting equipment

The process can be controlled by using a programmable logic controller (PLC), through which the working parameters of the compression process can be programmed to obtain biomass tablets. The process of tableting biomass involves subjecting the crushed biomass to high pressures inside a mold and forcing it to significantly reduce its volume. To compress the biomass inside the mold, a pressing cylinder, driven by a hydraulic unit, is used. Emptying the mold of the resulting compressed product (tablet) is done by means of a second cylinder - emptying - which is connected by the locking plate (closing) of the mold and, by a pull-push movement, opens and closes the mold, at the same time evacuating the resulting tablet in a tableting cycle.

The functional scheme of the experimental model of lignocellulosic waste tableting equipment - TDL is presented in figure 2.

The experimental model of lignocellulosic waste tableting equipment – TDL (figure 3), is composed of compaction die 1, compaction assembly 2 with hydraulic compaction cylinder that presses the biomass, forcing it to reduce its volume, feed hopper 3 with auger 4 that feeds the die what material, the die closing plate 5, the hydraulic cylinder 6 for emptying by actuating the plate in the closed-open position, the hydraulic group 7 which feeds and actuates the 2 cylinders, the hydraulic distributors 8, proximity sensors 9, 10 and 11 which allow monitoring displacement of the cylinders during the compaction process, automation box 12.

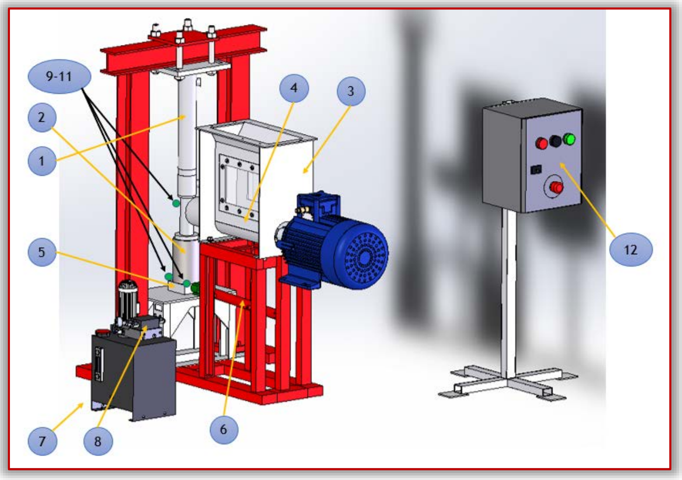

Figure 3. Experimental model of lignocellulosic waste tableting equipment

During operation, the feed hopper is loaded with the grinded biomass material in the dry state and the process starts automatically. The auger takes material from the hopper and feeds the die. The compaction piston descends inside the die and presses the material.

When the set parameters are reached, the piston of the compaction cylinder stops advancing, retracts to a set position, and the emptying cylinder acting on the counter plate pulls the latter until the die reaches the open position, at which point the piston descends again, removing the tablet from the mold.

When the tablet falls out of the die, the piston of the compaction cylinder is completely withdrawn from the die, and the emptying cylinder, by actuating the counterplate, pushes it into the closed position of the die, also performing the complete evacuation of the tablet.

CONCLUSIONS

Lignocellulosic biomass is considered one of the most promising resources for the future of bioenergy production. Lignocelluloses, such as timber resulting from maintenance pruning of orchards, have been identified as major sources of biofuels and other value-added products.

Tablets are an affordable way to compress biomass, the equipment has a much simpler construction than pelletizers or briquetting machines, and maintenance of this equipment is not expensive and has the advantage that the process results in solid biofuels that can be used in the same type of applications as in the case of pellets and lighters.

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