COMPARATIVE ANALYSIS OF METHODS FOR FUEL BIOBRIQUETTES PRODUCTION

Alexandru Muntean[1], Tatiana Ivanova[2], Bohumil Havrland[2], Victor Pobedinsky[1]
[1]State Agrarian University of Moldova; [2]Czech University of Life Sciences Prague
alexmuntean@inbox.ru, ivanova@its.czu.cz, havrland@its.czu.cz, pobedinsky@uasm.md

Abstract. Energy programme of the European Union development includes an increase in the usage of renewable energies by 20 %. An annual production amount of agricultural waste in the Republic of Moldova is four million tons. This is about 60,000 TJ in the energy equivalent. One of the most effective ways of waste minimization and use is utilization and processing of agricultural waste of a plant origin with the purpose of solid biofuel production in the form of bio-briquettes and pellets. From the set of available technological equipment usable for the solid bio-fuels production some items of equipment have been chosen and a comparative analysis of bio-briquette production by different briquetting equipment performed. The processes of agglomeration of material particles and the formation of briquettes in the working chamber of the briquetting press were studied. A comparative evaluation of the characteristics of the fuel briquettes (such as energy content, density, calorific value, etc.) obtained by different methods is given in the paper. A comparative technical-economic analysis of the briquette production by using different types of briquetting presses is presented, as well.

Keywords: agglomeration, briquettes, briquetting process, extruder, macroscopic analysis, piston press, solid biofuel.

Introduction

Today, the most common types of briquetting presses used in technological lines for fuel briquettes production are extruders (the main working body has a shape of a screw) and piston presses (hydraulic and mechanical) the main working body of which has a shape of a piston.

The briquettes produced by an extruder have a number of positive properties of which the key one is their high density. Their combustion is trouble free over a long period of time (about 180 – 240 minutes depending on the input raw materials used for their production). Extruded briquettes are usually of rectangular or hexagonal shape. One of a deficiency of the screw pressing method is its higher operating cost in comparison with mechanical and hydraulic piston presses. The reasons for this are:

- periodical need of stops to replace a screw;
- periodical need of manual control of several parameters such as clearance between the screw and die plate, temperatures of die plate heating, material moisture content;
- need for qualified personnel.

The production of fuel briquettes by the piston presses does not require such a high cost like the extruder technology.

Materials and methods

From the set of technological equipment for solid biofuel production a comparative analysis of bio-briquettes production by different selected briquetting presses was performed (see Table 1). The processes of agglomeration of material particles and the formation of briquettes in the working chamber of a briquetting press were studied as well.

Table 1

Comparative characteristics of briquetting presses

Press mark	C.F. Nielsen BP-3200	Briklis Brikstar 400	EB-350	Briklis Brikstar 50	SBM-15
Type of press	Piston mechanical	Piston hydraulic	Screw extruder	Piston hydraulic	Screw extruder
Shape of briquette	Cylindrical	Cylindrical	Hexagonal	Cylindrical	Hexagonal
Performance, $kg \cdot h^{-1}$	400 – 600	360 – 420	350 – 400	50	100 – 150
Power intake, kW	22	28	49.57	5.4	18

Table 1 (continued)

Press mark	C.F. Nielsen BP-3200	Briklis Brikstar 400	EB-350	Briklis Brikstar 50	SBM-15
Life period of the main pressing organs, h.	1,500 – 3,000	2,000	50	2,000	50
Specific energy consumption, kWh·t^{-1}	44	70	132.18	108	180
Producing country	Denmark	Czech Republic	Ukraine	Czech Republic	Ukraine

Results and discussion

On the basis of the data analysis (Table 1) it can be concluded that the piston type presses with performance from 50 up to 400 kg·h^{-1} has 1.15 – 1.85 times lower specific energy consumption (70 – 108 kWh·t^{-1}) than the presses-extruders (132 – 180 kWh·t^{-1}). Also the life period of key pressing organs (matrix and screw) in the piston presses (2,000 hours) is 40 times higher than that of extruders (50 hours); this is due to the fact that extrusion is a process of continuous operation (production of briquettes by a screw at high pressure and temperatures). At spinning, the screw creates pressure on material in a tangential direction; this leads to constant wear and tear of the screw working surfaces. The screw wears out more or less quickly depending on the degree of material abrasiveness (presence of dirt and additives, individual properties of raw materials).

A comparative evaluation of the characteristics of fuel briquettes (density, calorific value and others) is given in Table 2.

Table 2

Basic characteristics of fuel briquettes made by the piston and screw presses

Type of press	Type of raw material	Diameter/Length, m	Density, kg·m^{-3}	Calorific value, MJ·kg^{-1}
Piston	Grapevine + Straw 1:3	0.06917/0.06042	869.407	15.505
Piston	Grapevine + Straw 1:2	0.06436/0.06485	892.996	15.893
Piston	Grapevine + Corn stalks 1:1	0.06678/0.05008	946.28	17.207
Extruder	Straw	0.06544/0.320	1180	15.227
Extruder	Grapevine	0.06539/0.328	1200	17.514

It can be seen (Table 2) that the briquettes made by piston presses have a little lower density compared to the briquettes made by extruders but their other positive characteristics are not worse.

The above fact shows the benefits of fuel briquette production by the piston type presses. Therefore, we have conducted the detailed studies of a process of bio-briquette formation in the working chamber of the piston press matrix. It was found that the composition and technological characteristics of input raw materials have a strong influence on the process of the particles agglomeration during the pressing (briquetting) process. According to the research results conducted by the author team the optimal composition is made by a crushed mixture (1:1) of corn straw with chopped grapevine cuttings produced by pruning (see Figure 1).

Comprehensive assessment of the bio-briquette quality was done, as well. On the one hand, the briquette quality was evaluated by such parameters as moisture content, density, strength, hardness, briquette visual appearance and surface condition under the appropriate net calorific value Q^r (MJ·kg^{-1}) in accordance with the standard CEN/TC 335. On the other hand, it was assessed by the net calorific value Q^r (MJ·kg^{-1}) and gross calorific value Q^d (M·kg^{-1}), by ash content, chemical composition and gas emissions in accordance with the standards Önorm M 7135 and the ecological regulations Czech State Norm ČSN EN 13229.

For the quality evaluation of bio-briquettes an integrated criterion k_{ij} was adopted. The criterion includes the results of the briquettes testing on their strength – mechanical durability DU %, which is determined according to the standard CEN/TC 335 and ČSN EN 15210-2. In this context, the wooden briquettes BIOMAC were taken as a base P_j^{base} with the parameters: water content – 6.8 %; ash –

0.22 %; particle density – 750 ± 10 kg·m^{-3}; destruction force – 46.5 N·mm^{-1}; net calorific value – 17.1 MJ·kg^{-1}; gross calorific value – 18.74 MJ·kg^{-1}, etc.).

In addition to the set of already listed indicators a comparative analysis of input raw materials and bio-briquettes has been performed by means of an electronic microscope USB2.0 Digital Microscope in order to make the qualitative assessment complete.

Macroscopic analysis of bio-briquettes was carried out on their surfaces in four characteristic zones, according to the schema in Figure 1.

The mixtures of chopped straw (wheat or corn) and crushed grapevine and other wood waste were found as of the most prospective.

The process of changing the state and form of the particles (of the above materials) during the pressing can be traced on the comparative macroscopic analysis of raw materials and final products (briquettes), presented in Figure 1.

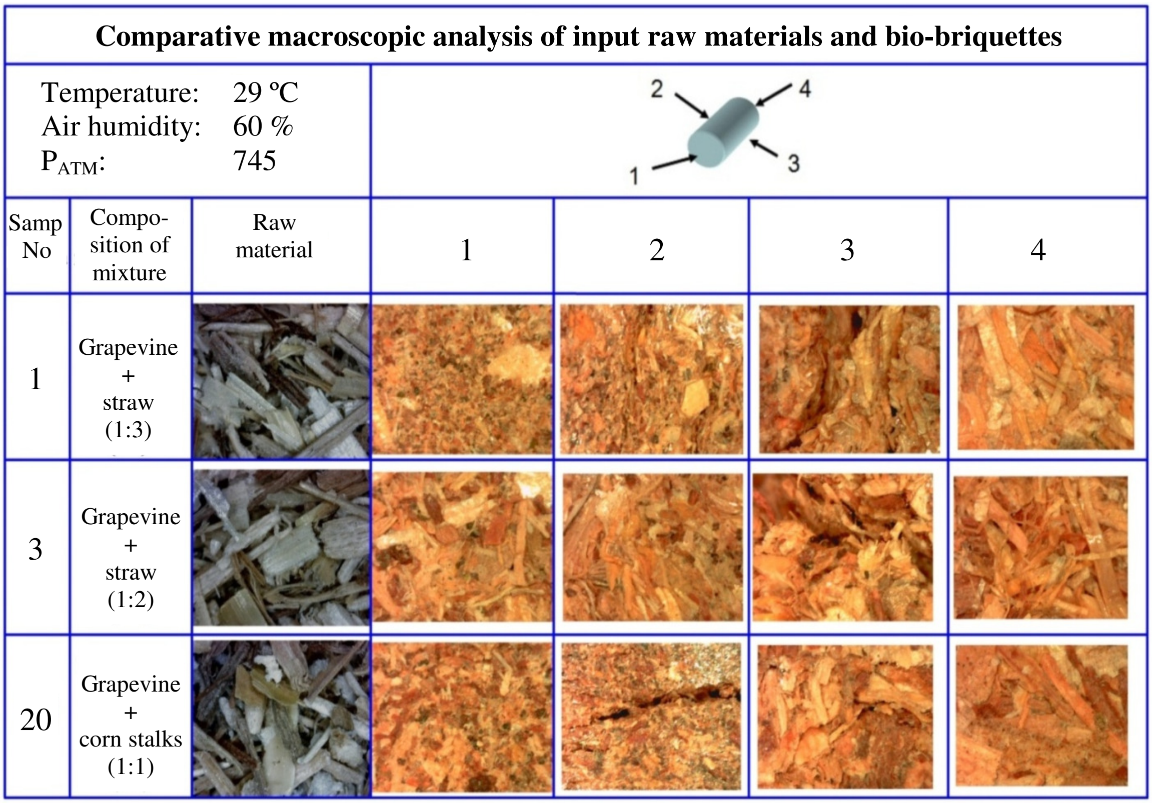

Fig. 1. **Comparative analysis of the results of pressing of bio-briquettes from different plant material by piston briquetting press "BrikStar"**

It is evident (from Figure 1) that the agglomeration of the particles takes place in different zones of interaction of the pressed material with the piston and matrix (see our previous publications [2; 4; 5]). The particles of input raw materials are joined and pressed better (especially in the case of mixture of parenchymatous particles of corn straw) but they are also faced to various types of deformation. However, due to the increase of the pressure and temperature (up to 80 ºC) lignin is secreted from the structure from the cellulose skeleton and intercellular space of the pressed plant material. Under a sufficient enlargement of the pictures done by macroscopic analysis it is visible that the lignin in the form of transparent natural resin coats the compressed particles. This provides high strength and density of the produced briquettes without adding any binding ingredients [2; 6].

The microscope Nocon SMZ 745T was used for a more detailed study of the briquette structure and for observation of interaction of agglomerated particles with lignin in separate zones of the briquettes produced by the pressing process (Microscope Nocon SMZ 745T - Laboratory Imaging, Software – NIS element, Praha 10 – Hostivař, Za Drahou 171/17, http:/www.lim.cz). An example of these studies is given below. Figure 2 gives a clear idea on the lignin locations on the briquette surface and also provides a mechanism for calculation of the total area affected.

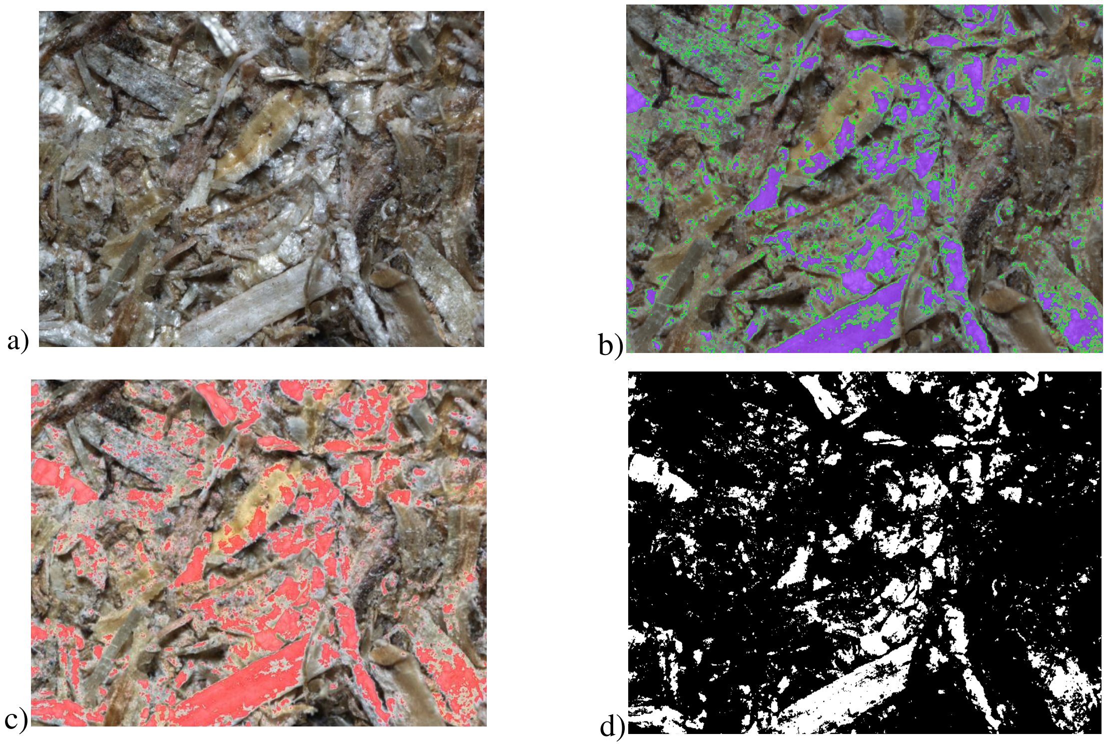

Fig. 2. **Processing of the image of macroscopic analysis of the briquette structure:**
a – macroscopic image of the structure of the briquette surface; b – detection of areas of the lignin secretion and measurement of the appropriate values; c – overlay image; d – binary image

Conclusions

At present, the briquettes look like far superior fuel with positive environmental attributes. The study found and analysed a number of advantages and disadvantages of the modern methods of production of solid bio-fuels in the form of briquettes. The production of fuel briquettes by the piston presses is more attractive from an economic point of view and has a number of benefits compared to the presses-extruders. Especially these benefits are: lower specific energy consumption and lower wear of the basic working organs of the piston briquetting presses in comparison with the extruders.

The main parameters (calorific value, ash content, density) of the briquettes produced by the piston presses are similar to the briquettes made by the extruders because they rather depend on the raw material properties.

References

1. Wolfgang P. Agglomeration Processes Phenomena, Technologies, Equipment. Wiley-VCH Verlag GmbH, Weinheim, 2002, 1104 p.
2. Havrland B., Pobedinschi V., Vrancean V., Pecen J., Ivanova T., Muntean A., Kandakov A. Biomass processing to biofuel. Prague – Chisinau, 2011, 86 p.
3. Muntean A., Marian G. The elaboration sight of solid biofuel from agricultural remains. Technical University, Ukraine, Kharkov, 2009, 189 p.
4. Muntean A., Havrland B., Pobedinsky V., Ivanova T., Marian G. Features of Bio-briquettes pressing with the Piston Briquetting Press. Proceedings of 9th International scientific conference “Engineering for Rural Development”, May 27, 2010, Jelgava, Latvia, pp. 246-251.
5. Побединский В., Гаврланд Б., Мунтян А., Вранчан В., Кандаков А., Иванова Т. Практикум по дисциплине: Заготовка и переработка сельскохозяйственной продукции и биоотходов (Manual for the Subject: Preparation and Processing of Agricultural Production and Bio-wastes) Chisinau - Prague, 2009, 162 p. (In Russian).
6. Побединский В., Гаврланд Б., Гутла П., Иванова Т., Мунтян А., Кандаков А. Сравнительная оценка качества твердых биотоплив (Comparative evaluation of the quality of solid biofuels). Tavria State Agrotechnological University, Ukraine, Melitopol, 2011, pp. 17 – 26. (In Russian).