BRIQUETTING DIFFERENT KINDS OF HERBACEOUS BIOMATERIAL

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Abstract. The paper analyses the features of producing briquette from different herbaceous biomaterial and cardboard waste and describes the problems that can arise in the pressing operation. The screw press was used. The proper briquette was formed from wheat straw, rye straw and cardboard and the satisfactory one from rye straw together with meadow hay. While the rye straw briquette exhibited the highest calorific value and the lowest ash content, the leaf briquette had the highest ash content and the lowest calorific value.

Key words: herbaceous biomass, screw briquette press, solid biofuel, combustion testing parameters.

Introduction

Biofuels have been increasingly used over the last years. Modern-day production and burning technologies allow the effective use of almost all waste products of wood, timber and agricultural manufacturing. The herbaceous biomass is widely used as fuel, followed also by grain and rape straw. By properties, grain straw is similar to timber. Initial data confirm that in Estonia in the year 2007, 605500 tons of grain was collected with straw amounting to approximately 810000 tons [1]. The implementation of the use of biofuel has become and actual subject in Estonia.

Biofuel is a fuel that is made from biomass such as agricultural products, including herbaceous and animal materials, forestry products, wastes and residuals biologically biodegraded fraction and industrial and household wastes biologically biodegraded fraction [2]. If forestry wastes are increasingly used for practical applications, then agricultural products and wastes are a resource that could also find more purpose and use. In Estonia, there is plenty of unused agricultural land that could be used for growing energy crops. The cultivated seedplants (e.g. wheat, barley, cole and corn) partly (seed), as a whole (the whole plant) or as waste (straw) could be used as energy crops. One way would be briquetting the biomass and burning it in households, boiler houses and heat and energy stations.

The purpose of this research was to investigate the briquetting of different energy plants and wastes (straw, hay, etc.).

Materials and methods

The tasks for the research were as follows:

1. to test knifeshredders for the preparation of the briquetting material and the BIOMASSER BS06 press for practical briquetting;
2. to explore the briquetting of different biomass with screw press;
3. to determine the technical burning parameters of different materials.

The following processes are involved in the briquetting/pressing:

1. pressure is applied to the briquetting material;
2. temperature goes up because of the friction between the particles of briquetting materials and the friction between the press and the briquetting material;
3. as a result of the high temperature and pressure during the process, the wooden plants cellular structure breaks;
4. because of the heat the lignin contained in the material softens and glues the particles of the material together.

As the material dries during briquetting, the energetic value of the fuel produced by briquetting increases. Pressed fuels of herbaceous origin have the following advantages over the unprocessed herbaceous mass:

1. because of low humidity and high calorific value the pressed herbaceous material is cheaper to transport and store;
2. dry fuel will not decompose biologically because of fungus and microorganisms, and can therefore be preserved for a long time;

3. equable moisture and size of the piece allow to regulate the burning regime in the ingle more precisely and thus ensure higher efficiency.

For the experiments BIOMASSER BS06 briquetting device was used. This device is a screw press meant for briquetting thatch and hay. The productivity of the device by the technical data is $Q = 40…50$ kg h^{-1}. The length of Cooler-stabilizer is $L = 3000$ mm. The material for briquetting has to be of fraction 2...5 cm and humidity $W = 15...30$ %. The briquette produced by briquetting is of random length and diameter $D = 70$ mm [3].

Fig. 1. **Briquette press BIOMASSER BS06**

To provide the necessary fraction, the straw shredder BIOMASSER RS06 [4] is a suitable device. This device is chargeable from the top and shreds only loose straw. Depending on the material the productivity of the device is up to $Q = 150$ kg h^{-1}. Moisture of the materials can be up to $W = 30$ %. Shredding level depends on the shredder's sifts opening diameter. The opening diameter of sifts in the device used was $d = 28$ mm.

The shredder can serve two briquetting devices. It is equipped with one cutting and four chopping blades. Some of the materials of longer length, such as straws, had to be pre-shred with drum-type shredder. Shredding was necessary to make the handling of the material easier. The binding material had to be removed before shredding.

Practical results

The results of briquetting different material are shown in Tables 1 and 2. Wheat and rye straw passed through the shredder RS06 without any malfunctioning. The briquetting device worked properly with both straws and the briquette produced was of expected quality. The productivity of the device was $Q = 41…55.8$ kg h^{-1}, and the density of the briquette fell in the range of $\rho = 650.2…799.2$ kg m^{-3}. The meadow hay shredding could not be performed with BIOMASSER RS06. The material formed wisps and got stuck between the blade and the walls of the device. Then, we first shredded the hay with the JAGUAR type of smasher and then with BIOMASSER RS06 [5, 6]. The pre-shredded material passed through BIOMASSER RS06 without problems.

With rape straw the BIOMASSER RS06 performed properly when it was pre-shredded with the JAGUAR type of smasher. However, the material got stuck during the briquetting process and was overloaded. The processing failed and no briquette was produced.

When rape straw was mixed with rye straw 1:1 (mass) there were no problems with shredders or the briquetting device but the briquette was very brickle and stratified. Till under the stabilizers pressure the briquette looked adequate but leaving from under the pressure the briquette was still warm and changed its shape. The briquette produced was of higher quality when it was allowed to cool under the pressure. The same solution is also used when making wooden briquette where the pressure line is often more than 20 m long, and also when producing peat briquette where pressure line passes through the outside environment under the roof to cool down the briquette.

When rape straw was mixed with hay 1:1 (mass) there were no problems with shredders or the briquetting device but the briquette was also very brickle and stratified. When the rape straw was

mixed with field grass 1:1 (mass) there were no problems with shredders and the briquetting device. The material easily fell down to the screws working zone but the briquette was still very brickle.

Table 1

Data of briquetting experiments

Materials	Material shredding	Temperature set	The shape of the briquette	Average density of the briquette ρ kg m^{-3}
Wheat straw	RS06, without a glitch	250 ºC	Correct	710.1
Meadow hay	JAGUAR + RS06	250 ºC	No briquette	–
Rye straw	RS06, without a glitch	250 ºC	Correct	758.5
Wheat and rye straw (4:1 by mass)	RS06, satisfactory	250 ºC	Correct	770.7
Meadow hay and rye straw (1:1 by mass)	Not stable	250 ºC	Brickle	713.0
Rape straw	JAGUAR + RS06	250 ºC	No briquette	–
Rape and rye straw (1:1 by mass)	JAGUAR + RS06	250 ºC	Normal if pressure line is 20 m.	–
Rape straw and meadow hay (1:1 by mass)	JAGUAR + RS06	250 ºC	Stratified and brickle	–
Cardboard	JAGUAR + RS06	250 ºC	Correct	–
Thatch	RS06, without a glitch	230, 250, 280 ºC	Brickle	–
Thatch and rye straw (1:1 by mass)	RS06, without a glitch	250 ºC	Stratified and brickle	–
Thatch and rape-seed cake	RS06	250 ºC	No briquette	–
Leaves (birch)	RS06	250 ºC	Stratified but stable	730.0
Leaves and rye straw (1:1 by mass)	RS06, without a glitch	250 ºC	Stratified and brickle	728.4
Cucumber plants	RS06, without a glitch	250 ºC	Correct, 100…300 mm	758.0

The roped bundles of thatch used in the experiments had been kept under the roof all summer long. There were no problems with shredding and the fraction was proper. The chopped material easily fell into the feeding hole but the briquette did not hold together. Already when under pressure some surface fractures appeared on the briquette and after the pressure was released the briquette fell apart.

Mixing thatch with rye straw 1:1 (mass) did not result in any problems to the performance of the briquetting system. The briquette looked adequate when under the pressure and no fractures appeared but after the pressure was released the briquette fell also apart. When thatch was mixed with rape-seed cake the latter fell faster to the feeding hole and therefore got stuck to the forming sleeve. Thus, the briquetting of thatch did not provide expected results and no proper briquette was formed.

Table 2

Different materials combustion testing parameters

Determinable parameter	Moisture	Ash (in dry matter)	Volatiles	Sulphur (in dry matter)	Chlorine (in dry matter)	Calorific value in dry matter	Calorific value, actual	Characterisation of ash behaviour			
								Beginning of sintering	Beginning of softening	Hemispheric point	Flowing point
Standard	CEN/TS 14774	CEN/TS 14775	CEN/TS 15148	ISO 334	ISO 587	CEN/TS 14918	CEN/TS 14918	CEN/TS 15370			
Briquette from wheat straw	11.4 %	4.7 %	77.6 %	0.12 %	0.36 %	19.10 MJ kg^{-1}	15.43 MJ kg^{-1}	870 °C	920 °C	1000 °C	1030 °C
Briquette from rye straw	11.4 %	3.6 %	78.1 %	0.08 %	0.29 %	19.04 MJ kg^{-1}	15.37 MJ kg^{-1}	870 °C	1070 °C	1090 °C	1100 °C
Briquette from meadow and rye straw	15.4 %	3.7 %	77.2 %	0.12 %	0.33 %	19.36 MJ kg^{-1}	14.84 MJ kg^{-1}	950 °C	1000 °C	1020 °C	1040 °C
Briquette from rape and rye straw	13.5 %	4.6 %	77.0 %	0.14 %	0.42 %	18.70 MJ kg^{-1}	14.66 MJ kg^{-1}	600 °C	620 °C	-	until 1350 °C did not flow
Briquette from rape and meadow straw	15.9 %	4.7 %	76.8 %	0.16 %	0.45 %	18.94 MJ kg^{-1}	14.38 MJ kg^{-1}	600 °C	-	-	until 1350 °C did not flow
Briguette from rape straw and field grass	13.9 %	5.2 %	76.5 %	0.15 %	0.34 %	18.62 MJ kg^{-1}	14.51 MJ kg^{-1}	740 °C	1190 °C	1230 °C	until 1350 °C did not flow
Briquette from cardboard	9.5 %	11.0 %	77.9 %	0.11 %	0.06 %	16.84 MJ kg^{-1}	13.77 MJ kg^{-1}	920 °C	1160 °C	1200 °C	until 1350 °C did not flow
Briquette from thatch	15.7 %	4.3 %	82.0 %	0.1 %	<0.05 %	17.41 MJ kg^{-1}	14.29 MJ kg^{-1}	880 °C	-	-	until 1350 °C did not flow
Briquette from thatch and rye straw	16.1 %	4.2 %	78.5 %	0.1 %	<0.1 %	15.87 MJ kg^{-1}	12.92 MJ kg^{-1}	680 °C	880 °C	1080 °C	1110 °C
Briquette from leaf and rye straw	18.2 %	16.2 %	67.1 %	0.1 %	0.3 %	15.85 MJ kg^{-1}	12.52 MJ kg^{-1}	1080 °C	1100 °C	1130 °C	1140 °C
Briquette from leaf	25.3 %	23.9 %	62.5 %	0.1 %	<0.1 %	15.83 MJ kg^{-1}	11.21 MJ kg^{-1}	1110 °C	1150 °C	1170 °C	1180 °C
Briquette from cucumber plants	16.5 %	21.7 %	64.0 %	0.2 %	0.2 %	13.91 MJ kg^{-1}	11.22 MJ kg^{-1}	770 °C	900 °C	1250 °C	1270 °C

The briquette pressed from leaves was adequately hard and no problems occurred in the briquetting press during the experiments. Although the surface of the briquette was fractured the briquette held together. Problems can be caused by foreign objects like stones, metal pieces, glass fragments and bigger tree branches. When leaves where mixed with rye straw 1:1 (mass) the briquette looked adequate on the outlet chute but it failed to hold together when after leaving the chute.

The briquette from cucumber plants was properly hard and held together very well. The surface of the briquette was smooth. The length of the briquette was in the range of 100...300 mm.

The combustion parameters of different briquette produced were tested, and these are shown in Table 2 [7].

Conclusion

The biomass of cultivated energy plants is difficult to briquette because of the biological properties of the matter. The briquetting device operator needed to exercise patience and full concentration during the production process.

We have provided an overview of the briquetting characteristics of the main types of matter originating from agricultural production. The shape and quality of briquette appeared to be influenced by the following factors*:*

1. type of briquetting device;
2. type of briquetted material (different cereal straw, meadow hay, leaves, cucumber plants, etc.);
3. parameters of material (dimensions of the pieces and humidity);
4. cooling process on the outlet chute (significant changes in mechanical qualities during cooling).

There was a significantly big difference in the density and productivity on different parts of the briquette produced. The briquetting experiments must be continued to find out what accounts for it. Meadow hay and cardboard must be pre-shredded. Proper briquette was formed from wheat straw, rye straw and cardboard, briquette of satisfactory quality was produced from rye straw mixed with meadow hay 1:1 (mass) and rye straw mixed with either leaves 1:1 (mass) or cucumber plants 1:1 (mass). To produce briquettes from straw, the following technical and technological problems must be solved:

1. monitoring the straw bales in the field;
2. pre-drying the material (if necessary);
3. smooth starting and stopping of the technological process;
4. dust elimination from the shredding process;
5. providing the material pieces of optimal dimensions;
6. feeding the material to the briquetting press (danger of vaulting).

In conclusion we can say that in spite of the problems that arose during the process, the herbaceous and other materials used in the experiments can be briquetted and used as fuel. All technical and technological problems can be solved.

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