Agronomy Research **17**(X), xxx–ccc, 2019
https://doi.org/10.15159/AR.19.021

The energy intensity of the briquetting process in terms of profitability of waste treatment

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Abstract. Modern agricultural industry is a source of a considerable amount of waste, which can come in various forms and states. Such waste, and not just agricultural waste in the form biomass, is highly desirable for further processing, depositing or utilising its energy potential. Briquetting technology is suitable for all these purposes. The briquetting press for industrial use is complex technical equipment. The economy of its operation has a major impact on the profitability of the produced briquettes and hence on the efficiency of waste and biomass processing as such. The paper deals with the energy demands of briquetting in terms of waste treatment and economic profitability of production in the whole context of waste processing as a whole.

Key words: briquetting, energy demands, bio-briquettes, economic profitability.

INTRODUCTION

Despite all political efforts, the share of biomass in all its forms is still relatively low and there is considerable room for increasing its production. At present, biomass accounts for about 14% of the world's annual energy consumption (Hall et al., 1992). In 2017 production of renewable energy sources (especially biofuels) generated 4 million jobs and contributed at least 2.5% to the performance of the US economy. It is clear that the small-scale production of biofuels at their very place of origin is really meaningful. It has undeniable positive environmental effects (including reduced requirements for the transport of waste and biomass). It can also have a positive impact on employment. In particular, the use of briquettes from biomass or other waste materials ensures a renewable, ecologically acceptable alternative to fossil fuels and leads to the generation of other economic income not only of farmers (Chen et al., 2009; Guo & Song, 2019). Therefore, it is very important to address the energy demands of the densification process, including the power consumption that needs to be spent on compressing the particular materials and producing the briquettes themselves.

MATERIALS AND METHODS

The energy demands of densification and production of briquettes on a briquetting press can be basically summarized into two groups:

1) Consumption of mechanical work

This is the labour consumption necessary for the compaction of the input material, it is the relationship between the density ρ (kg m^{-3}) and the desired deformation energy Ed (J). It is very important to know the necessary forces F (N) as well as the physical properties, the fraction and the moisture of the used input material. In addition to the physical properties of the materials and the required force to densification, another important factor that affects the quality of the finished briquettes is the temperature of the briquetting press and pressing chambers. The last of a group of major variables in terms of the evaluation of the consumption of mechanical work that plays important roles, is the structure, type and mode of work of the briquetting press (Repsa & Kronbergs, 2015; Muntean et al., 2017; Brunerová et al., 2018). Consumption of mechanical work is not the subject of this paper.

2) Consumption of electrical energy

The power consumption depends on the briquetting press and also on the selected input material. For this purpose, the briquetting press is understood to be a complete machine which is used to mould the input material and produce briquettes with a diameter of 50 mm.

For the experimental measurement, a typical representative of the middle classes of industrial briquetting presses used for processing biomass and other conventional waste (including paper scrap) was chosen small medium-duty single-shift operation (without an oil cooler). The machine is a product of Briklis, s.r.o. Czech Republic, specifically BrikStar 30, type 12. The basic machine parameters are summarized in Table 1.

Table 1. Selected technical parameters of the Brikstar 30, type 12 briquetting press

Parameter	Value	Unit
Performance {NL}; +-10%	20–40	kg hrs^{-1}
Installed electrical power	4.4	kW
Weight of the press with a hopper of 1 m^3 capacity	780	kg
Density of pressed briquettes	900–1,100	kg m^{-3}
Average of the briquettes	50	mm
Maximum operating pressure	180	bar
Covering of electrical elements	IP54	xxx

For the measurement itself was used Chauvin Arnoux C.A. 8334B network analyzer concatenation, which was connected in parallel to the TN-S distribution network. The block diagram is shown in Fig. 1, where the circles are the pliers for the current measurement. The device recorded the data every 1 second and stored it in its memory. The important parameters were:

- Performance (Wh)
- Time of the measurement (s)
- Voltage at each stage (V)
- Current at individual stages (A)

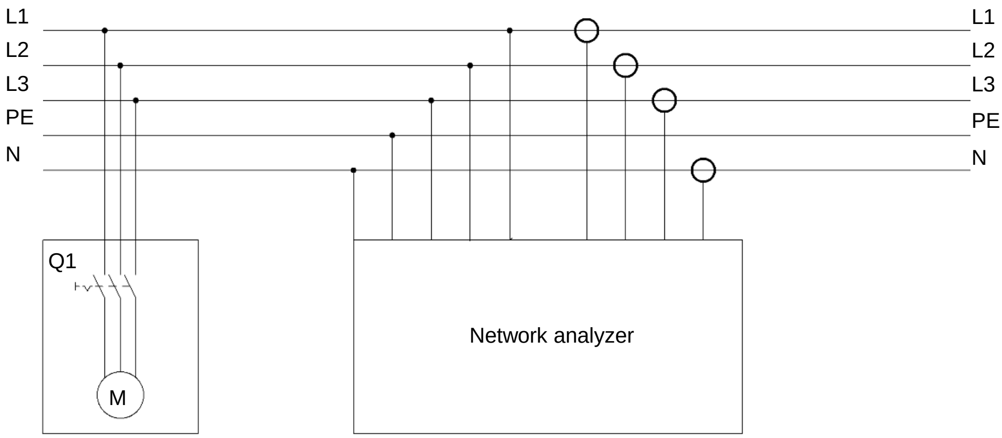

Figure 1. Block measurement scheme: L1 to L2 – phases of three-phase TN-S distribution system; PE – Protective Earthing; N – Neutral conductor; Q1 – motor terminal block; M – briquetting press three-phase asynchronous electric motor.

Theory and modelling

Based on the measured data, the energy consumption (kWh) of the briquetting press was calculated using the mathematical formula (1). The result gives the energy consumption in 1 hour of the briquetting press operation.

$$P_i = \frac{E_{ki} - E_{pi}}{k_i - p_i} \cdot 3.6 \qquad (1)$$

where P_i – power consumption of the i^{th} sample; i – data-set extent; k_i – end of measurement of the i^{th} sample; pi – beginning of measurement of the i^{th} sample; E_{ki} – the nominal end value of the reactive work of i^{th} sample; E_{pi} – the nominal initial value of the reactive work of i^{th} sample.

Depending on the briquette mass produced at the time of measurement, the actual performance of the briquetting press according to the mathematical relationship (2) was calculated (depending on the material).

$$A_i = \frac{W_{pi}}{m_i} \qquad (2)$$

where Ai – machine performance on the i^{th} same sample; W_{pi} – Consumption of the reactive work of i^{th} sample ; m – weight of the i^{th} sample.

Selected test sample

The used sampling methodology included three basic criteria:

- Material availability
- Rentability of the production
- Difficult another processing (eg, storage problem due the dustiness or bulk, other possible manufacturing processes that would be difficult or impossible in the natural form of the materials etc.)

Based on the criteria above, 8 samples were selected. These are described in Table 2. The emphasis was put on scrap paper (in several forms). There are several reasons for this. The first is its production is growing as well as the demand for its recycling. Another reason is the production of paper and scrap paper which is contaminated (mineral oils, etc.), which means it cannot be recycled in a normal way, is relatively high. The briquetting technology appears to be suitable for reducing the volume of contaminated paper and its subsequent energy utilization by incineration. This technology also appears to be useful to reduce the volume of material that is not possible to burn from environmental reasons or due to material compostion.

Table 2. Selected samples

Sample number	Material	Fraction
1	newspaper matte paper	scrap 4 x 18 mm
2	newspaper glossy paper	scrap 4 x 18 mm
3	carton	scrap 12 x 50 mm
4	old student books	scrap 4 x 18 mm
5	mix hop 50% & birch 50%	natural form/shavings
6	sugar thistle	mouldings
7	hop	natural
8	birch	shavings

First of all, it was necessary to prepare the collected material and unify its fraction. There are fractions of scrap paper in the Fig. 2 (the fraction of sample no 1, 2 and 3 are visualy the same as well as the fraction of the sample no 5 and 6). From the top left there are fractions of sugar thistle (mouldings), hop (natural form, outdoor photography) and brich (shavings). From the bottom left there are old student book (fraction 4 x 18 mm) and scrap carton (fraction 12 x 50 mm).

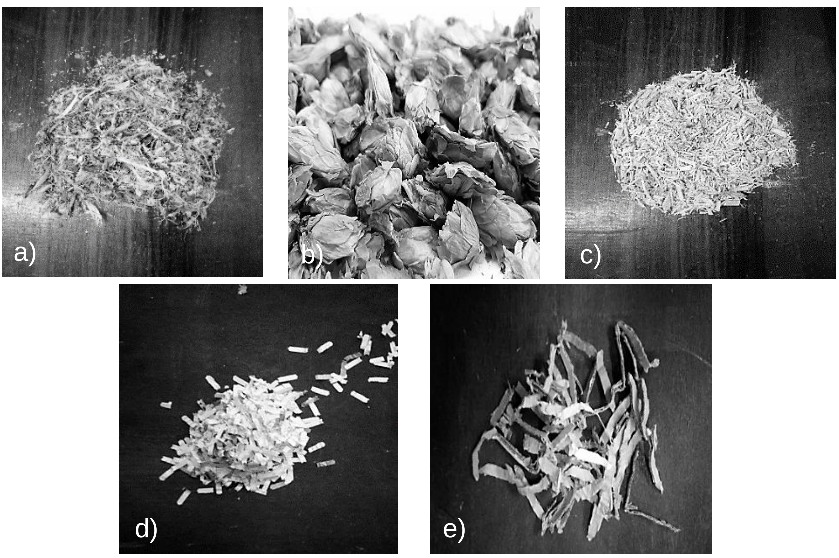

Figure 2. Photographs of the used samples. Photographs of the used samples: a) sugar thistle (mouldings); b) hop (natural form – outdoor photography); c) brich (shavings); d) old student book (scrap, fraction 4 x 18 mm); e) carton (scrap, fraction 12 x50 mm).

RESULTS AND DISCUSSION

The results of the experimental measurement carried out and evaluated by the methods described above (in the Theory and Modelling section) are clearly shown in the graph in Fig. 3. It is very clear from the graph and the displayed values that the power consumption, depending on the specifically compressed material, virtually does not change. sample no. 6 showed the largest energy demands. Scrap paper requires the most energy needed to compress scrap carton (sample no. 3). It is remarkable to note that the differences in energy demands of compressed scrap paper are virtually insignificant, namely 0.13 kWh. When we choose the other monitored materials, we find that the difference between the most energy-demanding material represented by sample no. 6 with 2.15 kWh and the least energy demanding sample no. 8 (with 1.85 kWh) is only 0.3 kWh. Due to the installed electrical power of the machine of 4.4 kW, this difference can be considered negligible. On the basis of the experiment, it can be stated that the type of compressed material does not play a fundamental role in the energy consumption demands of the industrial briquetting press. There are several factors which have impact on electricity consumption. The chemical composition of the material, the physical properties, moisture of the material and the amount of force used for pressing. Shape and particle size do not play the main role, as has also been shown in the results. Another important factor is the construction of the briquetting press itself. The principle of its operation is critical if it come to electricity consumption (hydraulics vs. mechanical transmission).

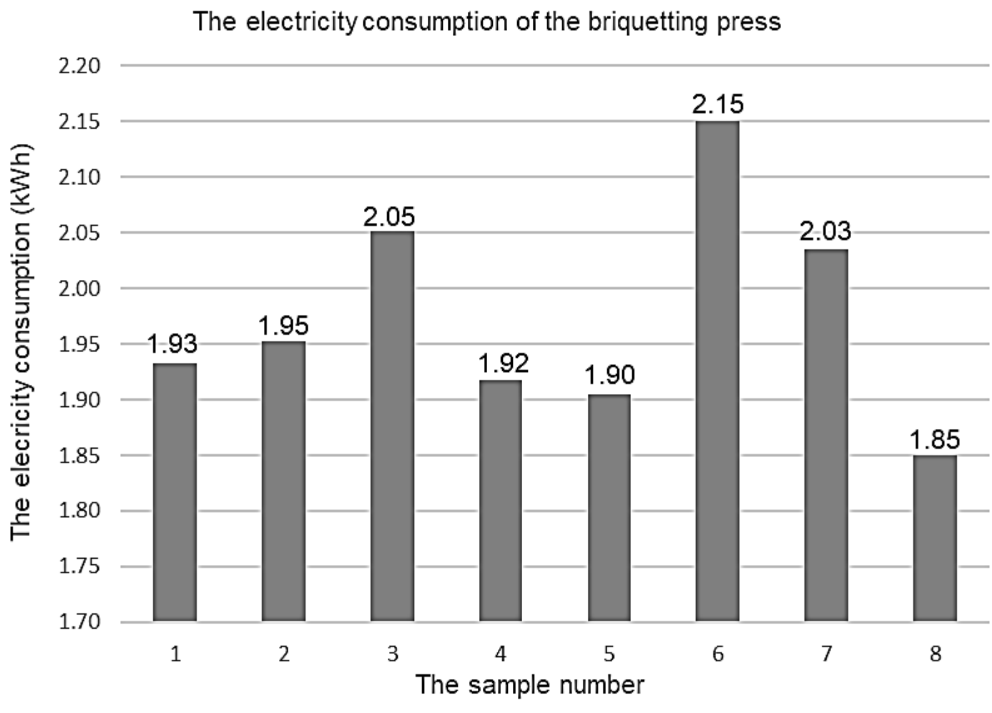

Figure 3. Electricity consumption.

For the purpose of economic evaluation, it was necessary to assess the resulting briquettes from individual tests and to determine the actual energy consumption of the machine depending on the briquetted material. The results are again clearly arranged in the table in Fig. 4. It is obvious that most of the electricity is consumed to produce the briquettes from sample no. 3. On the contrary, the least energy is needed for sample no. 2. Research presented in this paper was primary focus on the scrap paper. The other materials were (namely sample no 5, 6, 7 and 8) used to compare the energy consumption of the different scrap paper and the natural materials. It is clear from the data that the energy consumption samples no. 5, 6, 7 and 8 are practically the same. That can be caused by their very similar mechanical properties and by the size of the used fraction. From this point of view, there are more interesting the results of the scrap paper. Despite the comparable properties and similar fractions, the results differ more significantly.

In this case the results are already distinctly more pronounced, which is caused by several factors:

- The power of the briquetting press itself
  It is possible to use a machine with higher pressure. However, the purchase and operation would be more expensive.
- Compression of the compressed material due to its physical properties
- Specific weight of the particular compressed material

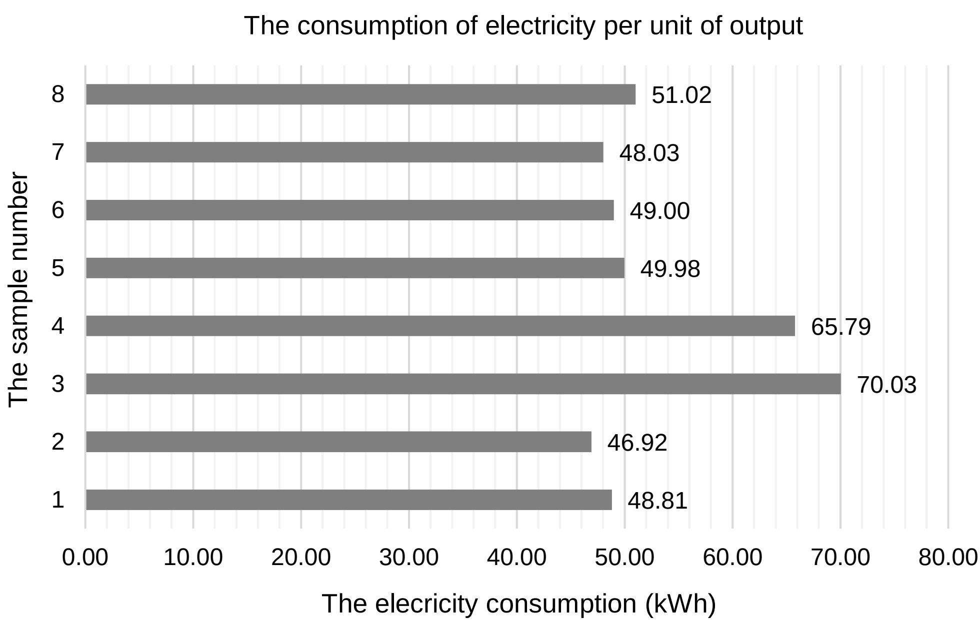

Figure 4. Specific consumption of electricity per unit of output.

In spite of the said and relatively demonstrable results, I must be critical. For the measurements a briquetting press from a leading manufacturer was chosen with paramaters which can be described as typical. However, it is likely that the values will be distinguished individually from the machine. Due to the similar design of piston hydraulic presses, it can be assumed that the resulting values will not vary significantly. Thus, it can be stated that the measurements made clearly show that most of the electricity consumption is consumed for the operation of the machine, respectively (its hydraulic systems). Moulded material does not play significant role.

Economic evaluation

Just by multiplying the cost of electricity and adding additional costs (eg, electricity transmission charges etc.) in a given country, briquette production costs of a particular briquetted material in a given region can be very accurately determined. The specific final price for 1 MWh of industrial customers can not be easily determined, depending on the size of the enterprise, its total consumption, installed power and also the conditions of specific energy providers.

From the point of view of financial fitness for electricity, the influence of briquetted material is negligible. It is clear that, from an economic point of view, it is necessary to rely more on investing in technology as a whole. In particular, it is necessary to calculate the cost of operation, maintenance and, of course, the amortization of the briquetting press, rather than considering the cost of electricity depending on the concreted briquetted material. But the performance of the machine is more interesting. Here is space for economic optimization by selecting a suitable material. In this particular case, the manufacturer reports the performance of the machine to +/- 20% accuracy, which was also measured and verified. By selecting a suitable material and its appropriate subsequent energy utilization (eg. retail sale to the end-user or industrial heating or water heating), considerable savings can be achieved with respect to the briquetting press in the order of tens of percent, and this can have the indicated multiplier effect and generate additional savings or revenue.

From the economic point of view, it is also necessary to consider the costs that need to be spent on preparing and processing the material before the briquetting process itself. There is the practical economic advantage (regardless of the electricity consumption) to use of this technology at the point of production of the material that is suitable for briquetting (eg, selected samples in this paper). From the point of view of the briquetting process itself, significant differences in processing of selected samples were not observed. Thus, it is necessary to consider all the circumstances described above and to decide what material is advantageous to briquet and which is not. Consumption of electrical dependence on material is not the only decisive factor.

CONCLUSIONS

Based on the results of the measurements and the measured values, the energy demands of the individual basic compressed materials were clearly shown. Such an evaluation can lead to the selection of material that is suitable for briquetting and which is not. In particular, economic appreciation can greatly assist in deciding and implementing technological processes in industrial and agricultural plants that produce biomass, especially in economic considerations about the profitability of its processing.

This research is basically directly preceded by the current experimental research on the briquetting press for home use of the Profilis 15 Home. The comparison of the measurements on the Briklis briquetting press with the Profilis briquetting press and subsequent economic evaluation can bring further interesting results. It will be possible to determine the point of profitability, i.e. a point in volume production from which the production of briquettes on the domestic press becomes unprofitable and it is advantageous to use an industrial press.

The research was supported by the Internal Grant Agency (IGA), Faculty of Engineering, Czech University of Life Sciences Prague; Grant title: The energy intensity of densification in the production of briquettes from waste materials with a focus on waste biomass in the small-scale production.

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