PRODUCTION OF BRIQUETTES FROM WASTE PAPER

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Abstract

The article focuses on the possibility of recycling waste paper, which has become one of the major commodities collecting raw materials for its wide use in many economic areas. In the introduction to the description of the overview of the development segment of waste paper in the Czech Republic. The article presents information about the opportunities of new products and materials from processed recycled paper. In another part of the article presents practical information from the process to produce briquettes from three kinds of waste paper with a description technology and obtained a description of the physical characteristics of produced briquettes.

Key words: biodegradable municipal waste, material recycling, composting, production of briquettes.

INTRODUCTION

In the Czech Republic, 800,000 tons of waste paper is collected annually in average via separate sorting, but out of this amount only 315,000 tons is processed, and the rest, i.e. approx. 60% out of the mentioned total amount, is being exported abroad at the expense of the environment and the Czech economy. Although a paper consumption in the Czech Republic is estimated at 1.5 million tons, only 900,000 tons of paper is produced there. Out of this quantity, 700,000 tons is exported simultaneously, which means that it is necessary to import 1.3 mil. tons of new paper (BARTÁK, 2010). These figures clearly confirm that 85 % of the paper intended for consumption must be imported to the Czech Republic.

Today the comfortable life is paid with the expressive consumption of energy in all its forms. The non-renewable energy source reserves are limited and they are to exhaust. Nevertheless, they supply about four fifths of energy consumption. In last decades, the renewable energy sources have been preferred. One of alternative forms of fuel, made from renewable sources, is the fuel on the basis of paper waste. First of all, it is recommended to recycle this raw material – to use it as a material (MCKINNEY, 1995).

From the results of works published before (BROŽEK 2013; BROŽEK, NOVÁKOVÁ, 2013), it follows that compared to briquettes from wood waste, briquettes made from recovered paper and board are of low moisture content, high density, high mechanical durability and relatively high force is necessary for their rupture. But at the same time, they have high ash amount and low gross calorific value.

The constant industrial activity rise and world population growth are directly related to the increase of overall energy consumption, and it is estimated that in 2025, energy demand will surpass by 50 % the current needs (RAGAUSKAS ET AL., 2006). Nowadays, almost 80% of the world's energy supply is provided by fossil fuels (SIMS ET AL., 2007) with harmful impacts to the environment.

The goal of research is to obtain the heating value of paper briquettes and to compare with available fuels on the Czech market. Part of the research is to calculate the bulk density of briquettes made of paper. Result of research can help to find a new fuel from recycled paper.

MATERIALS AND METHODS

Determining the volume of shredded paper using measuring cylinders of known volume and weight of the material.

There were chosen 3 kinds of waste paper for the experiment:

- Office paper shredded with the Fellowes MS 450Ms paper shredder,
- Shredded paperboard (see Fig. 1),
- Shredded waste paper (a mixture of magazines, newspapers and other paper packaging), shredded with the HSM DuoShredder 5750 at WEGA recycling Ltd.

The materials were scattered into a 1000 ml measuring cylinder. The material was not compacted, just sprin-

kled into the measuring cylinder of the same height. Subsequently, the material was sprinkled on a scale and the weight of the material was measured in [g]. There were performed 10 measurements for each material and the mean value was determined, from which the specific weight of input shredded material was calculated.

Other devices:

- The measuring cylinder with a volume of 2000 ml,

Laboratory scale KERN PFB 2000-2 with weighing range up to 2 000 g with a 0.01 g accuracy.

Briquetting of three kinds of shredded waste paper.

The material was inserted into the reservoir of briquetting machine BrinkStar CS25 with a matrix of 65 mm, and three types of briquettes were produced depending on a waste paper. Maximum operating pressure of the briquetting machine was 18 MPa (180 bar). Materials for pressing had to meet the following conditions: moisture content from 8 to 15 %, dimensions smaller than 15 mm and bulk density of at least 70 $kg.m^{-3}$. Briquette height was measured in two spots and the average value was calculated. Using the matrix diameter 65 mm, the height and the weight of the briquettes, the resulting bulk density was calculated.

Calculation of density of the produced briquettes.

Briquettes were measured in height in two places and the average value was calculated. Due to the matrix diameter 65 mm, the height and weight of the briquettes the resulting bulk density was calculated. The compression coefficient was calculated as the ratio between the density of the material prior to entering the briquetting facility and the density of the resulting briquettes.

Calculation of heating value by using the norm ISO 1928.

The briquettes were also analyzed to obtain a combustion heat and heating value according to ISO 1928. According to the manual of the briquetting machine, the briquettes should have had a shape of a cylinder of diameter 65 mm, length from 30 to up to 50 mm, and the heating value from 15 to 18 $MJ.kg^{-1}$.

RESULTS AND DISCUSSION

The density of selected materials (Tab. 1) was calculated in the first part of the research, and it was found out that a cardboard has the highest density. It is due to a higher proportion of pulp after multiple recycling, which is contained in the cardboard compared to other kinds of waste paper.

Tab. 1. – Measurement of density of selected paper waste in a vessel of volume 1000 ml

Number measurement	Separate paper [g]	Cardboard [g]	Office paper [g]
1.	55.263	76.120	73.820
2.	56.760	75.820	68.200
3.	51.774	74.280	62.000
4.	56.113	80.020	64.200
5.	57.906	79.458	63.220
6.	52.821	74.120	64.680
7.	56.219	71.720	68.400
8.	58.066	78.860	66.000
9.	54.017	73.520	67.100
10.	57.323	78.102	65.600
Average	55.626	76.202	66.322

In the next part of the experiment the production of briquettes of cylindrical shape with a diameter of 65 mm (Fig. 1 a, b, c) using a briquetting press was performed. The test waste material was gradually inserted into the reservoir and after the creation of briquettes the entire reservoir was cleaned before being used again for another test material.

20 pieces of produced briquettes were tested for each measured commodity of the paper waste. Each briquette was measured at two points to calculate the height and its average value. Furthermore, the volume of the briquettes was calculated and so was its weight and the bulk density. At the end it was calculated the compression ratio of mentioned kinds of waste paper (Tab. 2).

a) b) c)

Fig. 1. – **a, b, c** – Briquette manufacturing process: a) a container with the material, b) conveyor of the briquettes c) manufactured briquette

Tab. 2. – Calculation of compression ratio of measured kinds of waste paper

Input material	Bulk density of measured commodities [kg.m^{-3}]	Bulk density of briquettes [kg.m^{-3}]	Pressing coefficient [-]
Separate paper	66.322	278.343	4.20
Cardboard	76.202	252.322	3.31
Office paper	55.622	258.126	4.64

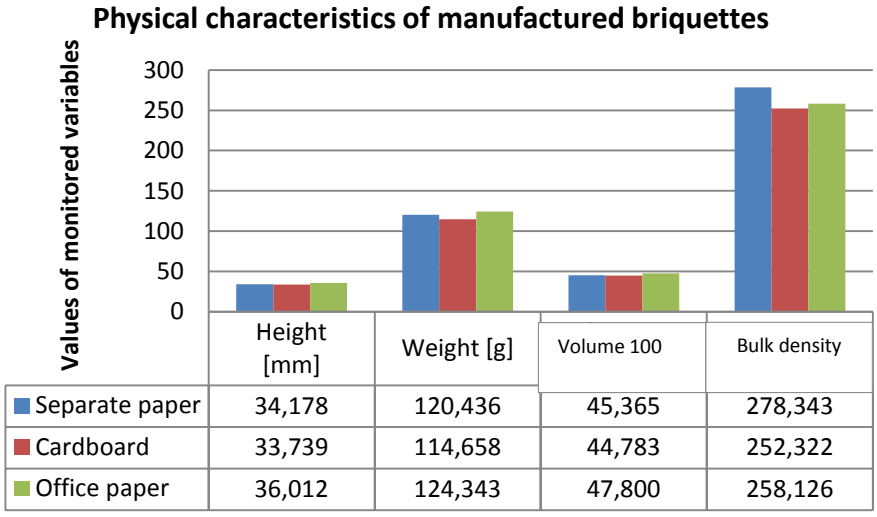

Fig. 2 – Chart with evaluation of measured physical characteristics of manufactured briquettes

Fig. 2 shows a relationship of measured values for the individual measured commodities of waste paper. For the visibility of the value of volume in Fig. 2 the value is stated as 100 pcs briquettes dm^3.

The briquettes were analyzed to obtain a combustion heat and heating value according to ISO 1928 (Tab. 3). The heating value of briquettes made of paper fell bellow the interval indicated by the manual of the briquetting machine. The cardboard briquettes demonstrated the highest heating value, probably because of the content of chemical binders.

The aim of the experiment where briquettes were produced by pressing three types of waste paper was to assess quality of the compression and possibility of further material use after its shredding. It is well known that there is a large amount shredded waste paper in office buildings that is according to current practice disposed of mainly together with a mixed municipal waste to a landfill. The briquettes produced can be used both in the process of energy production via combustion, and in the compost production process where they can significantly reduce the cost of transportation thanks to the compression ratio.

Tab. 3 – Chemical analysis, heating vaue and combustion heat of the briquettes

Materials		office paper	separate paper	cardboard
Parameter	units			
Humidity	[% weight]	4.13	4.23	4.82
Ash	[% weight]	12.63	20.41	11.58
C	[% weight]	36.17	35.31	39.35
H	[% weight]	5.11	4.77	5.41
N	[% weight]	0.06	0.09	0.14
S	[% weight]	0.04	0.03	0.05
O	[% weight]	44.15	37.22	41.18
Combustion Heat	[MJ.kg^{-1}]	12.94	13.19	14.72
Heating value	[MJ.kg^{-1}]	11.82	12.15	13.54

This is going to be the subject of further reflection and experimentation. The size of manufactured briquettes is in accordance with data reporting the size of wood chip material from various wood chippers (EPSTEIN ET AL., 1997), and corresponds to the commonly used sizes exploited in composting plants as mentioned by SOUCEK & BURG (2009).

The bulk density of the paper briquettes is up to 4 times lower than the density of briquettes made from herbaceous phytomass, and there is no problem of increased level of nitrogen that is generated by energy utilization of herbal phytomass as indicated by e.g. ZAJONC & FRYDRYCH (2012) or THEERARATTANANOON ET AL. (2011).

The most important indicator of quality briquettes is heating value. The produced briquettes reached heating value values ranging from 11.82 to 13.54 MJ.kg^{-1}. Comparison of results produced briquettes from waste paper with the other, freely available briquettes that are used today as the fuel, and are available on the Czech market, is shown in (Tab. 4).

Tab. 4 – Higher heating value and lower heating value of sewage sludge (MIKLUŠ, 2007)

Materials	**Humidity**	**Ash**	**Heating**	**Notes**
	[% units]	[% units]	[MJ.kg^{-1}]	
office paper	4.13	12.63	11.82	
separate paper	4.23	20.41	12.15	
cardboard	4.82	11.58	13.54	
EKO briquettes	10	5	13	sawdust made of soft wood
Briquettes Rekord	9	0.4	18	without bark and other binders
brown coal	5-20	10	13,3	assorted
black coal	1	6,5	20-29	

From Tab. 4 it can be observed significant differences between paper briquettes and available fuel for Czech households. It is evident that the paper briquettes have a very small percentage of moisture extruded material against the wooden briquettes and brown coal. Deficiencies in the paper briquettes on the other hand a higher percentage of ash to the total weight of the original produced briquettes. During the test Burning and obtaining the percentage of ash in paper briquettes it was already evident after the briquettes have a high ash content (see Fig. 3a, b). It was also noticeable that the paper even after burning left input material characteristics, whether of briquettes or shredded cardboard. It can however noted that the ash after incineration of paper or paper briquettes is not hazardous and can be further processed like ash after the combustion of wood, ie. for example composted.

Heating value of waste paper from different kinds of waste paper approached the heating value of the graded brown coal heating value and cardboard were higher for both graded brown coal as well as exceed the heating value of eco briquettes It can therefore be concluded that there is potential, therefore, as an alternative fuel, according to the results is possible.

Fig. 3. – a) Ash from incineration briquette, b) the ash from burning of input materials for the production of briquettes

CONCLUSIONS

The research contained four parts of the research. The main objective was to obtain a heating value of paper briquettes and compared with available fuels on the Czech market. Calculated a heating value briquettes was between 11.82 to 13.54 MJ.kg^{-1}. From these results, it can be argued that the briquettes which reach heating value over 13 MJ.kg^{-1} are high-quality fuel. For example, brown coal reaches in average 13 MJ.kg^{-1}. The difference of the ash content in the briquettes and brown coal is 1.58 %. This difference is negligible. According to the results of research it can be argued that the paper briquettes are a suitable substitute for brown coal. The question is the cost against the price of brown coal, but it can be a topic of follow-up article.

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REFERENCES

1. BARTÁK, V.: Paper and paper waste. World Press.4. 2010.
2. BROŽEK M., NOVÁKOVÁ A.: Briquettes from recovered paper and board. In: Engineering for Rural Development. Jelgava, Latvia University of Agriculture: 488–493, 2013.
3. BROŽEK M.: Properties of briquettes from paper waste. Manufacturing Technology, 13, 2013a: 138–142.
4. EPSTEIN, E.: The Science of Composting. Technomic Publishing. Co INC, Pensylvania, 1997.ISBN No. 1-56676-478-5.
5. MCKINNEY, R.: Technology of paper recycling. New York: Chapman & Hall, 1995. ISBN 0751400173.
6. MIKLUŠ, M.: Spalné teplo a výhřevnost čistírenských kalů: Higher heating value and lower heating value of sewage sludge [CD-ROM]. Brno: Vysoké učení technické, Fakulta strojního inženýrství, 2007.
7. RAGAUSKAS, A.J., WILLIAMS, C.K., DAVISON, B.H., BRITOVSEK, G., CAIRNEY, J., ECKERT, C.A., FREDERICK, W.J. , HALLETT, J.P., LEAK, D.J., LIOTTA, C.L.: The path forward for biofuels and biomaterials. Science, 311 (5760), 2006: 484–489.
8. SIMS, R.E.H., SCHOCK, R.N., ADEGBULULGBE, A. FENHANN, J., KONSTANTINAVICIUTE, I., MOOMAW, W., NIMIR, H.B., SCHLAMADINGER, B., TORRES-MARTÍNEZ, J., TURNER, C., UCHIYAMA, Y., VUORI, S.J.V., WAMUKONYA, N., ZHANG, X., METZ, B., DAVIDSON, O.R., BOSCH, P.R., DAVE, R., MEYER, L.A.: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA (2007).
9. SOUČEK, J., BURG, P.: The amount and opportunities of using material generated during maintenance of trees. Yearbook of Lawn, vol. 5, n.1, Olomouc, Publisher Baštan, 2009: 89-92. ISBN 978-80-87091-08-1.
10. THEERARATTANANOON, K., XU, F., WILSON, J., BALLARD, R., MCKINNEY, L., STAGGENBORG, S.: Physical properties of pellets made from sorghum stalk, corn stover, wheat straw, and big bluestem. Industrial Crops and Products, vol. 33, 2011: 325–332.
11. ZAJONC, O., FRYDRYCH, J.: The Mechanical Properties Of Pellets From Energy Grasses, Agritech Science, VÚZT, Praha, roč. 6, č. 2, 2013: 1-4. ISSN 1802-8942.

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