Briquetting of municipal solid waste by different technologies in order to evaluate its quality and properties

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Abstract. In this paper the main differences between briquettes produced from municipal solid waste (MSW) on mechanical and hydraulic press are described. One of the possibilities to evaluate municipal waste is gasification. Municipal waste is not in suitable form for gasification and therefore it has to be dried, shredded or disintegrated and compacted into suitable form – a briquette. As the municipal waste is full of inorganic materials, the briquettes are not compact. It is very important to determine the technological parameters and influences which can affect the final quality of briquettes. In this paper the processes of converting municipal waste into a more compact form – briquettes – are described. The quality and properties of the compacted briquettes are estimated by different methods. The description includes different aspects, such as manipulation, burning, mechanical and thermo-chemical properties of the briquettes. From the point of view of the gasification process some requirements for briquettes, such as transportability, compactness, moving in the oven and flaming up are presented. This research presents a good overview of the parameters of the technology of briquetting and material composition for producing briquettes from municipal waste.

Key words: Recycling, municipal waste, refuse derived fuels, briquetting technology.

INTRODUCTION

Energy from waste is a proven renewable energy technology that recovers energy from waste. In order to recover energy from mixed municipal waste the following technologies are most often used: direct combustion, pyrolysis, and gasification (Bridqwater, 2003). Direct combustion technology is used for burning waste which cannot be recycled by any other method. The combustion process produces high-pressure steam that is converted into electrical power by using a turbine and a generator (Williams, 2005). The generated heat can be used for producing hot water or steam which can be used by industrial or domestic heating systems. Pyrolysis is the thermaldegradation of the waste in the absence of air (Bridqwater, 2003). The produced syngas can be then used to generate energy. Gasification involves partial oxidation of the waste, again producing a syngas which is then used to generate energy (Williams, 2005). Initiative for the current recearch came from industry, as several companies were interested in the treatment of municipal waste into compacted forms suitable for gasification. Utilization of municipal waste as a substitute fuel for fossil energy-carriers is very advantageous from economic as well as from ecological point of view. The basic ecological reason for stopping deposition of the combustible wastes in dumps is the fact that biological decomposition process forms methane gas which is harmful for the environment. Methane as a greenhouse effect gas is 23 times more harmful than carbon oxide (Halmann, 1998). The energetic value of non-recyclable municipal waste or contaminated municipal waste can be recovered by gasification process. Before gasification this waste has to be crushed and compacted for handling, transportation, and storage. Municipal waste consists different types of materials; the mixture is heterogeneous in composition and size (Al-Salem, 2009). Therefore it is necessary to process the municipal waste before compacting, e.g. by disintegrating, drying, and homogenization (see Fig. 1) (Kers, 2009). In the current paper the processes of converting municipal solid waste into more compact form – briquettes – are described. The quality and properties of the compacted briquettes are estimated by different methods.

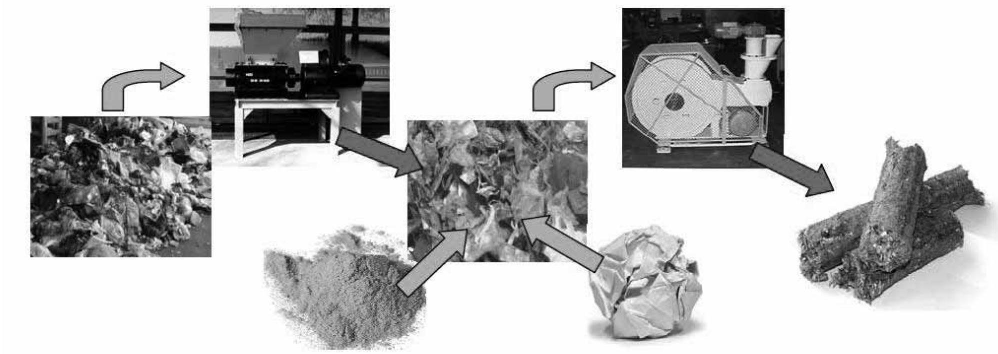


Figure 1. Schematic illustration of municipal waste treatment before gasification.

MATERIALS AND METHODS

The Slovak University of Technology in Bratislava has a laboratory of disintegration machines and briquetting equipment which was used for briquetting municipal waste. Before briquetting, municipal waste has to be processed for size reduction, adding binder agents and reducing the moisture content. The municipal waste used for the current research was brought directly from dumps by a recycling company. The MSW had high moisture content; it was contaminated and heterogeneous in composition. Therefore, the MSW had to be dried to reduce the moisture content in the material and shred for size reduction. Both of these parameters belong to the group of parameters which have great impact on the briquetting process. Independently the type of material to be compacted, its moisture content, fraction size, pressing temperature, and compacting pressure are the most important parameters to manufacture briquettes with acceptable quality. The pressing temperature and compacting pressure depend on the type of briquetting machine used. Fraction size has great influence on the briquetting process. The coarser the fraction is, the higher compacting power is needed for briquetting. Briquette has lower homogeneity and stability. By increasing the fraction size, the binding forces inside the material decrease which effects on faster decay by burning (briquette burns faster and that is not an advantage). Fraction size enlargement raises the compacting pressure which decreases briquette´s quality (Matuš, 2010). Usually the combination of a one-shaft shredder with a two-shaft shredder is used for size reduction. The principle of mechanical size reduction process is very simple. Rotorblades of the one rotor rotate against the cutting elements of the second rotor. The cutting elements of the rotors catch material and cut output fraction. The dimensions of the material before disintegration are in hundreds of millimeters. The productivity of disintegration machines depends on the dimensions of the machine, rotation velocity, size and shape of input fraction. Disintegration in a single shaft-shredder follows the disintegration in a two-shaft shredder. Grinding process takes place in the single-shaft disintegration machine. Output fraction passes through the openings in the screen. The screen is mounted under the rotor and assures homogeneity of output fraction (see Fig. 2).

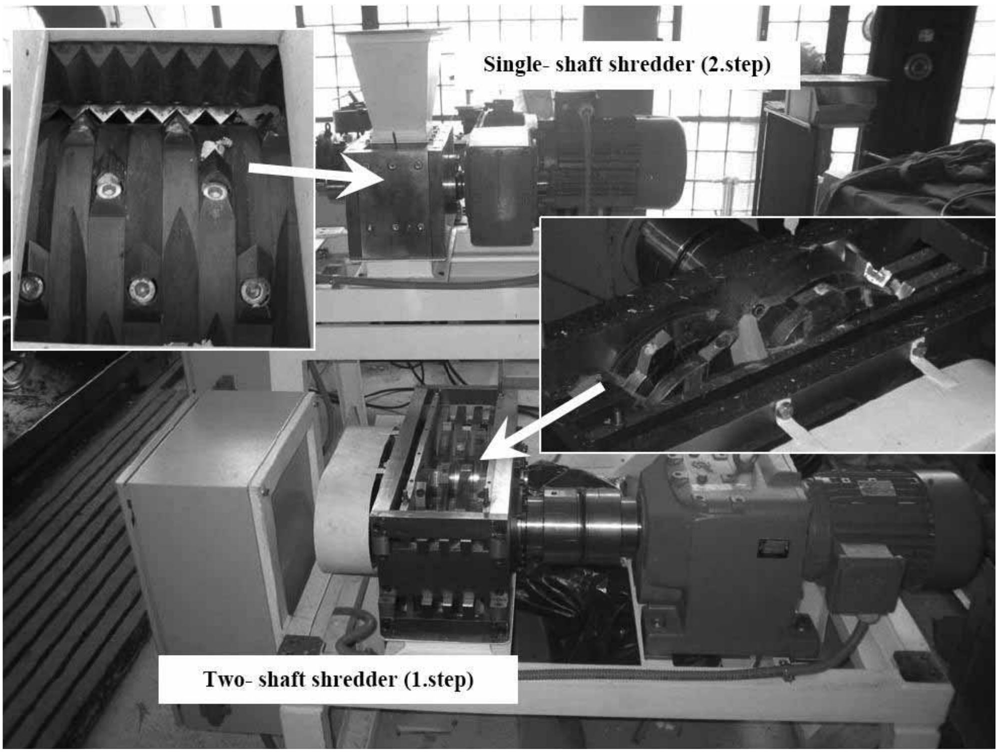


Figure 2. Size reduction on laboratory shredders.

Smaller fraction size is also an advantage for the drying process. The drying process ends faster and better drying quality is achieved due to the fact that the material is disintegrated into smaller pieces (Matuš, 2010). Therefore the waste material should be ground into suitable fraction size and dried into certain moisture content before the briquetting process. Several experiments were carried out to measure the influence of the material moisture content at the briquetting process with various biological materials. If the material moisture content is very low or very high, material elements are not consistent and the briquette may fall into pieces. When the material moisture content is very high, the vaporization of surplus water tears the briquette to pieces (Matuš, 2010). When the material moisture content is very low, for good briquette quality higher pressure should be used which is very expensive and uneconomic (Križan, 2010).

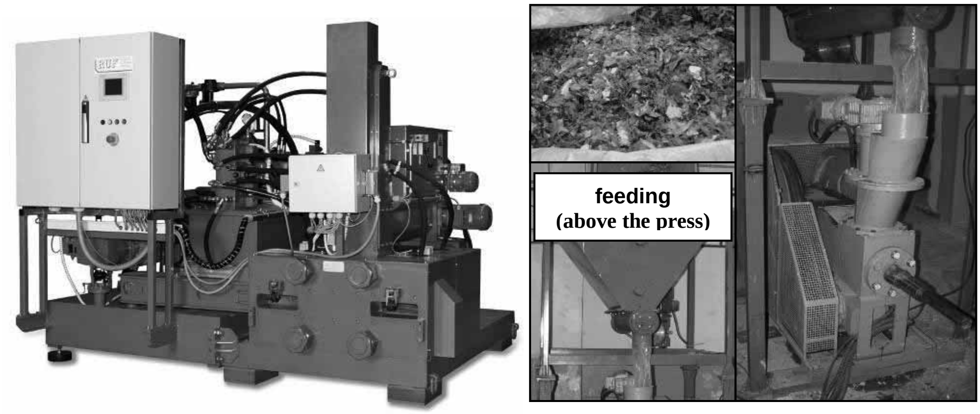
After several days on air drying the municipal waste had 40% less moisture content than at the beginning. Briquetting was executed by a mechanical crank-shaft briquetting press (see Fig. 3) and the same samples were produced on a hydraulic briquetting press. Briquetting is the best known and the most widespread technology of material compaction. The technology uses mechanical and chemical properties of materials to compress them into compact form (briquettes) without the use of additives or binders in the high pressure compacting process (Križan, 2008). Briquetting is mostly used for compacting biomass (sawdust, wood shavings, bark, straw, cotton, paper, etc.). The biomass undergoes the process of briquetting, while high pressure and a temperature simultaneously act upon the mass, the cellular structures within the material release lignin, which binds individual particles into a compact unit – a briquette. Briquetting can also be used for compacting compounded plastic waste or municipal waste, etc. The material is pressed into the pressing chamber with high compacting pressure and high pressing temperature. The process of compacting the municipal waste into the briquette is not as simple as briquetting biomass waste. Municipal waste (plastics, textile, etc.) does not contain a great bulk of biological materials and therefore it does not contain lignin which is a natural binder. For briquetting municipal waste the higher pressing temperature and compacting pressure should be applied.

Five different samples of compounded material containing plastic, carton, textile, wood, and other type of waste material were used. For compacting the briquettes, two types of briquetting machines were used: mechanical press (MP), and hydraulic press (HP) (see Fig. 4).

List of samples:

- Sample 1 - RDF from mixed municipal waste consisted of: 38% wood chips from soft wood, 45% disintegrated carton waste, 11% disintegrated PET bottles, 6% textile waste (MMW);
- Sample 2 - RDF with addition 20% of disintegrated carton waste (80/20 - MP)*;
- Sample 3 - RDF with addition 4% of cement (4 C);
- Sample 4 - RDF with addition 20% of wood sawdust (20 WS);
- Sample 5 - RDF clear, without any additions (RDF - MP)*;
- Sample 6 - RDF with addition 50% disintegrated carton waste (50/50 - HP)*;
- Sample 7 - RDF clear, without any additions (RDF - HP)*;

* MP – mechanical press; HP – hydraulic press;



a) b)

Figure 3. Types of briquetting presses: a) Hydraulic press, b) Mechanical crank-shaft press.

From each group of samples (1…7) the qualitative properties of seven briquettes were tested. Briquettes had to be be equal in composition; cracks and fine particle separation was not acceptable compounded material. The diameters and length of each briquette were measured before testing.

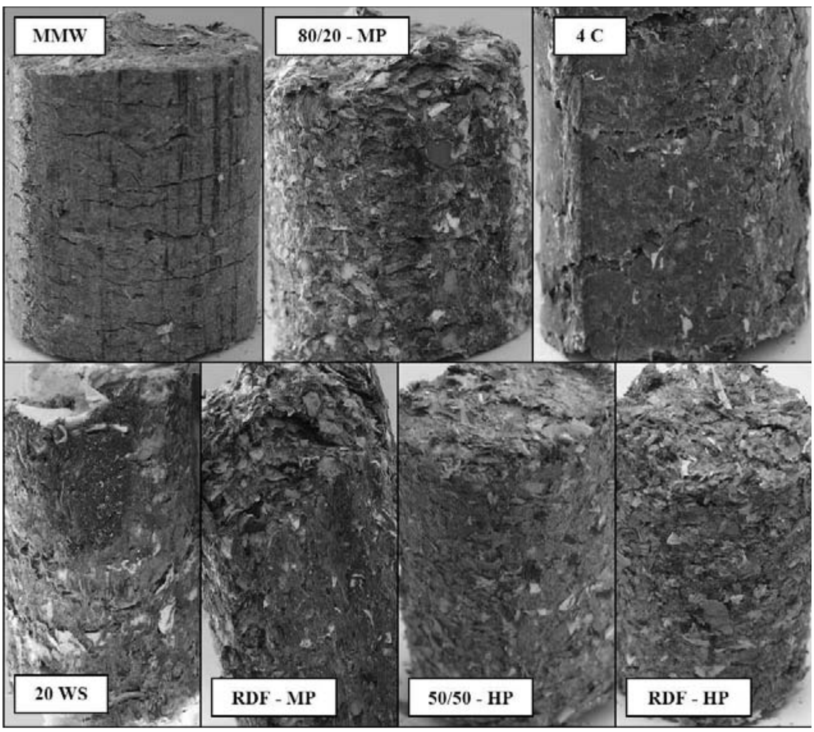
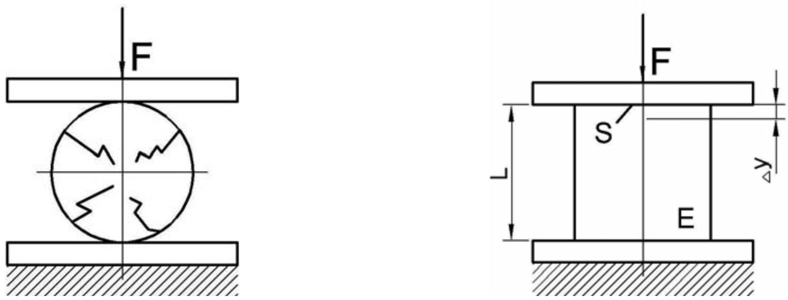


Figure 4. Briquettes from various compounded materials.

Density is an important parameter at briquetting. The higher the density, the higher is the energy/volume ratio. Hence, high-density products are desirable in terms of transportation, storage, and handling. The density of biowaste briquettes depends on the density of the original biowaste, the briquetting pressure and, to a certain extent, on the briquetting temperature, and time (Križan 2010, Kers 2010).

The compression strength of briquettes in cylindrical shape is determined by cleft failure and by simple pressure (see Fig. 5). A briquette is placed between round dies of press where it is equally compressed by increasing the compression force till cleft fracture. For testing only the compacted and intact briquettes were used. By maximizing the applied force the stresses inside the briquette were increasing during the test until the specimen failure by cleft. Determined maximum value specifies briquette compression strength. The ratio between maximal applied compression force and briquette length is the indicator of compression strength. Testing briquette strength by simple pressure is very similar, only the briquette is placed between dies in other orientation (see Fig. 5). The strength of briquettes in cleft and also in simple pressure is very important from the point of view of transportation, manipulation, and storage of briquettes.



a) b)

Figure 5. Compression strength testing methods: a) by cleft failure conditions, b) by simple pressure.

RESULTS AND DISCUSSION

Sometimes the briquetting material does not have suitable composition from good adhesion binding. Then mixing the binding agent into the shredded MSW can be used. If the binder is cheap or unnecessary material, it is an advantage. According to this reason the following additives: cartoon paper, cement, and wood sawdust were used. Of course from gasification point of view, a binder should be combustible. The briquette density value is influenced not only by material composition but also by type of briquetting press. Briquettes produced on mechanical press have higher density than briquettes produced on hydraulic press. Positive aspect is also the usage of a binder: paper, wood sawdust, or cement. Adding more binder leads to better briquette density. Fig. 6 presents a comparison of produced samples – briquettes from clear softwoods, hardwoods, and straw. Briquettes from these materials are produced as high-grade solid biofuels. The Standards for these solid biofuels determine that briquettes should have density over 1.12kg dm^{-3}. The Standards also define the material composition; high-grade solid biofuels can be produced only from clear wood. For gasification it is not necessary to achieve high grade of briquette density. Briquettes from municipal waste will be gasifying in furnace. An advantage will be more effective gasifying process, decreasing the transportation costs and simplifying the storage process.

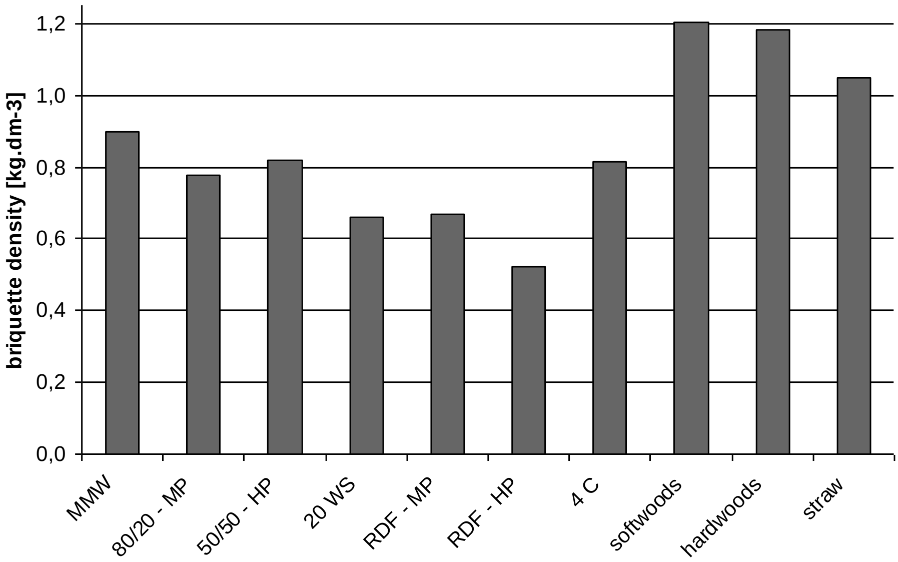


Figure 6. Briquette density according to the sample of compacted material in comparison with organic materials.

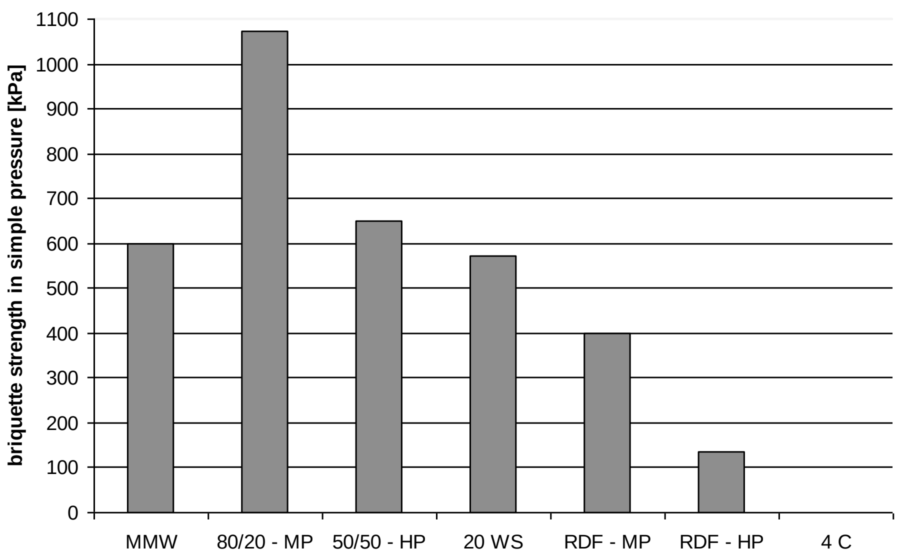


Figure 7. Briquette strength in simple pressure according to the sample of compacted material.

In Fig. 7 the results of strength in simple pressure testing and in Fig. 8 strength in cleft testing are presented. It was proven that the usage of organic binders (cartoon paper, wood sawdust) influenced the final strength of briquettes. Organic materials contain binders, the so-called 'nature glue' (lignin) which is able to join the non-organic particles of pressed material (PET bottles, textile, foils, plastics, etc.).

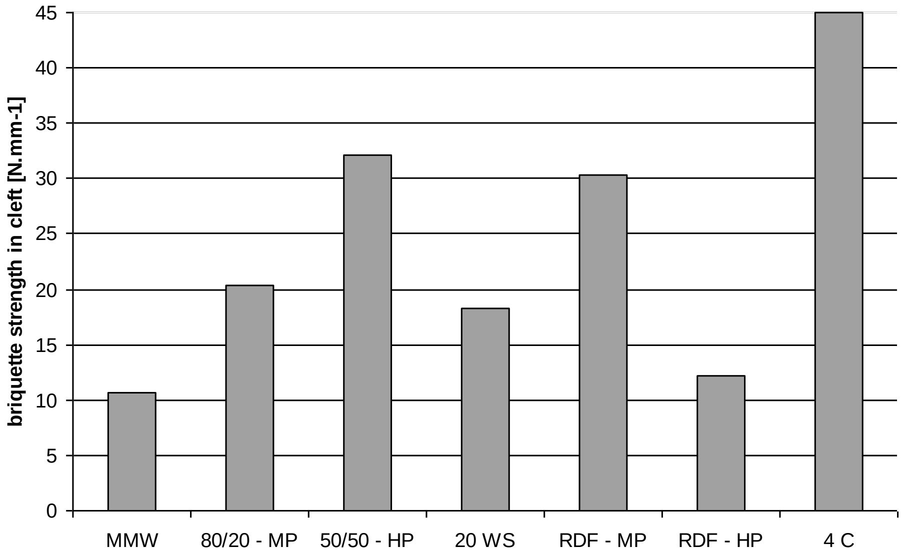


Figure 8. Briquette strength in cleft according to the sample of compacted material.

CONCLUSIONS

Municipal waste can be briquetted by using pre-treatment technology (drying, shredding, and mixing with the binder). Material composition has great influence on the final quality of the produced briquettes (the density and strength of the briquettes). Therefore it is strongly recommended to mix municipal waste with organic binder (paper, wood, sawdust) before briquetting. From mechanical indicators from the point of view of the quality of the briquettes (density, strength) we recommend to use the mechanical press for producing the briquettes. Continuous running pressing in 'open' chamber has positive impact on the creation of bindings mechanisms between particles of materials which influences the final quality of the briquettes. From the point of view of dimension and shape precision requirements it is recommended to use hydraulic press for producing briquettes. Briquettes produced on hydraulic press have equal diameter and the same length. An advantage of briquetting in 'closed' chamber is the stability of dimension and precision of shape of the briquettes. Briquettes produced on mechanical press do not have equal heads; moreover, the length of the briquettes is slightly different. This disadvantage of mechanical presses can be eliminated by a dividing saw.

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