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The dependence of the durability of digestate briquettes and sorption properties on represented particle sizes

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Abstract. Digestate, a product of the anaerobic digestion process, is traditionally used as liquid fertiliser. Besides agriculture use, it became possible to dry its separated solid part and compress it into briquette or pellet form. In the context of the characterisation of briquettes, the description here largely covers the mechanical properties of texture components and the distribution of particles within the briquette space. In order to define these properties and understand the relations between the mechanical part and any influencing factors, researchers started to identify the relationship between particles size distribution in briquettes and sorption properties and therefore mechanical properties. The objective of the present research was to compare size distribution in particles in different digestate samples and to study the connection to water sorption by briquettes and the durability of briquettes that have been made from two kinds of digestate material. For a comparison, two types of digestate were used, for which particles were split into a few size files according to the sieve size. By using digital image analysis, the dimensions of particles were specified and compared with values that were measured by means of a calliper. Sorption properties were defined through experimentation: exposing briquettes to a water source with water adsorption being determined via moisture content. Other mechanical properties were represented by toughness and the rate of abrasion. As result, digestate is an appropriate sorption matter which can multiply its initial mass by a factor of five if the water supply is sufficient. In the case of a dimension measurement of particles, digestate texture is represented by particles with one prevalent dimension, in most cases this being length. The length of particles was between approximately 1mm to 9 mm. The digestate has been proven to be a good water sorbent material and can be applied in various sectors of agriculture.

Key words: anaerobic digestion, absorption, physical properties, distribution, image analysis.

INTRODUCTION

In an attempt to use agro-biological material more productively, a good many disposal technologies are being invented or improved. One of them is the process of anaerobic digestion (AD), which is something that is purposely ongoing in biogas plants (BGPs). The number of BGPs in the Czech Republic is approximately 554 (Amon et al., 2007; EBTP, 2013). This number of plants is quite high and they consume a large volume of biomass matter. The BGPs soon became part of almost every agricultural farm. As part of their operations, a substrate from lower quality grasses and manure was used up, but its quantity was not high enough for a complete view of biogas use to be formulated.

More biomass was needed for full and total operation. This is why, in recent times, maize or grass-cuttings have made up approximately one half of the total mass input, and this plant material is purposely grown for BGP operations (Amon et al., 2007). All BGPs are optimised in order to be able to manage advanced biogas production and therefore provide higher levels of electricity production (Ward et al., 2008). Biogas is then front-product burned in order to provide power to generators that are producing an electric charge, with the rest being a by-product after the process of AD. Digestate is still used in the same way, like a fertiliser (Alexander, 2002) or is separated into 'liquor' and 'fibre'.

'Liquor' usually contains 10% dry matter and, in most cases, is partially used again in the AD process with a new dose of input substrate or is used as liquid fertiliser (Hills & Roberts, 1981; Li et al., 2011; ADBA, 2012). The composition of dry matter in the solid part varies (it is generally between 40–85%) according to input feedstock material. The feedstock material is usually animal manure, slurry, food wastes, energy crops residues, and bio-wastes, so the representation of lignocellulosic components is rich in digestate (Černá, 2015). The solid part of the digestate is commonly used in stables as bedding for animals or is used as fertiliser with additional additives (Alghren et al., 2010). Another use for separated digestate can be in its compressed form (as a briquette or pellet) for direct burning, but this is not such a frequent utilisation because it tends to be primarily long fibre material, so the most useful application is as a soil conditioner (ADBA, 2012). Using digestate for energy purposes is not such a convenient method. The first reason for this is that the process of producing digestate briquettes is more expensive and energy demanding than energy production itself, which is between 15–16 MJ kg^{-1}; it is smaller in comparison with other easily accessible biomass materials that have higher calorific values. Another reason is the higher content of nutrients in matter and ashes, which are more useful as fertiliser than as an energy source (Kratzeisen et al., 2010). Yet another reason to use digestate as fertiliser in a compressed form is the option it provides to mix amendment additives into briquette without any change of the briquette's compatibility, as well as its good sorption properties (Černá, 2015).

Such biodegradable and agro-waste material has a high bulk density, making it hard to store, and therefore it is desirable to compress the biomass to much higher densities, to improve transportation efficiency, better biomass handling, better storage, and the better utilisation of the original matter, which is due to its high moisture content, irregular shape, and sizes that are less appropriate or which are entirely inappropriate for direct use (Zhang & Guo, 2014; Miao et al., 2015).

In an attempt to use such biodegradable agro-waste material in better and alternative ways, excluding for fuel purposes, this paper is focused on the mechanical properties that are represented by inner textural characteristics, specifically by particle dimensions, mainly by size; shape is not closely observed in this paper. Abundantly available agro-waste materials are primary composed of cellulose, hemicellulose, and lignin (Hassanein & Koumanova, 2010). Therefore, the particle shape of such biomass materials is very irregular. Researchers investigated the possibility of particle shape increasing the strength of the material, making it stronger and harder and, putting aside durability or density, it also plays an important role in briquette characteristics (Kakitis et al., 2011). Particles can be distinguished by a spherical (as described in one dimension) or non-spherical shape (using two different dimensions), as illustrated in Fig. 1. Even small changes in the content of fine particles are providing measurable changes in cohesiveness (Guo et al., 2012). In the study by Hann & Stražišar (2007) it was noticed that the yield strength of bulk solids increased with the size range of particles. Each particle change, along with other changes (mechanical or chemical), such as fibre content, particle size, moisture content, temperature, feed rate, size and shape of die etc, influences briquette properties (Chen et al., 2015). For example, mechanical compression can influence particle structure, including porosity, surface area, and texture, which are important parameters (Tabil et al., 2011a; 2011b). All image analysis projections are in 2D in this paper, with the third dimension not being visible as seen in Fig. 1.

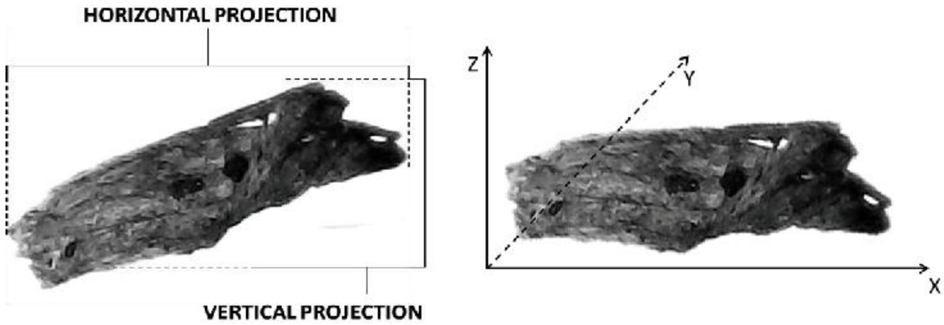


Figure 1. Non-spherical particle in 2D projection.

Lignocelluloses are very effective adsorbents (bonding water to its surface area at the microscopic scale), due to permeated macropores in the matter, which are used for various purposes such as, for example, pollutant absorbers. Porosity can be changed through the process of biomass treating (Miao et al., 2015), and sorption is affected by some parameters such as sorbate concentration, sorbent dosage, and agitation (Hassaneim & Koumanova, 2010). Sorption and moisture content are discussed in this paper because high moisture levels affect briquette cohesion and can result in unwanted swelling and the disintegration of briquette (Singh, 2004).

Particles can be measured by using different approaches, but the image analysis method is the universal method, one that allows texture elements to be compared and quantified and information on materials to be expressed by using quantitative data, such as particle size distribution in graphic or numeric form, or the mean value of monitored variables (Černá et al., 2015). Particle size analysis supplies a variety of approaches for the reporting results. The best way of expressing the result is to describe the width of distribution. As has already been reported, particles influence a number of properties in particulate materials and are an important indicator of quality and performance (Rawle, 2003; HORIBA Instruments, 2014).

The objective of this research is to compare the size distribution of particles in various digestate samples and to analyse the influence on water sorption by briquettes, and the strength of briquettes that are made from two forms of digestate material. The secondary goal of this paper is to observe the relation between the length or width of each particle and its mass.

MATERIALS AND METHODS

The research that has been conducted on digestate briquettes provided the initial characteristics for those briquettes. Those initial characteristics have been noted in Table 1 in terms of diameter, height, volume, and so on. From these values, properties were observed that corresponded to the points below:

- physical and chemical characteristics;
- sorption levels;
- particle measurements.

Research Material

The material being studied – digestate – was obtained from two different biogas plants. Feedstock material for anaerobic digestion and therefore the composition of digestate matter was 40% maize (green), 20% grasses, with the rest being silage from maize, clover, and alfalfa. These samples (D1 and D2) were dehydrated and separated into their solid and liquid parts. Both digestate samples were, after the mechanical dehydration process, additionally dried in the laboratory to the moisture content levels that were required for pressing purposes (to a maximum of 14.5%). The greater part of dried digestate with a moisture content of 13% and 18% was compressed to briquette form and the non-compressed remainder of the digestate (with a moisture content of 9.5%) was used for sieve analysis in order to obtain the size distribution of particles.

The nutrient composition of solid matter was also investigated, and the results are presented in Table 2. All measurements were conducted under laboratory conditions, where the temperature was 20–22 °C and ambient air humidity was in the range of 45–60%.

The properties of briquettes

Before pressing, the structure of the particle weight distribution for digestate (D1) was gained through sieve analysis at an AS 200 screening machine for each particle size fraction corresponding to the sieve mesh's sizes. In Table 3 the mean values are noted from five repeating sieving procedures; one procedure took ten minutes without interruption.

Briquettes were produced using a hydraulic piston press with a working pressure of 12 MPa and the diameter of briquettes was approximately 60 mm (corresponding to the diameter of the pressing chamber). As comparison material for sorption properties, measurements were used that were taken from woodchip briquettes (WCH) made from spruce (*Picea abies* L.) wood chips, and compressed under the same conditions as digestate D1 and D2. In Table 1 the mean values are noted from six repeating measurements.

Table 1. Initial characteristics of briquettes

Briquettes	Diameter, cm	Height, cm	Volume, cm^3	Moisture, %	Density, $g\ cm^{-3}$
D1	6.67	4.83	168.55	4.92	0.7869
D2	6.65	4.08	141.79	5.16	0.7689
WCH	6.52	4.11	137.22	5.61	0.7921

The mechanical durability of briquettes was measured by using the abrasion rate according to EN 15210-2:2011 in a standard test drum. An abrasion test for D1 and D2 digestate briquettes was carried out for briquettes with a moisture content of 5.1–5.5%. The percentage of abrasion expresses the cohesion of briquettes in relation to the number of manipulations involving them (the number of drum revs in a given cycle corresponds to the number of manipulations). Briquettes were tested consecutively, five times. Their initial weight was D1 – at 2,043.6 g – and D2 – at 2,061.0 g. In each sample file there were seventeen briquettes of different weights.

The hardness of the briquettes was simultaneously measured with a durometer by using the 'Shore' scale, for the purposes of additional information.

Water sorption measurements

Produced briquettes were left in laboratory conditions for two weeks in order to balance out any difference in moisture levels. Initial values are noted in Table 1. Water sorption was measured simultaneously and repeatedly for D1, D2, and WCH briquettes in special wooden boxes (flow boxes – see Fig. 2). Briquettes were incorporated into the same type of soil in order to simulate soil conditions, with the same initial moisture content and no added water within the process of the experiment. Water sorbed by briquettes was observed and measured by noting any changes in the dimensions of the briquettes and through any changes in moisture content in relation to the time in which the briquettes have been left in the soil. The system simulates fully controlled soil conditions. Briquettes were placed in a flow box in three parallel lines. See Fig. 2 for details. In order to prevent evaporation through the box walls, PVC foil was used.

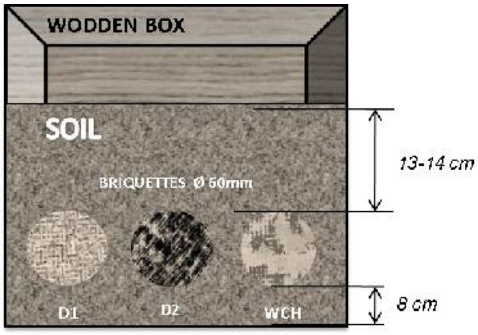


Figure 2. Experiment box for sorption observation.

Particles measurements

Because the process of sieve analysis for both D1 and D2 is very similar, measurements of particle dimensions were conducted only for the D1 sample, for particles passing through a 1mm sieve (particle size were at an interval of 0.5–1 mm). These particles were chosen thanks to the possibility of being able to measure them directly; each particle could be measured in parallel by using image analysis and callipers. Powder particles that make up approximately 1% of the sample are easily measureable by using image analysis, but manually they cannot be measured comparably. Particles were measured physically using callipers and digitally by using image analysis with a Bresser digital USB microscope and ImageJ freeware. The method used in measuring with callipers is not comparable to that used in image analysis (due to the number of corresponding measured points), but it is an easy-to-handle manual verification of the accuracy of the program settings and of the measuring process itself. This approach was used in order to compare the accuracy both of the measurement methods and the influence on particle density determination; eventually to be able to set out the dependence of briquette strength against the size of the particles.

Length (L), width (B), and thickness (Y) were measured with callipers. Weight (M) was also measured for each particle using scales. Due to the fact that digital images are provided in the planar projection (2D), only the length, width, and area (S) were measured (see Fig. 3). Thickness is invisible for such images. The analysis approach was as follows: firstly, measuring scales were set out and calibrated in the software program, ImageJ; then particles were screened with a microscope camera using appropriate light levels. The screening was sent to ImageJ, where it was cleaned up and converted into a binary image. Particle dimensions such as length and width were measured by hand via the ImageJ program and the image shown of the particles. Once the particle dimensions were measured three times in one direction (point to point) then the values were averaged to a mean value for the given dimension. After obtaining the mean size value of length (L) and width (B) of a particle, the threshold function was applied in order to measure the area (A) of a given particle. The threshold function is defined so that the program could decide when to consider something as being part of the object and when not to do this. Afterwards, the image was passed over to the threshold (this is the simplest method of image segmentation, carried out by transferring the image to greyscale), and the area was measured automatically (Wojnar, 1999). All data points are recorded and can be transferred to an Excel file. Volume (V) and density (ρ) were calculated for each particle from the known values.

The size of sample file D1 contained a total of 64 particles (measured by calliper); while for image testing of the same particles the file was smaller (at 54 particles), due to a difficult manipulation process and the fragility of the particles themselves.

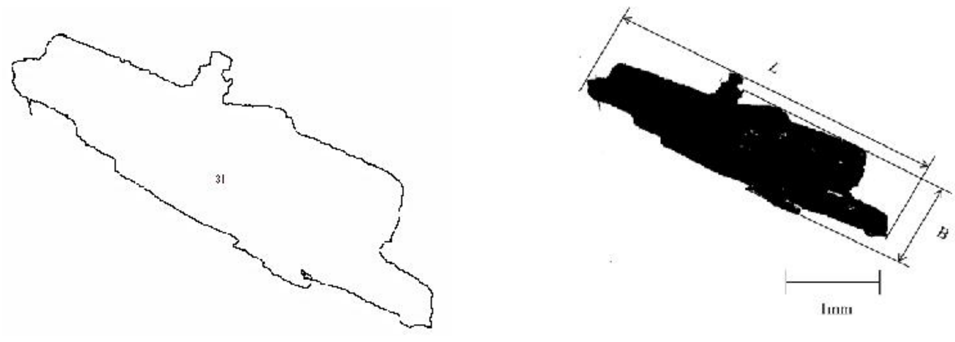


Figure 3. Particle area (S) measurement and particle dimensions – length (L) and width (B) – measurements made with ImageJ software.

RESULTS AND DISCUSSIONS

All of the results have been presented below in tables and/or figures to meet the set objectives. Table 2 shows the values for the content of identified nutrients in samples

D1 and D2 for 100% dry matter. As can be seen here, samples D1 and D2 contain relatively high amounts of fibre (30–35%) and organic matter (88%). From this it can be said that digestate material is fibrous material, and particles are non-spherical in shape (Hann & Stražišar, 2007; Guo et al., 2012). Ash content varies at around 12–13%, which is in comparison to the figure for wood pellets (1.5%), which is ten times higher (EN 14961-1, 2010).

Table 2. Nutrient values of digestate briquettes, 100% DM

[%]	Ash	N·6.25	NFE	Fats	Fibre	OM
D1	11.93	12.27	40.75	0.30	34.76	88.07
D2	12.41	20.30	40.37	1.00	25.92	87.59

*DM – dry matter; N – nitrogen; NFE – nitrogen free extracts; OM – organic matter.

In order to investigate the dependency of both of the textured digestates that were represented by the size distribution of particles D1 and D2 (Table 3 and Fig. 4), and the durability of briquettes as represented by their abrasion levels, it can be noted that any difference in abrasion levels between samples D1 and D2 is probably caused by a greater representation of longer particles in D2, which are notably flat and straight. Such particles do not form a solid mechanical connection after compression. Therefore, they are easier to crumble, which is shown in Fig. 5. In contrast to this, particles from the D1 sample are shorter on average, but they are not straight and their mutual mechanical join in the briquette (their interlocking ability) is therefore stronger (Rawle, 2003; Kakitis et al., 2011; Guo et al., 2012). Moreover, the digestate D2 even has a different value when it comes to adsorbed water in the soil, as shown in Fig. 6. Any difference in the level of abrasion between briquettes D1 and D2 is very obvious in the first round of abrasion tests, because the sharp edges of the briquettes around their perimeter are very easy to break off and, therefore, this process decreases the weight of the sample to a detectable degree. In order to eliminate the time effect on the amount of abrasion in both samples, abrasion was carried out on them in one day. Due to the influence of the environment and various manipulations involved in the use of briquettes, self-abrasion occurs on the briquettes so the suggestion here is to introduce abrasion tests as soon as possible after the creation of digestate briquettes.

Table 3. The structure of distributed particle dimensions in digestate samples D1 and D2

	Size of sieve mesh, mm								
	bowl	0.1	0.25	0.50	1.00	2.50	5.60	10.00	Σ
No.	1	2	3	4	5	6	7	8	
D1, g	0.55	1.02	2.38	3.12	10.96	17.25	10.74	19.14	65.31
%	0.86	1.56	3.65	4.79	16.84	26.42	16.50	29.40	100.0
STD1	0.11	0.19	0.46	0.74	1.00	1.15	1.09	3.60	
D2, g	0.98	1.54	3.44	9.00	22.82	27.59	22.64	14.14	102.15
%	0.96	1.50	3.36	8.81	22.34	27.03	22.16	13.84	100.0
STD2	0.08	0.28	0.57	2.03	3.20	1.67	2.30	8.97	

*STD – standard deviation.

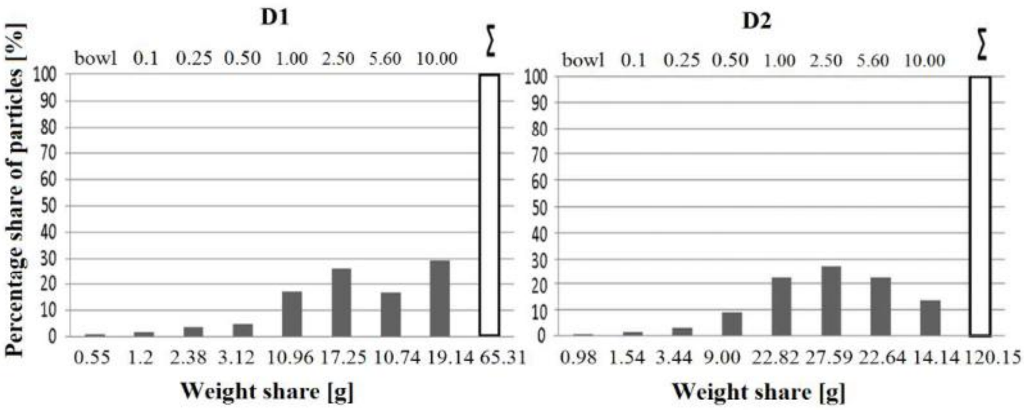


Figure 4. Illustration of weight distribution across the whole sample (D1 and D2) ordered according to the size of sieve mesh in % terms.

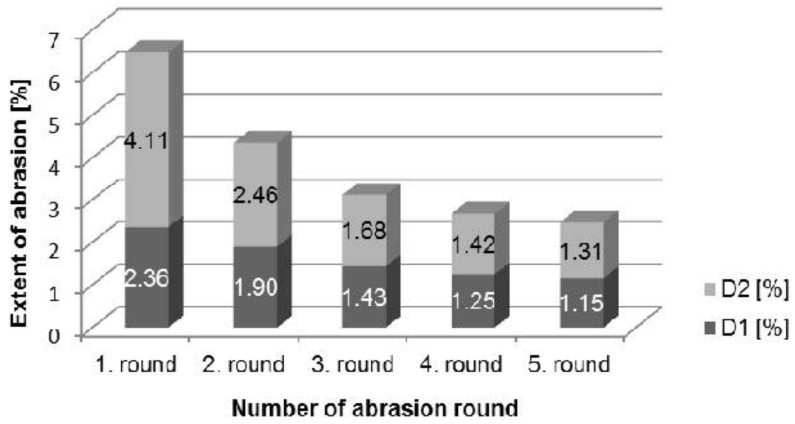


Figure 5. Abrasion testing for D1, D2 expressed in % terms.

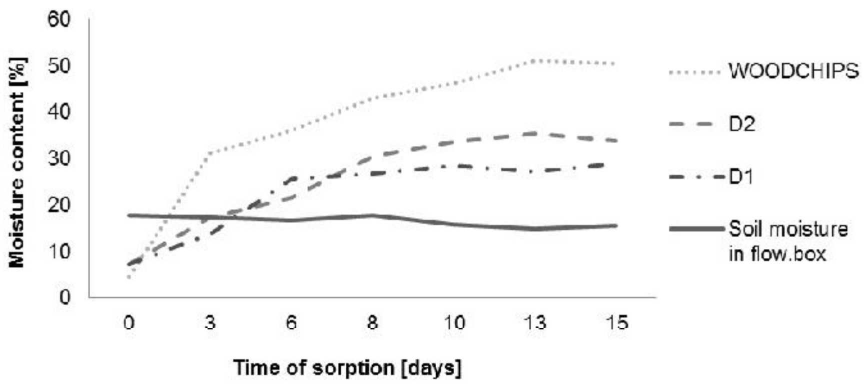


Figure 6. The progression of water sorption by D1, D2, and woodchips briquettes in soil conditions.

The influence of particle size and shape on the durability of briquettes (Miao et al., 2015) is demonstrated in the assumption that abrasion in briquettes D1 and D2 is carried out in the same way and by using the same piece of equipment. Therefore, the abrasion tests that have been carried out represent more 'coherence' in terms of the briquettes that are being used and thereafter also more coherence in their durability. It can be seen that the abrasion rate represents the handling of briquettes rather than anything else. Each round of briquette abrasion represents a number of manipulations, where one round is approximately 105 rotations which, theoretically, is the equivalent of the total number of drum rotations managed by the test equipment. The first and second rounds are the most significant thanks to a large difference in the abrasion extent results, which were caused by higher levels of abrasion on the sharp edges; this tendency has also been observed in another study that was published by Brunerová et al., in 2016. This can be explained as the actual kinetic energy of the briquette sample after it hits the internal drum surface and converts into mechanical energy, which causes abrasion on the briquette sample, which can then be comfortably measured as a loss of its weight. It should be borne in mind that abrasion values are average ones because it is impossible to monitor with any great accuracy the abrasion of individual briquettes in the sample.

Briquettes that have been incorporated into the soil are consistently showing very high values in terms of sorption progress, as proved by the experiments carried out by Pecen et al. (2013), where the sorption properties of different materials are compared. The briquette material is essentially an aspect of the water uptake volume, and the dimensions of pressed particles and the compression force being used are important factors, as described in Tabil et al. (2011a) and Chen et al. (2015). All of these factors, including the process of depositing the briquettes in soil, the technology used in briquette production, and the conditions under which such production was carried out were the same both for digestate and woodchip materials. Therefore there is only one variable – the materials themselves. Fig. 6 shows that both samples of digestate have similar water uptake levels. Briquettes, both from digestates and woodchips, show a similar water sorption start uptake (Pecen et al., 2014; Černá, 2015; Černá & Pecen, 2015), but after about ten days the water sorption by briquettes practically stops; different values for different briquette materials were achieved. This final phase is characterised by an equilibrium of conditions between briquette moisture levels and soil moisture (Singh, 2004). It should be noted that this is mechanical and physical sorption, which is dependent mainly upon the texture of the briquettes. Fig. 6 shows that the visible changes in soil moisture levels (between the beginning and end of the experiment) are very small in comparison to any changes in briquette moisture levels (Pecen et al., 2014). This pattern of sorption is very similar from repeated attempts at the process (Černá, 2015). Therefore, water sorption data are expressed as average values. Fig. 6 well illustrates the differences in water sorption levels between briquettes that are made using different materials. Woodchip briquettes have smaller density levels and then accept a higher water content when compared to digestate briquettes with a higher density level. The progress shown in the graph is the same in both digestates, D1, D2, and WCH samples. The smallest difference was noticed in sorption by soil during the progression period.

Considerable attention was paid to an analysis of digestate particle size. This area was examined in two ways: first using digital callipers (with a resolution of 10 μm), and second electronically, using the image analysis program, ImageJ.

The length and width of each particle was measured electronically. From this data, the area of each particle was calculated. Surface area was also directly measured with this method. Callipers were used to measure the length, width, and height of each particle. From this data, the volume and density of each particle was calculated. The weight of each particle was determined using scales, with a resolution of 0.1 mg. The height data for particles were used in calculating the volume and density using the applied method of image analysis. As a model material for a detailed analysis of particle size, digestate D1 was used. A particle size fraction of 0.5–1 mm was measured from the sieve analysis. The resultant mean values are listed in Tables 4 & 5, including the calculated differences for area, volume, and density (Table 6).

Table 4. D1 particle dimensions as measured using callipers

Calliper measuring							
Parameter	Length	Width	High	Area $L_0 B_0$	Volume	Density	Weight
Abb.	L_0	B_0	Y_0	S_0	V_0	ρ_0	M
Unit	mm	mm	mm	mm^2	mm^3	$g \cdot cm^{-3}$	g
No.	1	2	3	4	5	6	7
$MEAN_A$	3.94	0.98	0.27	3.78	1.11	0.5573	0.0005
MAX	8.25	1.68	0.55	9.49	4.26	5.4681	0.0017
MIN	1.13	0.27	0.04	1.30	0.05	0.1899	0.0001
STD	1.63	0.28	0.13	1.78	0.90	0.6667	0.0003

*****Area $S_0 = L_0 \bullet B_0$| Volume $V_0 = L_0 \bullet B_0 \bullet Y_0$.

Table 5. D1 particle dimensions as measured using image analysis

Image analysis measuring							
Parameter	Length	Width	High	Area $L_1 \cdot B_1$	Volume $S_1 \cdot Y_1$	Density	Weight
Abb.	L_1	B_1	Y_1	S_1	V_1	ρ_1	M
Unit	mm	mm	mm	mm^2	mm^3	$g \cdot cm^{-3}$	g
No.	8	9	10	11	12	13	14
$MEAN_A$	4.03	0.84	0.27	3.37	0.88	0.6977	0.0005
MAX	8.79	1.44	0.55	9.98	4.09	5.7596	0.0017
MIN	1.19	0.27	0.04	0.76	0.05	0.2059	0.0001
STD	0.15	0.26	0.13	1.75	0.78	0.8197	0.0003

***** Area $S_1 = L_1 \bullet B_1$ | Volume $V_1 = S_1 \bullet Y_1$.

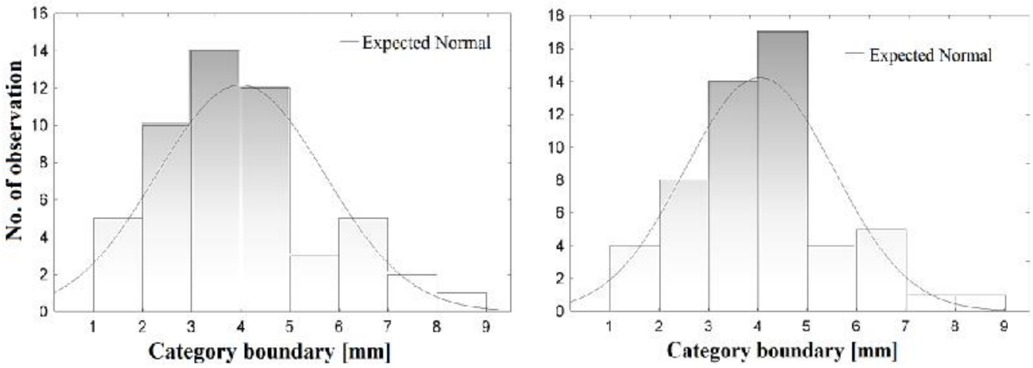
Table 6. Differences between calliper and image analysis measurements

	Difference		
Parameter	Area	Volume	Density
Abb.	ΔS	ΔV	$\Delta \rho$
$MEAN_A$	-0.9215	-0.2151	0.0330
MAX	4.2538	0.9770	2.1222
MIN	-6.1280	-2.4484	-0.7101
STD	1.9365	0.5426	0.3828

***** $\Delta S = S_1 - S_0$ | $\Delta V = V_1 - V_0$ | $\Delta \rho = \rho_1 - \rho_0$

The uncertainty involved in measuring with callipers is in the order of a few percent (0.1 mm); in the case of image analysis the uncertainty value is smaller (0.01 mm).

Fig. 7 shows the frequency distribution (histogram) of the measured particle length values for the D1 sample for both measuring methods (digital callipers L_0 and image analysis L_1).



Summary statistics: L_0	Summary statistics: L_1
N = 52, Mean = 3.995, Minimum = 1.13,	N = 54, Mean = 4.032, Minimum = 1.19,
Maximum = 8.25, Standard deviation = 1.705	Maximum=8.79, Standard deviation = 1.515

Figure 7. Histograms of length L_0 (left) and L_1 (right) values for digestate D1 including statistics and expected normal values.

Fig. 7 demonstrates that both methods of measurement are appropriate in the assumption of normal distribution for the sample (measured values for particle lengths). A similar result can also be obtained for the width and height of individual particles (Rawle, 2003).

The results of particle size measurement using image analysis are more accurate, as confirmed in Fig. 8. This is ultimately reflected in the calculated higher value of particle density, which is closer to the average density value as calculated from the determined weight and volume of briquettes, as noted in Table 1. The average density value as calculated from the briquette weight and volume depends mainly upon the levels of pressure used; briquette density increases alongside increased working pressure.

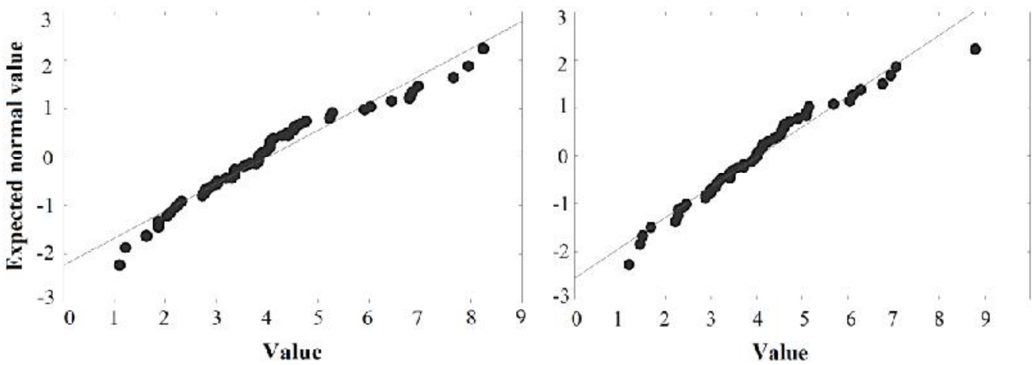


Figure 8. Normal P-plot for length L_0 (left) and length L_1 (right) values for digestate D1 and their expected normal values.

The size and shape of digestate particles also affects the average density of briquettes, toward the higher values (Hann & Stražišar, 2007). The influence of particle size and shape on water sorption by briquettes is illustrated in Fig. 6, where D1 briquettes exhibit less water sorption than D2. Particles in sample D2 are longer and straighter and therefore do not form compact briquettes, whereas in D1 the briquettes have less space between the individual particles. Therefore, in D1 briquettes water sorption is smaller when compared to D2 briquettes. The influence of particle size and shape is also reflected in the abrasion value, as shown in Fig. 5. D1 briquettes therefore exhibit less wear than D2 briquettes.

CONCLUSIONS

The rate of abrasion of digestate briquettes depends primarily on the material properties of the briquettes themselves. The size and shape of particles in uncompressed digestate also have a significant influence on the durability of the briquettes. Particles that are of one dimension longer (plate particles) are, in digestate briquettes, bounded with a smaller force between particles, so that briquette fragments are easily released. Abrasion comparison (resistance in the compatibility and cohesion of compressed particles) between the materials being studied on the basis of fraction distribution was not observed and is recommended as a point to include in the next round of research. Previous research experience shows that the biggest particles in digestate briquettes have higher rates of abrasion and even sorption ability, ie. they are less stable.

Water sorption in briquettes that were incorporated into the soil and the speed of such sorption depends largely on the type of materials used for the briquettes and partly on particle size. Woodchip briquettes were approved as being better water sorbent briquettes when compared to digestate ones, but the difference is no more than a maximum of 10%. While initial soil moisture is not decisive in achieving constant moisture in briquettes, which occurs up to approximately ten days after the briquettes have been deposited in the soil, the moisture levels in the briquettes at this stage is always significantly greater than in the surrounding soil.

An analysis of digestate particle sizes as measured with a digital calliper and using image analysis confirmed the normal distribution of particle size in the sample, and also showed the higher accuracy levels in the determination of particle size when using image analysis. The influence of particle size, especially the length of particles (which, on average, are at a scale of 4.5–5 mm), and shape, was reflected in the measured values of durability and water sorption in those briquettes that were being stored in the soil.

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