RESEARCH OF CATTLE MANURE COMPOST FERTILIZER GRANULATION AND DETERMINATION OF GRANULES QUALITY INDICATORS

VÝZKUM GRANULACE HNOJIVA NA BÁZI KOMPOSTU Z HNOJE HOVĚZÍHO DOBYTKA A STANOVENÍ INDIKÁTORŮ KVALITY GRANULÍ

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Abstract

By pelleting the manure compost it is possible to increase the bulk density, to improve the material storability, to reduce the transportation costs and to make these materials easier to handle by using the existing handling and storage equipment. For solving of this actual problem there were investigated the granulation process and the factors affecting the organic granular fertilizer physical-mechanical properties. Research was carried out in Aleksandras Stulginskis University with the cattle manure compost fertilizer, which was granulated by the granulator with a horizontal granulator matrix, the diameter of produced pellets was 6 mm. There were prepared and investigated 5 experimental manure samples and pelletized manure waste in 2014-2017 years. During the researches there were estimated the biometric and physical-mechanical properties of organic fertilizer granules – biometric indicators, granulometric composition of granulated compost fertilizers, pellet humidity, volume and density, and pellet resistance to impact forces. The research results show that produced granules are greatly resistant to compression on a static force and they are convenient for transportation, storage and for mechanical spreading.

Keywords: organic waste, manure, fertilizer, granulation, pellet properties

INTRODUCTION

It is important to search the new and more rational ways to use biodegradable waste for new forms of energy. Some of these ways are: fuel, biogas production, fertilizers production, building materials and other products. One direction of biodegradable waste management is pelleting as the processing of recyclable materials into organic products. In recent years in the EU countries only 5-7 % of bio-waste was recycled. For comparison, if more bio-waste will be recycled, it could replace up to 30 % of non-organic fertilizers. Currently, the EU imports about 6 million tons of phosphates a year but could replace up to 30 % of this total by extraction from sewage sludge, biodegradable waste, meat or manure (European Commission, 2016).

According to Waste Classification (EPA, 2015) livestock manure are classified as waste: - animal faeces, urine and manure (including spoiled straw), effluent, collected separately and treated off-site (code - 02 01 06). Livestock manure is organic material consisting primarily of a more or less homogenous mix of faeces and urine from livestock, including bedding material, and secondarily of other material that would be discarded as waste from a livestock production such as fodder residues, silage effluents, and process water (AgroTechnologyATLAS, 2017). The terms "manure," "waste," and "residue" are sometimes used synonymously. The idea of looking at manure as a resource, not a waste, has been central to much of the more recent thinking on the whole subject of good farm management (Burton and Turner, 2003).

In this article, manure refers to materials that have been composted and granulated. Organic fertilizer application through composting of local materials is the easy way, which enhances the quality of life for farmers and society, and in the long term it enhances the environmental quality and the resource in which agriculture depends. However, there are limits of compost application, so pelletized compost was developed for an alternative fertilization including for soil and nutrient conservation (Ngo and Siriwattananon, 2009).

Granular manure is a universal complex organic fertilizer containing all the macro and micro elements. Pelleted manure nutrient content for soil micro flora is optimal, it quickly dissolves in water and is easily absorbed by plants. Granular manure can be called concentrated fertilizer, because the recycling process reduces the volume of material more than 10 times, due to water removal (Polovcev and Cherkasovet, 1992).

Pelletizing is a method of increasing the bulk density of biomass by mechanical pressure. Pellets have a low moisture content wet basis for safe storage, and a high bulk density for efficient transport and storage. Other benefits of organic compost pellets are: reducing the conservation space because of densification, suitable for mechanization, suitable for residential places because of producing no dust, no pollution for environment, more precision with spreaders and reducing manure consumption, suitable for transporting to long distances, suitable for planters and no need to separate operation, ability of long time conservation, ability of adding other materials for increasing the quality of pellets (Zafari and Kianmehr, 2014).

According to scientific researches the crush strength is the most commonly used method for measuring the overall hardness of fertilizer granules. It is defined as the minimum force required to crush individual particles. For fertilizers it is a useful factor in predicting the expected handling and storage properties of the sample (Latifian et all, 2012).

When assessing the suitability of manure compost for granulation, it has been established that this organic waste dried up to 10-12 % content humidity may be granulated using traditional feed granulators and process of granulation does not require any special equipment (Pocius et all, 2015). Lithuanian researchers investigated that the experimental manure compost pellets with static stability limit 430 N were the most mechanically stable when subject to vertical compression, and the deformation level up to 1.2-1.3 mm (Pocius et all, 2016).

The aim of research is to investigate the pellets production of animal manure compost, physical-mechanical properties and to determine the produced pellet quality indicators.

MATERIÁLS AND METHODS

Pellet production technology and equipment depends on the raw material, fractional composition, moisture content etc. The following physical-mechanical characteristics of granulated cattle compost manure fertilizers were investigated and determined: pellet moisture content; pellet biometric parameters and granulometric composition; pellet measurements, mass, density, bulk density; strength of granules. This research has been performed using the standard and modified methods.

Pellet production. There were produced 5 variants of cattle manure pellets on laboratory conditions in 2014-2017 years. For pellets' production is used press in which crushed and milled biomass is moved by the rollers through matrix holes (6 mm). After granulation stabilization period starts. During this period, formation of some properties of pellets takes place: moisture content, hygroscopicity, strength. For pellet production were used two types of granulator: a small capacity granulator 7.5 kW with a horizontal granulator matrix with 6 mm diameter holes (for pellet production with the experimental granulator in 2014-2015 years), and big capacity granulator 30 kW with a cylinder granulator matrix with 6 mm diameter holes (for pellet production in 2016-2017 years with the industrial granulator when using the compost produced by traditional and intensive compost production technologies). After pellet pressing and cooling, their granulometric composition, biometric parameters (dimensions, humidity, volume and density) and other properties were investigated.

Pellet granulometric composition was determined using a set of 200 mm diameter sieves with round holes of diameters 0.25 mm, 0.5 mm, 1.0 mm, 2.0 mm, 3.15 mm, 4.0 mm, 5.0 mm, 5.6 mm and 7.1 mm. The mass remaining on the sieves was weighed, and sample fraction percentages were calculated. Each test was repeated 5 times.

Pellet moisture content was determined in a laboratory drying chamber oven according to the standard methodology (Šiaudinis et all, 2015). The samples were weighted and dried for 24 hours in the temperature of 105 ºC.

Pellet parameters were determined by measuring their length and diameter (accuracy to 0.05 mm). For all experimental trials were randomly selected 10 pellets. The pellet weight was assessed by KERN ABJ scales (accuracy to 0.001 g). The weights were calculated for each type of pressed organic fertilizer using 10 of the granules to obtain the average error. The pellet volume was calculated using the pellet size (diameter and length). Average mass meanings of the measured 5 sort granules were calculated.

Pellets density. The pellet volume was calculated using the pellet size (diameter and length). After determination of pellet mass and volume there are calculated their density (Jasinskas et all, 2016). It also has been determined the *bulk density of pellet* according to the LST EN 15103:2010. The pellets were transferred into a cylindrical 0.5 dm^3 vessel up to the top level. The bulk density of the pellets was calculated by dividing the mass from the container volume.

Fall and natural slope angles. Pellet fall and natural slope angles were determined by using the stand, by applying the method of pellets sliding down freely from a container, and measured with the accuracy of ±1.0 degree. All measurements were repeated three times and the mean values of the angles and their error values were calculated. A portion of pellet sample (3 kg mass) was poured into a rectangular container, and after opening of the valve, part of the chaff mass crumbled off. With the help of a turned ruler and protractor the angles of crumble were measured: the angle of natural slope (on the horizontal plane) and the angle of fall (at the bottom of the container) (Jasinskas et all, 2016).

Pellet compressive strength. Pellet strength tests were carried out in Aleksandras Stulginskis University (ASU), Institute of Agricultural Engineering and Safety by using the research equipment *Instron 5960* and the command and parameter registration computer system *Bluehill*. (Jasinskas et all, 2016). Tests were carried out by placing pellets on a horizontal plane (table) and pressing by vertical load.

The test results are recorded every 0.1 second until the pellet disintegrates completely exposed to the force. *Instron 5960* equipment draws pellet resistance to compression characteristic of Young's modulus. The tests were performed by placing the granules on a plane with horizontal loads. Tests are repeated 5 times for pellets of each sample. Measurement error is 0.02 %.

After performed tests, research data was processed by statistical – mathematical methods. Averages and their confidence intervals, estimated substantial difference in the threshold at 95 % probability are calculated during data processing time (Tarakanovas and Raudonius, 2003).

RESULTS AND DISCUSSIONS

Determination of organic fertilizer pellet granulometric composition. Research results of investigated granulated animal compost fertilizers granulometric (fractional) composition is presented in Table 1. Granulometric composition and other properties of organic pellet depends on the produced pellet main parameters. It has been determined that the produced 6.0 mm diameter organic fertilizer pellets average mass was 0.33±0.07 g, average length was 9.8±1.3 mm (Table 2).

Table 1: Granulometric composition of granulated animal manure compost fertilizers (%)

Fraction, mm	**2014** (used experimental granulator, compost of traditional composting technology)	**2015** (used experimental granulator, compost of traditional composting technology)	**2016** (used industrial granulator, compost of traditional composting technology)	**2016** (used industrial granulator, compost of intensive composting technology)	**2017** (used industrial granulator, compost of intensive composting technology)
>7.10	0.18±0.04	2.36±0.21	0.40±0.03	0.01±0.0004	0.03±0.0001
7.09-5.60	73.62±0.27	82.04±0.32	74.35±0.32	63.25±0.28	72.68±0.31
5.59-5.00	12.26±0.14	4.68±0.21	11.20±0.06	8.52±0.03	9.91±0.11
4.99-4.00	7.41±0.18	5.20±0.16	6.48±0.04	4.22±0.02	2.76±0.03
3.99-3.15	4.21±0.19	2.12±0.10	3.67±0.04	2.96±0.02	1.76±0.04
3.14-2.00	1.21±0.11	2.18±0.09	2.69±0.03	5.99±0.04	4.42±0.06
1.99-1.00	0.23±0.08	0.86±0.06	0.80±0.07	6.70±0.08	5.32±0.04
0.99-0.50	0.14±0.01	0.12±0.009	0.18±0.01	4.65±0.07	1.92±0.02
0.49-0.25	0.23±0.01	0.12±0.08	0.09±0.007	2.56±0.06	0.58±0.03
<0.25	0.51±0.04	0.32±0.09	0.14±0.02	1.14±0.05	0.62±0.02

It was determined that the largest fractional composition of investigated organic pellet was received when the diameter of the sieves holes was 5.6 mm, fraction of 7.09-5.60 mm varied from 63.25±0.28 % (in 2016) to 82.04±0.32 % (in 2015). A relatively large fraction of the mass is also concentrated on the sieve with 5.0 mm diameter holes, it varied from 4.68±0.21 % (in 2015) to 12.26±0.14 % (in 2014). It was estimated that when was granulated the compost of traditional composting technology (in 2014-2016), very small amount of fraction formed on the sieves with 0.25-1.00 mm diameter holes, it reached only 0.86 %. This fraction was significant bigger when was used the industrial granulator and compost produced by intensive composting technology (in 2016-2017), the fraction formed on the sieves with 0.25-1.00 mm diameter holes reached 5.3-6.7 % (Table 1).

Determination of manure compost pellets biometric indicators and physical properties. Moisture content has a great influence on the pellets main properties, therefore, it is important to estimate biofuel‘s humidity. Research has shown that moisture content of different types of pellets vary from each other, even if storage conditions of pellets were very similar. The obtained moisture content of organic fertilizer pellets is shown in Table 2.asy.

Table 2: Organic fertilizer pellet biometric indicators and physical properties

The year of granulated manure compost fertilizer production	Pellet average moisture content, $w_i \pm \Delta y$, %	Pellet length, mm	Pellet diameter, mm	Pellet mass, g	Pellet volume, m^3	Pellet density, kg m^{-3} (natural moisture content)	Pellet density, kg m^{-3} (dry matter, DM)
Experimental Granulator							
2014	12.09±1.18	11.1	6.0	0.40	3.13×10^{-7}	1278.07 ±58.71	1123.56 ±58.71
2015	14.66±2.06	9.6	6.0	0.33	2.71×10^{-7}	1217.47 ±64.37	1038.98 ±54.93
R_{05}	0.845	0.061	-	0.029	0.17×10^{-7}	75.84	-
Industrial Granulator							
2016	14.84±0.30	9.7	6.0	0.32	2.74×10^{-7}	1183.71 ±45.04	1008.06 ±45.04
2016 *	12.25±0.98	8.9	6.0	0.28	2.51×10^{-7}	1116.81 ±54.33	979.96 ±54.33
2017 *	14.87±1.48	9.5	6.0	0.34	2.68×10^{-7}	1255.90 ±67.01	1069.16 ±67.01
R_{05}	0.526	0.086	-	0.030	0.24×10^{-7}	82.099	-

** Used the compost of intensive composting technology*

According to the obtained research data it may be stated that the maximum moisture content is of the pellets produced in 2014 – 11.1 %, and the lower is of the other pellets – 8.9-9.7 % (produced in 2015-2017).

From the data of Table 2, it could be seen that the density of all produced manure compost pellets is so big, close to 1000 kg m^{-3}. The highest pellet density is of 2014 year production – 1123.56±58.71 kg m^{-3} DM (dry matter), and the lowest density is of 2016 year production when was used the compost of intensive composting technology – 979.96±54.33 kg m^{-3} DM.

The set bulk density of investigated manure compost pellets in the vessel was very similar and varied from 714.2±20.4 kg m^{-3} (2017 year production) to 813.9±18.1 kg m^{-3} (2014 year production) (Table 3).

The determined average pellet natural slope angles were 1.4-1.8 times bigger than the fall angles. The pellet natural slope angles vary from 33.00±1.84 to 35.33±3.82 degrees, and the fall angles vary from 49.00±1.84 to 59.67±2.8 degrees (Table 3).

Table 3: Organic fertilizer pellets bulk density and flow angles

The year of manure compost pellet production	Pellet average moisture content, $w_i \pm \Delta y$, %	Pellets mass in the vessel, g	Volume of vessel, dm^3	Bulk density of pellets, kg m^{-3}	Pellet flow angles, degrees	
					Pellet natural slope angles	Pellet fall angles
Experimental granulator						
2014	12.09±1.18	406.97	0.50	813.9±18.1	33.33±3.82	52,00±4,86
2015	14.66±2.06	374.67	0.50	749.3±19.9	35.33±3.82	52,33±5,61
R_{05}	0.845	21.255	-	42.51	8.957	13,682
Industrial granulator						
2016	14.84±0.30	364.70	0.50	729.4±26.7	34.67±1.06	56.67±3.82
2016 *	12.25±0.98	375.60	0.50	751.2±45.5	34.67±2.80	49.00±1.84
2017 *	14.87±1.48	357.10	0.50	714.2±20.4	33.00±1.84	59.67±2.80
R_{05}	0.526	24.68	-	49.36	2.39	3.999

** Used the compost of intensive composting technology*

Determination of manure compost pellet compressive strength. Pellet compressive strength is an important parameter of pellets, this is especially important for pellets during transport and storage. After compressive strength tests there were determined the resistance to degradation of selected manure compost pellets, and we obtained results that are presented in Figures from 1 to 5.

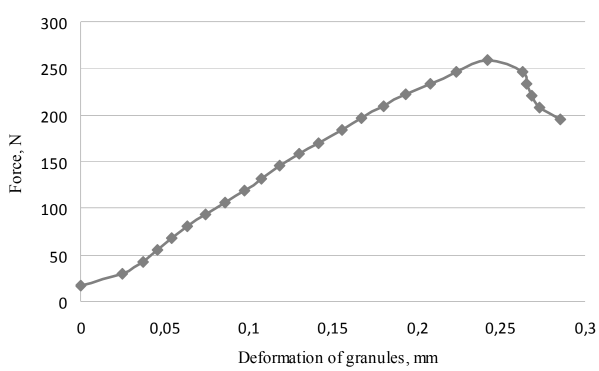

Fig. 1: Deformation and disintegration force of manure compost pellets (2014 year production, used the compost of traditional composting technology)

The test results showed the different year production manure compost pellet deformation and degradation start, and the force under which a pellet disintegrates completely.

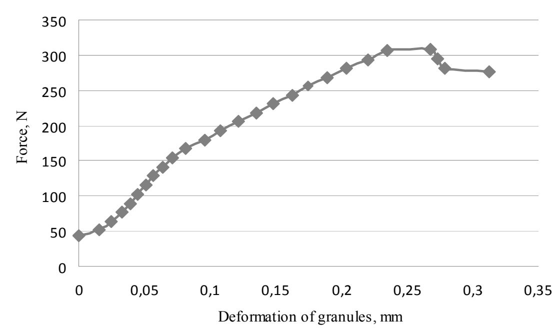

Fig. 2: Deformation and disintegration force of manure compost pellets (2015 year production, used the compost of traditional composting technology)

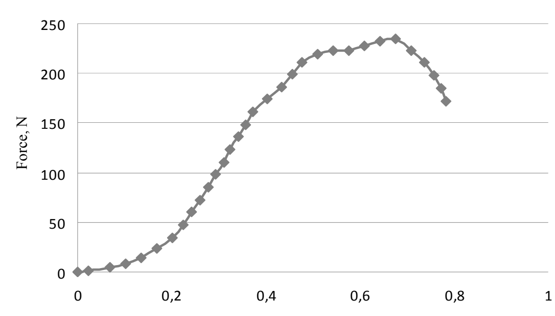

Fig. 3: Deformation and disintegration force of manure compost pellets (2016 year production, used the compost of traditional composting technology)

Analyzing the 2014 year production manure compost pellet deformation curve (Fig. 1), we see that the pellet deformation started at 20 N force, and at 259.4 N force it disintegrated completely.

2015 year production pellet deformation (Fig. 2) started with the force of 50 N, and disintegrated fully with the force 307.7 N, it was the biggest force for pellet fully disintegration.

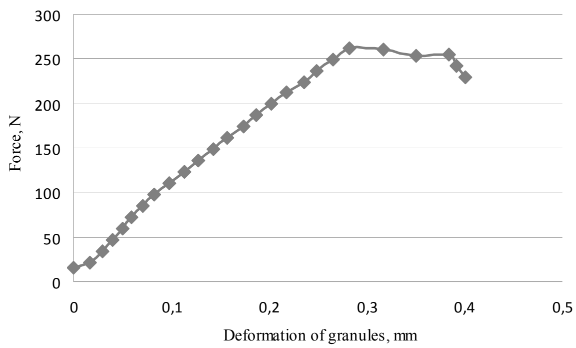

Fig. 4: Deformation and disintegration force of manure compost pellets (2016 year production, used the compost of intensive composting technology)

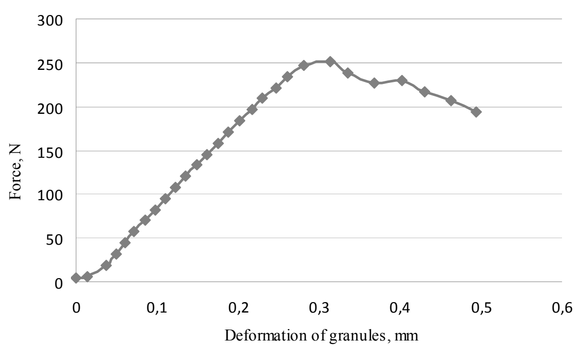

Fig. 5: Deformation and disintegration force of manure compost pellets (2017 year production, used the compost of intensive composting technology)

2016 and 2017 year production pellet disintegrated forces was very similar and reached these maximum values: 235.0 N (Fig. 3), 262.2 N (Fig. 4) and 250.6 N (Fig. 5).

Considering size of the force, its displacement and pellet moisture content, it is possible to state that all sorts of investigated manure compost pellets are sufficiently resistant to static force and do not disintegrate quickly, so these composting and granulation technologies and equipment can be recommended for farmers.

CONCLUSIONS

1. In 2014-2017 years were produced and investigated five variants of cattle manure compost pellets whose parameters were as follows: diameter was 6.0 mm, mass was 0.33±0.07 g, average length was 9.8±1.3 mm.
2. The largest fractional composition of investigated organic pellet was received when the diameter of the sieves holes was 5.6 mm, fraction varied from 63.25±0.28 % (in 2016) to 82.04±0.32 % (in 2015). When was granulated the compost of traditional composting technology (in 2014-2016), very small amount of fraction formed on the sieves with 0.25-1.00 mm diameter holes (only 0.86 %).
3. Investigated humidity of the produced manure compost pellets show that the highest moisture content is of the pellets produced in 2014 – 11.1 %, and the lower are of the other pellets – 8.9-9.7 %. The density of all produced manure compost pellets is so big, close to 1000 kg m^{-3}.
4. The bulk density of investigated manure compost pellets was very similar and varied from 714.2±20.4 kg m^{-3} to 813.9±18.1 kg m^{-3}. Determined average pellet natural slope angles were 1.4-1.8 times bigger than the fall angles.
5. Cattle manure compost pellet resistance to deformation results show that the most resistant to external forces are pellets made in 2015 years, they disintegrated fully with the force 307.68 N.
6. Investigated five sorts of cattle manure compost pellets are sufficiently resistant to static force and do not disintegrate quickly, so used composting and granulation technologies and equipment can be recommended.

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Abstrakt

Peletováním hnojiva z kompostu je možné zvýšit sypnou hmotnost, zlepšit skladovatelnost materiálu, snížit náklady na dopravu a usnadnit manipulaci s těmito materiály pomocí stávajících manipulačních a skladovacích zařízení. Pro řešení tohoto aktuálního problému byl zkoumán granulační proces a faktory ovlivňující fyzikálně-mechanické vlastnosti organického granulovaného hnojiva. Výzkum byl proveden na univerzitě Aleksandrase Stulginskise s hnojivem na bázi kompostu z hovězího hnoje, který byl granulován granulátorem s horizontální matricí, průměr vyrobených pelet byl 6 mm. V letech 2014-2017 bylo připraveno a zkoumáno 5 experimentálních vzorků hnojiva a peletovaných zbytků z hnoje. Během výzkumů byly stanoveny biometrické a fyzikálně-mechanické vlastnosti granulí z organického hnojiva - biometrické ukazatele, granulometrické složení granulovaných kompostových hnojiv, vlhkost pelet, objem, hustota a odolnost pelet proti nárazu. Výsledky výzkumu ukazují, že vyrobené granule jsou velmi odolné vůči stlačování statickou silou a jsou vhodné pro přepravu, skladování a mechanické rozmetání.

Klíčová slova: organický odpad, hnůj, hnojivo, granulace, vlastnosti pelet

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