PHYSICAL MECHANICAL PROPERTIES EVALUATION OF EXPERIMENTAL GRANULATED POULTRY MANURE FERTILIZER

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Abstract. Currently there are searches for new and more rational ways to use agricultural organic waste for new forms of energy, creating fertilizers and other products. One of biodegradable waste management ways is raw material granulation, as processing of recyclable materials into compressed organic products. According to the EU legal requirements manure is considered to be waste the livestock owner has to account for and eliminate using as crop fertilizer and not polluting the environment. Poultry manure granulation can increase the bulk density, improve storability, reduce transportation costs, and make these materials easier to handle using the existing handling and storage equipment. Granulation process parameters and factors affecting the manure-based material of organic granular fertilizer physical-mechanical properties were investigated. Poultry manure raw material samples were dried naturally till about 46% moisture content. Before granulation samples were dried artificially till about 15% moisture content. There were prepared 5 experimental poultry manure samples and granulated mixtures of manure waste with molasses and lime sludge adds in laboratory conditions. For granule production a small capacity 7.5 kW granulator was used with a horizontal 6 mm matrix. During the research, the physical – mechanical characteristics were estimated: biometric indicators (dimensions, mass), raw material and granule volume and density, moisture content and granule strength. The aim of this work is to investigate the granular organic fertilizer with relevant physical-mechanical properties which influence the product quality.

Keywords: poultry manure; granules; physical-mechanical properties; density, granule strength.

Introduction

With reference to Lithuania, according to official statistics, from 2015 to 2019 a total of poultry 11 836 292 heads were reared [1]. The number of most popular animals at the beginning of the year is presented in Table 1. The number of poultry tends to increase, and such concentration of livestock farming activity makes it critical from the environmental points of view. Such farms are becoming larger, and the number of farmed poultry is increasing. According to Polish scientists, quantities of poultry manure generated in poultry production are expected to continue to grow [2]. Therefore, it is necessary to improve the manure management technologies in line with the required reduction of livestock farming environmental pressure [3].

Table 1

Number of poultry at the beginning of 2015–2019 [1]

Animal kind	2015	2016	2017	2018	2019
Poultry (head)	10 218 417	93 695 63	10 098 885	10 405 427	11 836 292

The amount of poultry manure varies according to the specifics of the poultry type: 120 kg for layer chickens, 80 kg for meat chickens, 200-350 kg for turkeys and 150 kg for ducks (1000 birds per day generate the amount of manure in kg) [4; 5]. According to scientists, the speed of producing manure waste in poultry farming consists of about 40-45 t of waste for 1000 birds in a year [6]. Poultry farming has a significant impact on the environment and should be improved as part of a proper waste management system. There is a number of technologies for processing poultry manure into added value products or recovered energy, however, still the most common way of processing poultry manure is biological treatment, such as composting or anaerobic digestion, but still the problems related to the excessive emission of ammonia, and thus nitrogen loss, and odors have not been sufficiently solved [2]. One of manure management technologies trend is to process poultry manure into valuable granular fertilizing products. High levels of nutrients, nitrogen, potassium and phosphorus amounts in poultry litter indicate suitability for fertilizer and soil improver production [2; 7]. Granular poultry litter is more useful and suitable as an organic fertilizer compared to the not treated raw form [8]. Therefore, the production of granules from poultry manure and litter, as they contain macro and micro nutrients, has a great potential for agricultural applications, which is enhanced by their satisfactory mechanical quality, especially the mechanical granule strength [2; 9; 10]. Granulated chicken manure positively affected soil moisture retention, infiltration, and increased the aggregate stability [11]. By analysing the results of the experiment for the mixtures used in granulations with different percentage compositions of chicken manure and straw, it can be found that the hardness of granulate significantly increases together with greater contents of chicken manure and smaller contents of straw [12].

The main objective of this study was to produce granules from poultry manure with litter and molasses, lime sludge additives and to investigate the physical-mechanical properties, paying special attention to the strength of the produced granules.

Materials and methods

The following physical–mechanical characteristics of poultry manure fertilizers were investigated and determined: the moisture content and bulk density of raw material mass; biometric parameters of granules: measurements, mass, density; strength of granules.

Raw material preparation. Laying hen manure was collected in a farm in Marijampolė district. The farmer used straw for manure litter in the barn. Poultry manure samples were dried naturally till about 46.6% moisture content in an open area. To achieve about 10-15% moisture content the samples were dried artificially in a ventilation canal with a slow heated air flow for 24 h. Afterwards the prepared material was placed in a hammer mill GMM-1 (Lithuania), where it was grinded to a mill fraction (about 1-2 mm).

Raw material bulk density. The bulk density was determined according to the standard methodology (EN 1237:2002). An empty 6 dm^3 cylinder is weighted. The prepared mill is filled in the cylinder till the upper edge. The vessel with the mill is weighted and the mass of mill is calculated. The bulk density was calculated by dividing the mass by the container volume.

Moisture content was determined according to the standard methodology (EN 12048:1996). The samples were weighted and dried for 24 hours in a laboratory drying chamber in the temperature of 105 ºC.

Granule production. 5 variants of poultry manure granules were produced in laboratory conditions (Table 2). For granule production a small capacity 7.5 kW biomass granulator ZLSP200B (POLEXIM, Poland) was used, with a horizontal granulator matrix with 6 mm diameter holes. Granulation requires the addition of moisture throughout the granulation process, typically through the inclusion of a liquid binding agent, usually in the form of water. Before the granulation, raw material mill samples were moistened by spraying them with water emulsions. The first sample was obtained from poultry manure with straw as litter and moistened by spraying it with water containing no additives and the sample was named VI1. Other samples were moistened by spraying a water emulsion using molasses as an additive. The raw material made of mixed water and molasses with ratio 1:1 was called VI2, and the emulsion with ratio 1:2 was called VI3. The VI4 samples were moistened by spraying the emulsion, which had the water to lime sludge ratio of 1:1 and the emulsion with water to lime sludge ratio 1:2 was called VI5 (Table 2).

Table 2

Produced and investigated organic raw material for granulation

Sample codes	Laying hen manure raw material and additives types used for experimental granule production
VI1	Manure without additives
VI2	Manure with molasses (water to molasses emulsion rate 1:1)
VI3	Manure with molasses (water to molasses emulsion rate 1:2)
VI4	Manure with lime sludge (water to lime sludge rate 1:1)
VI5	Manure with lime sludge (water to lime sludge rate 1:2)

The granule parameters. The granule parameters were determined by measuring their height and diameter (digital caliper, accuracy to 0.01 mm). Granule weight was assessed by Kern ABJ (Germany) scales (accuracy to 0.01 g). The height, diameter and weights were calculated for each type of samples using 10 granules to obtain the average error. The granule volume was calculated using the granule size (diameter and length). After determination of the granule volume and weight, the density of all investigated granules samples was calculated [13; 14]. Each test was repeated 3 times. The analysis of variance with three replication design was performed on the data of the fulfilled experiments, using the analysis of variance to determine the significance at 95% probability level.

Granule strength measuring. Granule strength tests were performed in the test machine "Instron 5960" (USA) and the command and parameter registration computer system "Bluehill". The tests were performed by placing granules on a plane with horizontal loads. Tests were made for 5 times for each sample. Compressive tests selected granules of height to diameter ratio greater than 2:1 (height about 12 mm; diameter about 6 mm). The test results were registered every 0.1 second until the granule was completely damaged. Pressing speed (20 $mm \cdot min^{-1}$) was the same for all samples. The measuring error was 0.02%. During data processing, average values and their confidence intervals (CI) under the 0.95% probability level were found.

Results and discussion

Bulk density of poultry manure with litter raw material was 647.1 ± 4.05 $kg \cdot m^{-3}$. This is a higher rate compared to cattle manure compost raw material bulk density (556.4 ± 5.81 $kg \cdot m^{-3}$) [13], or composted pig manure raw material (525.8 ± 56.06 $kg \cdot m^{-3}$) [14]. Average moisture content of the prepared mill after artificially drying in the ventilation canal was 11.2 ± 1.4% (Table 2). It has been determined that the produced granulated fertilizers were in the range of the granule diameter 5.8 ± 0.11 mm. Average granule weight was about 0.54 ± 0.06 g. Granule average length 14.29 ± 1.25 mm. Average density of VI series granules was 1426.17 ± 65.53 $kg \cdot m^{-3}$. Additives of molasses and lime sludge had no significant effect on the granule density. VI1 granules (without additives) showed the best granule density (1476.61 ± 50.55 $kg \cdot m^{-3}$). The lowest density was found in the VI4 series granules and it was 1398.40 ± 62.36 $kg \cdot m^{-3}$ (Table 2).

Table 2

Moisture content and density of VI series experimental granules

Granule code	Mill moisture content before granulation, %	Granule density, $kg \cdot m^{-3}$
VI1	9.48 ± 0.11	1476.61 ± 50.55
VI2	11.5 ± 0.57	1408.29 ± 27.39
VI3	12.4 ± 1.01	1422.51 ± 41.83
VI4	11.5 ± 2.11	1398.40 ± 62.36
VI5	11.2 ± 1.43	1425.09 ± 31.83

The granule crushing strength test of poultry manure with litter granule curves is shown in Figure 1. There was picked an average inherent curve from 5 samples on the purpose to show the character of the force (N) variation in the granule crushing strength test. There were picked points from which the force started to decrease for each sample in VI series granules.

Analyzing the deformation curves, it can be observed that the maximum crushing force in horizontal direction is achieved at more 924 N and deformation was in the range from 0.4 till 0.5 mm in VI3 series granule case with the biggest molasses addition (ratio 1:2), in the second place was VI5 with the result of 794 N (Fig 1) with the biggest lime sludge addition (ratio 1:2). These granule series showed the greatest resistance to mechanical load (Fig 2). Most of deformation begins at 0.2 mm and continues till 0.5 mm in all sample cases. The weaker granules were in poultry manure samples VI1 without the addition, VI2 with molasses addition (ratio 1:1) and VI4 with lime sludge addition (ratio 1:1), in such cases the granule strength did not exceed 680 N.

Maximum crushing load test results from VI series granule samples and the average values and their confidence intervals (CI) are shown in Figure 2. Maximum crushing load force values were collected from Instron Bluehill test control software data. The granule sample VI3 with molasses addition (ratio 1:2) and granule samples VI5 with lime sludge addition (ratio 1:2) with a semi-static stability of 850 N were found to be the most mechanically stable. Average of all VI series granule crushing strength was 722.6 ± 134.29 N in horizontal direction, but there is no significant difference comparing VI1, VI2 and VI4 series granules (Fig. 2).

It can be argued that the addition of molasses and lime sludge by involving it with the emulsion of water (water and addition ratio 1:2) during granulation process increased the strength of the granules.

However, the question remains as to whether such granule strength is required, as even without additives or with less concentration the granules in this series have shown excellent strength test results (about 680 N). Weaker granules are suitable for use as a fertilizer, such granules dissolve into the soil easier, but there exists a risk that the granules can be too weak for operational loads.

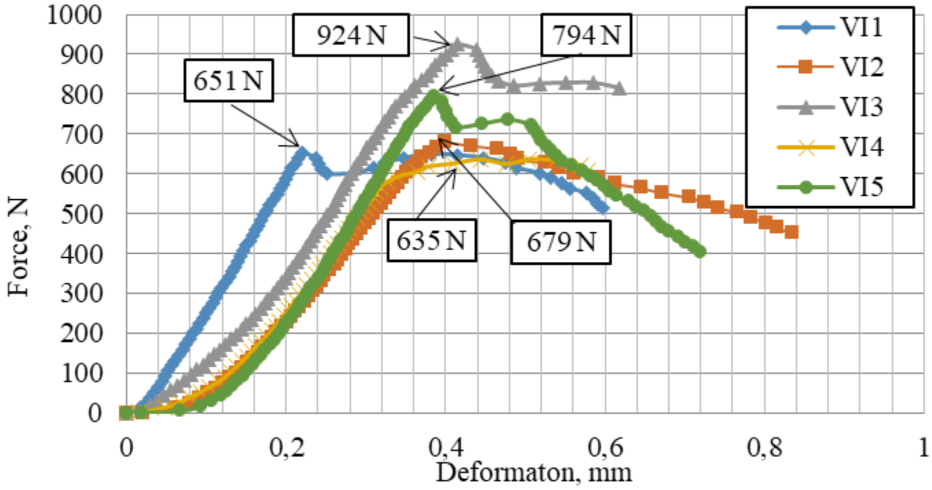

Fig. 1. **Typical curves of poultry manure with molasses and lime sludge additive granule strength test**

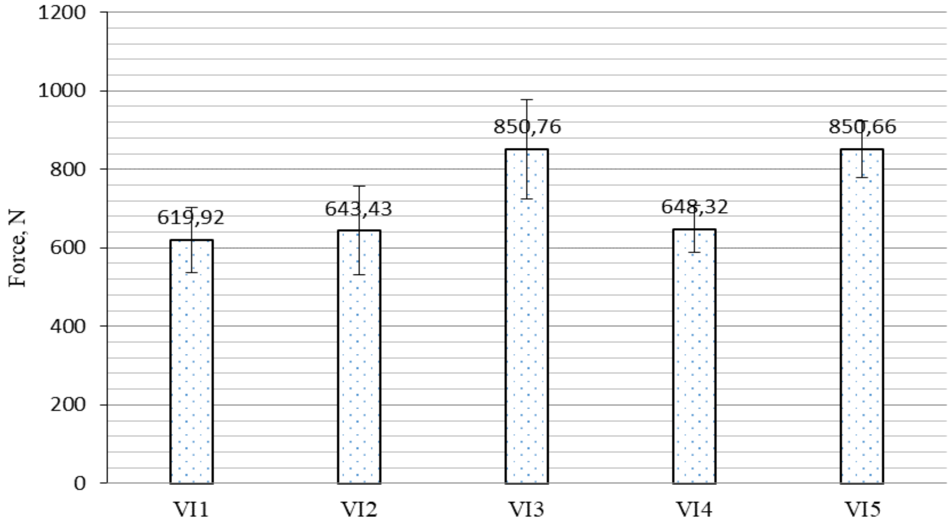

Fig. 2. **Laying hen manure with litter granule strength test:** VI1 pure, VI2 with molasses addition (ratio 1:1), VI3 with molasses addition (ratio 1:2), VI4 with lime sludge addition (ratio 1:1), VI5 with lime sludge addition (ratio 1:2)

Compared to previous studies of cattle manure compost granules, it may be seen that granules under the force of 425 N in horizontal compression disintegrated totally. Granules with molasses addition reached 491 N in horizontal direction [13], average pig manure compost granule strength was 628.3 ± 38.9 N [14]. Poultry manure with litter granules has shown better results. According to Polish scientists, mechanical strength of pellets made with a similar biomass ZPL series granulator from chicken manure mixed with chopped rye straw varied from 290 till 465 N [12]. Poultry manure with litter granular fertilizer should be strong enough for storage, transportation and pass through a fertilizer disc spreader without braking.

Conclusions

1. The determined initial moisture content of the raw materials ranged 62.81 ± 2.48%. After drying and material mixing the moisture content varied from 8.15 ± 1.9 to 17.50 ± 2.78%. The bulk density of the raw material was 647.1 ± 4.05 kg·m^{-3}.

2. Granules produced from poultry manure with litter raw material were in the range of the diameter from 5.8 ± 0.11 mm and average length 14.29 ± 1.25 mm. Average density of VI series granules was 1426.17 ± 65.53 $kg{\cdot}m^{-3}$. Additives of molasses and lime sludge had no significant effect on the granule density.
3. It can be argued that the addition of molasses and lime sludge by involving it with the emulsion of water (water and molasses/lime sludge addition ratio 1:2) during the granulation process increased the strength of the poultry manure with litter granules. With increasing the concentration of molasses (VI3 series) and lime sludge (VI4 series) in poultry manure with litter it is possible to achieve high, more than 850 N, strength granules. The weaker granules were in poultry manure samples VI1 without any addition, VI2 with molasses addition (ratio 1:1) and VI4 with lime sludge addition (ratio 1:1), in such cases the granule strength did not exceed 680 N. All tested granular fertilizers should be strong enough for storage, transportation and pass through a fertilizer disc spreader without braking.

References

[1] Official Statistic Portal 2021. [online] [31.02.2019]. Available at: https://osp.stat.gov.lt/en/statistiniu-rodikliu-analize?portletFormName = visualization&hash = 749f72a5-4d75-4056-8f80-a872e8630d6a#/
[2] Dróżdż, D., Wystalska, K., Malińska, K., Grosser, A., Grobelak, A., Kacprzak, M. Management of poultry manure in Poland – Current state and future perspectives. Journal of environmental management, vol. 264, 110327, 2020.
[3] Petersen, S. O., Sommer, S. G., Béline, F., Burton, C., Dach, J., Dourmad, J. Y., Leip A, Misselbrook T, Nicholson F, Poulsen H.D., Provolo, G. Recycling of livestock manure in a whole-farm perspective. Livestock science, vol. 112(3), 2007, pp. 180-191.
[4] Collins E.R., Barker J.C., Carr L.E., Brodie H.L., Martin J.H. Poultry waste management handbook. New York, Natural Resource, Agriculture, and Engineering Service, 1999.
[5] Williams C.M., Barker J.C., Sims J.T. Management and utilization of poultry wastes. Reviews of Environmental Contamination and Toxicology, vol. 162, 1999, pp. 105-157.
[6] Bilitewski, B., Härdtle, G., Marek, K. Handbook of waste management. Theory and practice, Wydawnictwo Seidel-Przywecki, Warszawa, 2006.
[7] Maliba B.G., Zobolo A.M., Siebert S.J. Poultry manure enhances grass establishment at a quarry rehabilitation site in subtropical South Africa. African Journal of Agricultural Research, vol. 6, 2011, pp. 46-50.
[8] Suppadit T. Poultry waste pelleting, villager technology. International Journal of Livestock Production, vol. 18, 2000, pp. 51-54.
[9] McMullen J., Fasina O.O., Wood C.W., Feng Y. Storage and handling characteristics of pellets from poultry litter. Applied Engineering in Agriculture, vol. 21, 2005, pp. 645-651.
[10] Singh K., Risse L.M., Das K.C., Worley J., Thompson S., Mani S. Studying compaction behavior of fractionated poultry litter and use of pyrolysis condensate as binder during pelletizing. Transactions of the ASABE, vol. 52, 2009, pp. 949-956.
[11] Feng, G., Adeli, A., Read, J., McCarty, J., Jenkins, J., Consequences of pelletized poultry litter applications on soil physical and hydraulic properties in reduced tillage, continuous cotton system. Soil Tillage Res., vol. 194, 104309, 2019.
[12] Zdanowicz, A., Chojnacki, J. Mechanical properties of pellet from chicken manure mixed with chopped rye straw. Journal of Research and Applications in Agricultural Engineering, vol. 62 (4), 2017, pp. 216–218.
[13] Mieldazys, R., Jotautiene, E., Jasinskas, A., Aboltins, A. Evaluation of physical mechanical properties of experimental granulated cattle manure compost fertilizer. Proceedings of International conference “Engineering for Rural Development”, vol. 16, 2017, pp. 575-580.
[14] Mieldažys, R., Jotautienė, E., Zinkevičienė, R., Jasinskas, A. Manure processing into granular fertilizers using additional additives. Proceedings of International conference “Engineering for rural development”, vol. 18, 2019, pp. 635-640.