EVALUATION OF BONE MEAL GRANULAR FERTILIZER PHYSICAL MECHANICAL PROPERTIES

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Abstract. Currently there is searching for more ways to use organic waste for new ways of getting energy, creating fertilizer materials and other products. One of biodegradable waste management ways is raw material granulation, as processing of recyclable materials in compressed organic products. Bone meal – a product obtained by heating, drying and grinding bones and bone parts of warm-blooded land animals. The product must not contain hooves, horns, bristles, fur, feathers and stomach and intestinal contents. Bone meal is an excellent source of calcium and available phosphorus and can reduce the need to supplement inorganic phosphorus in the soil. Bone meal granulation can increase bulk density, improve storability, reduce transportation costs and make these materials easier to handle using existing storage and spreading equipment. Granulation process parameters and organic granular fertilizer physical-mechanical properties were investigated. Experimental bone meal flour samples were prepared and granulated in laboratory conditions. For granule production a small capacity 7.5 kW granulator was used with a horizontal 6 mm matrix. During the research physical – mechanical characteristics: biometric indicators (dimensions, mass), density, content of moisture and mechanical strength were estimated. The aim of this work is to investigate the granular organic fertilizer physical-mechanical properties.

Keywords: bone meal; granules; physical–mechanical properties; density, granule strength.

Introduction

Fertilizing only with mineral fertilizers poses a threat to soil degradation. Due to improper fertilization, the amount of humus in the soil may begins to decrease, as well as the amount of other substances necessary for plants, and the soil begins to acidify. Mineral fertilizers also have significant environmental impacts, including water quality degradation, smog formation, eutrophication, and greenhouse gas emissions [1]. Fertilizing with organic fertilizers not only improves the condition of the soil but also achieves the goal of obtaining a better crop yield. Therefore, safe and efficient recycling of nutrient-rich agricultural waste could be a viable alternative to carbon-based synthetic fertilizers and could help maintain soil productivity and reduce environmental impact [2-4]. Properly used bone meal from various animals can become a valuable raw material for production of organic fertilizers. Bone meal – a product obtained by heating, drying and grinding bones and bone parts of warm-blooded land animals. The product must not contain hooves, bristles, fur, stomach and intestinal contents. Soil improvement materials obtained from the processing of products and other economic waste and by-products are distinguished: meat meal, blood meal, fish meal, animal horns and hooves, horn shavings, feather meal and others.

Global meat consumption has increased by 40% over the past decade [5]. In 2020, the world produced about 253 million tons of meat [6]. Meat production generates a huge amount of waste during slaughtering of animals. Bone meal is a by-product of the slaughtering industry, obtained by washing and grinding bones. Traditionally, meat and bone meal has been used as a source of protein, phosphorus, calcium, vitamin B-12 and many other minerals in cattle feed [4]. However, following the *Bovine spongiform encephalopathy* (BSE), commonly known as mad cow disease, crisis in Europe, the addition of meat and bone meal to cattle feed as a high-protein product has been restricted [7]. In recent years, many applications of bone meal have been proposed. Recently, some studies have highlighted the agronomic efficiency of using bone meal due to its essential nutrient composition, such as calcium (Ca), phosphorus (P) and nitrogen (N), and other elements such as K, Mg, Fe, Na. Studies were conducted to determine the characteristics of bone meal. In study bones from cattle, sheep and chicken were collected directly from a slaughterhouse. To remove fat, connective tissue and other contaminants from the bones it was washed with distilled water and dried. The prepared bones were reduced to particles by grinding [4]. According to other scientists, due to the high levels of total nitrogen (8%), phosphorus (5%), and calcium (10%) in meat and bone meal, these organic matters can be considered as useful fertilizers for soil improvement [8; 9].

Granulation is a process of moulding a material into the shape of a granule (pellet). Compression and temperature, as well as composition of the raw material are the major factors affecting the process. The goal of pelletizing is to produce an easily manageable product for land crop fertilization that conserves all the properties of the original material (nutrient content) and with better storage and handling properties as compared to a dusty product in powder form.

The aim of this work is to investigate the bone and horn meal (BHM) fertilizer main physical and mechanical properties of the studied material and produced experimental cylindrical granules, paying attention to the strength of the granules.

Materials and methods

The following physical–mechanical characteristics of bone and horn meal were investigated: fractional composition and the moisture content of the milled material, parameters of produced granules (measurements, mass, density) and the strength of granules.

Raw material preparation. Bone and horn meal flour (approximately 2 kg) was purchased from the company "Vajatex" (Palipuzės k., Mazeikiu distr., Lithuania).

Fractional composition. Fractional composition of bone and horn meal flour was determined using a sieve shaker Retsch AS 200 (Germany), a set of 200 mm diameter sieves. The sieve diameter range was 0 mm, 0.25 mm, 0.5 mm, 0.63 mm, 1 mm, 2 mm and 3.15 mm. When sieving a 100 g mass sample, a set of sieves in the horizontal surface turned in a semicircle for 1 min. The mass remaining on sieves was weighted, and a sample part of every fraction in percentage calculated. The test was repeated 3 times.

Granule producing. One variant of bone and horn meal flour cylindrical granules were produced in laboratory conditions. For granule production a traditional biomass granulator ZLSP200B 7.5 kW (Poland) was used, with a horizontal granulator matrix with 6 mm diameter holes.

Granules parameters. The granule parameters were determined by measuring the height and diameter using a Vernier caliper LIMIT 150 mm (accuracy to 0.01 mm). Granule weight was determined by Kern ABJ (Germany) scales (accuracy to 0.01 g). The height, diameter and weights were calculated using 10 granules to obtain the average error. Granule density was calculated using the above data according to standard methods [10].

Granule strength determination. Granule strength tests were performed using a mechanical property test machine "Instron 5960" (USA) and test parameter registration system "Bluehill" (USA). The granules were placed horizontally on the plate and compressed until granule breakage achieved. Granule compressive loud (N) was determined as the maximum force recorded when compressing the granule at fracture. A semi-static load with a constant speed of 20 $mm \cdot min^{-1}$ was used. Tests were repeated for 10 times. During all data processing using the appropriate number of repetitions, average values and their confidence intervals (CI) under 95% probability level were found.

Results and discussion

Experimental investigations of bone and horn meal (BHM) flour conversion into granular fertilizers were carried out in 2024 – 2025, in a laboratory based at the Department of Agricultural Engineering and Safety of the Vytautas Magnus University Agriculture Academy (Lithuania).

Purchased bone and horn meal according to the manufacturer was 100% wild animal horn and bone meal, which constitutes NPK ratio 4-12-0.1. Chemical composition of organic bone and horn meal (BHM) flour is presented in Table 1. According to the producer it is a natural universal organic fertilizer (in powdered form) of natural origin (bone and horn meal) intended for fertilizing seedlings, flowers, vegetables, garden and ornamental plants, garden soil, potting soil, growing container and greenhouse soil. Organic matter contained in fertilizers has a significant positive effect on the biological, physical and chemical properties of the soil. It significantly improves the soil structure, increases the humus layer, and stimulates the microbiological activity of the soil. The high content of phosphorus (P) promotes rooting and establishment of plants. Fertilizer products can be classified as soil improvement materials obtained by processing waste and by-products from production and other economic activities. The results of other studies are very similar when compared to those presented in Table 1. Comparing with the results, where bones from cattle, sheep and chicken were used: pH of the bone meal was 8.1, and it contained 37% organic matter [4].

Table 1

Chemical composition of bone and horn meal flour (according to producer)

Parameters	Values
pH KCl	8.0
Dry material, %	91.5
Organic matter, %	31.4
Nitrogen (N), %	4
Phosphorus (P), %	12
Potassium (K), %	0.1
Calcium (Ca), %	25.1
Sulphur (S), $mg \cdot kg^{-1}$	2723
Copper (Cu), $mg \cdot kg^{-1}$	5.2
Zinc (Zn), $mg \cdot kg^{-1}$	90.7
Iron (Fe), $mg \cdot kg^{-1}$	28.4
Manganese (Mn), $mg \cdot kg^{-1}$	796

Purchased from the producer bone and horn meal (BHM) flour contained the most of material (23%) in the mass fraction up to 0.5 mm. In the second place BHM flour contained mostly 0.25 mm of material (21%) (Fig. 1). Since most of the flour consists of a finer fraction, it is not suitable for fertilizing with mechanized spreading equipment. This form of fertilizer powder is suitable only for local application to the soil. This is one of the main reasons why the decision is made to granulate bone and horn meal flour. The fractional composition was in most cases up to 2 mm, only a small portion exceeded the 2 mm fraction (about 6.5%), so it can be said that the raw material was suitable for granulation.

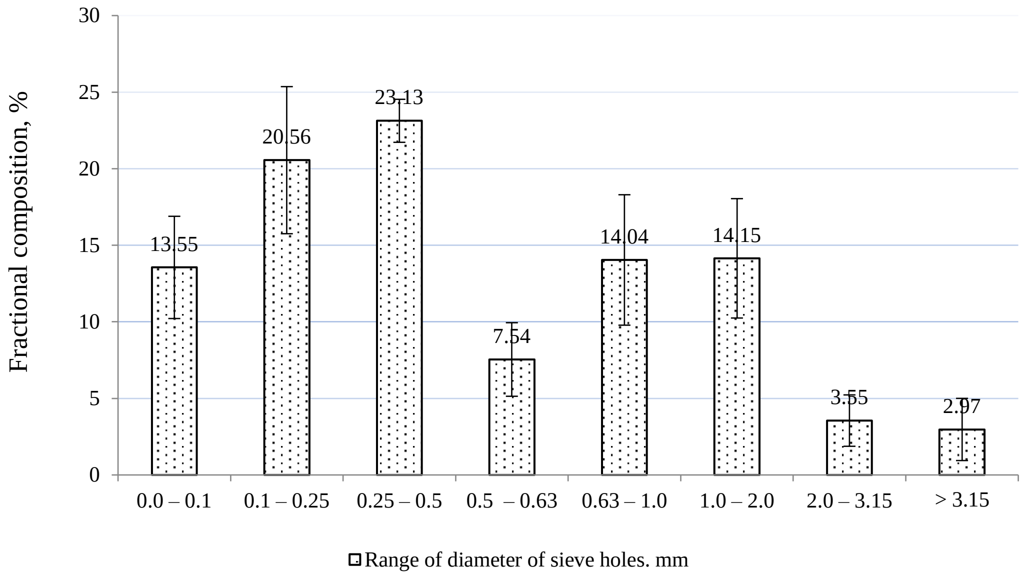

Fig. 1. **Bone and horn meal (BHM) raw material fractional composition**

The average moisture content of purchased BHM flour was 8.5%, according to the manufacturer's data. The milled sample was irrigated to achieve a moisture content of about 14%, because according to the granulator ZLSP200B producer the moisture of the raw material should be adjusted to 14-18%.

After granulation it has been determined that the produced granulated fertilizers were in average in the range of the granule diameter 6.06 ± 0.03 mm. The granule average length was 15.92 ± 0.84 mm, in average the granule mass was 0.73 ± 0.07 g. A general view of the produced granules is presented in Figure 2. A relatively high density of granule bone and horn meal granules was achieved, it was 1704.31 ± 69.35 $kg \cdot m^{-3}$. The result could have been due to the large amount of fines in the flour, it was mentioned before that mainly part in the mass fraction was up to 0.5 mm. It was difficult to find similar sorts of organic granules in the comparative scientific research literature, but it can be compared with granules made from different organic materials using the same ZLSP200B granulator with 6 mm diameter matrix. For comparison, cattle manure compost granule density was 1497.32 ± 70.58 kg·m^{-3}, for pig manure granules – 1461.66 ± 105.75 kg·m^{-3} and poultry manure granule density was 1234.15 ± 42.25 kg·m^{-3} [11].

Fig. 2. **Main view of produced cylindrical bone and horn meal (BHM) granules**

The granule crushing strength test of the granular fertilizer BHM is shown in Figure 3. BHM granules deformed at a maximum compressive force more than of 455 N, with deformation ranging from 0.1 mm to 0.3 mm until the granules completely disintegrated in the case of sample 4. Most of deformation begins at 0.1 mm and continues until 0.3 mm in all sample cases. The weaker granules were in the case of 8sample 8, their strength was about 265 N (Fig. 3).

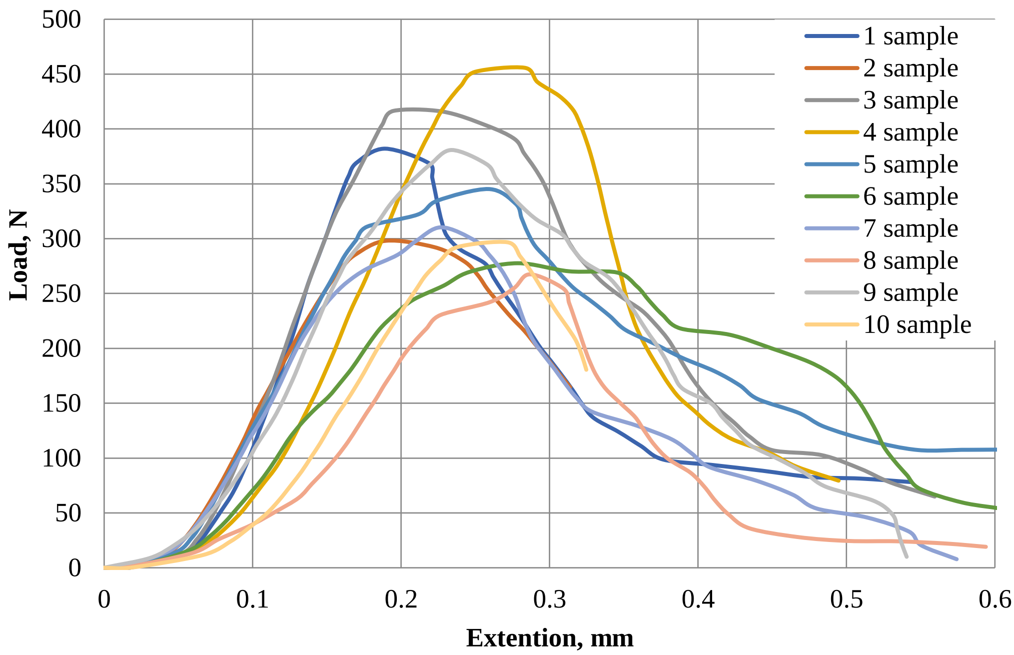

Fig. 3. **Curves of produced bone and horn meal (BHM) granule strength test**

It was determined that all experimental granule samples showed a high compressive strength that exceeded more than 265 N. The produced bone and horn meal (BHM) granule average force required to crush reached 341.79 ± 46.24 N from 10 samples selected for the experiment. It can be argued that all tested granules were sufficiently mechanically stable and should be strong enough for storage, transportation and passing through a fertilizer spreading equipment without breaking down. For comparison, bone meal granule (pellets) maximum destructive force N was 39 N, but it should be mentioned that the diameter of pellets was 4.5 mm, not 6 mm as in this study [12]. For comparison, in other studies organic cattle manure compost granules produced using the same ZLSP200B granulator withstood the compressive strength of 513.1 ± 84.22 N [11].

Conclusions

1. From bone and horn meal raw material, using granulation technologies, it is possible to produce fertilizers that are easily transported and can be used for fertilizing crops. Bone and horn meal granular fertilizers likely increase the yield and quality of plants and the amount of humus in the soil. The use of organic granules is in line with the ideas of sustainable, environmentally friendly farming.
2. Bone and horn meal flour contained the most material (23%) in the mass fraction up to 0.5 mm. The fractional composition of raw material was in most cases up to 2 mm, so it can be said that bone and horn meal was suitable for granulation. The moisture content of the mill was about 8.5%, therefore, additional wetting of the material was required for a successful granulation process.
3. It has been determined that the produced granulated fertilizers were in the range of the granule diameter of 6.06 ± 0.03 mm. The granule average length was 15.92 ± 0.84 mm. The average density of the experimental cylindrical granules was 1704.31 ± 69.35 $kg \cdot m^{-3}$.
4. The bone and horn meal granular fertilizer should be strong enough for storage, transportation and spreading on soil using mechanical equipment. The force required to crush granules reached the maximum compressive force more than of 455 N. The average force required to crush granules was 341.79 ± 46.24 N.

Author contributions:

Conceptualization, E.J. and R.M.; methodology, R.M. and A.J.; software, R.M.; validation. E.J., R.M. and A.J; formal analysis, E.J.; G.V. and R.M.; investigation, E.J., R.M., and A.J; data curation, E.J., R.M. and A.J.; writing-original draft preparation, R.M.; writing-review and editing, E.J. and A.J.; visualization, R.M.; project administration, E.J.; funding acquisition, G.V. All authors have read and agreed to the published version of the manuscript.

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