INVESTIGATION OF GRANULATION PROCESS PARAMETERS INFLUENCE ON GRANULATED FERTILIZER COMPOST PROPERTIES

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Abstract. In Lithuania stable organic fertilizer granules, which could be used for crop fertilization, have not been yet investigated and made. There were produced stable granules with the moisture content from 24.3 to 25.9 %. These fertilizers contain 2.76 % nitrogen (N), 1.34 % phosphorus (P_2O_5), 5.45 % potassium (K_2O), 0.6 % magnesium (Mg), 2.1 % calcium (Ca) and other trace elements. There were analyzed and evaluated the factors and the granulation process parameters that influence the granulated compost fertilizer granules geometrical characteristics and physical- mechanical properties. There are reviewed and evaluated the indicators for determining the quality parameters of the granular material and the granulated compost fertilizer chemical composition.

Keywords: granulation, granulated compost fertilizer, granular physical-mechanical properties.

Introduction

It is indisputable that part of soil fertility improvement is organic fertilizer. The main source of organic fertilizer remains livestock waste – cattle and poultry manure. Whereas scarcely used, when the price of mineral fertilizer increased and ecological problems appeared, a decrease of soil fertility and humus has been noticed [1].

When applying conventional manure removal, preparation and application methods in addition to not using stricter environmental requirements can have a negative impact on the key components of the environment. This can be prevented by properly wasting, composting and granulating agricultural waste. The resultant product is humus compost, which presents no problems and no the difficulty of keeping it and has no unpleasant odor, pathogenic organisms or other fitotoxical materials, it also accelerates the metabolism of nutrients between the soil and plant roots of plants [1; 2].

Organic granular fertilizer improves the dynamics of microbiological processes in granules and around them which allows reducing the spread of nutrients in the soil and their transition to less agile forms, besides that it results in better circumstances for processes taking place between the fertilizer, soil and plant.

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; moreover, 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 and material thickening while extruding [2; 3].

Granulation – the set of natural and physical-mechanical processes, which take place during the formation of little pieces, which has a dimension of the ranges, forms, structures and physical properties. Granulation allows significant simplification of the storage, transport and dosage; moreover, it increases powdery while together eliminating dusting and improving the working conditions in the production sphere, besides that, it can regulate the granule structure and related properties.

The granulation process efficiency depends on the method of granulation and technology. The consequence of all physical-mechanical processes that are taking place while palleting is that granulated material density increases.

In the pallet making process we can see all known physical-mechanical and physical-chemical bonds, accompanied by such forces as the capillary force and forces between the solid particles (monomolecular Van der Waals-forces and electrostatic forces), temperature changes affecting the forces and so on.

The granulation process itself depends on the feedstock grain size and physical-mechanical properties. (Temperature, moisture content, pH, etc.). The main parameter describing the performance of pelletizer and the energy cost required by material compaction is the granule formation speed [4]. As the speed of granulation increases the granular material density and mechanical strength decrease.

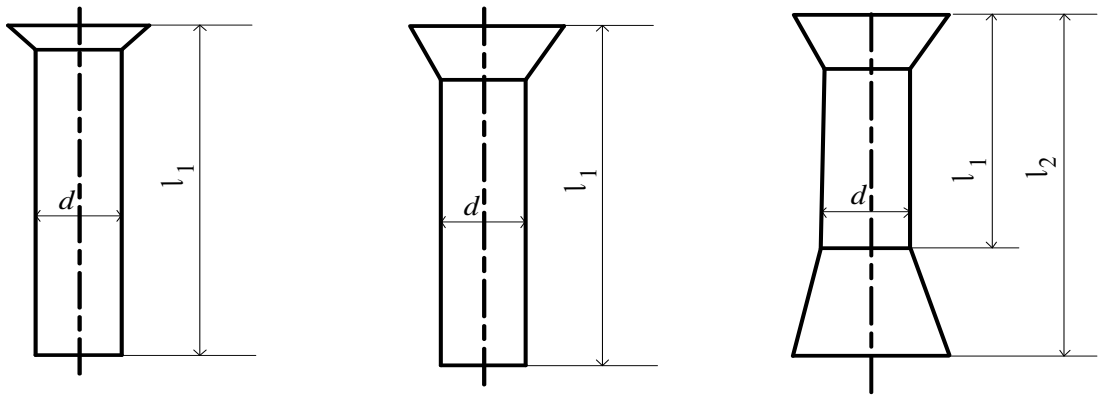
When using a cylindrical matrix greater strength is obtained if traction forces occur between the material particles in the extruding process and the compression time in the matrix channel is higher than the pellet relaxation time [4; 5].

The high-quality organic fertilizer pellet production technological process consists of the following stages: production of compost, compost milling and drying and granulation. The key technology of this cycle becomes a continuous extruding operation where the granulated material having an initial bulk γ_0 is compacted to γ. During this operation in the channel matrix there is constant compaction of dry substances, characterized by the relative density of the granulated material (γ/γ_0). Material deformation depends on the kinematic state when certain forces are in action.

The relationship between different levels of deformation depends on the granulated material, particle shape and dry substance material compaction rate. When powdery material is cast more it increases its density and decreases porosity. This process is irreversible because it is related to structural deformations [5]. The main indicator of this process is compaction density γ_{lim}. The factual impact to compaction density is related to a few things: the extruding pressure absolute value, depending on the material properties and compressible material compaction and shifting zone length, pressure rise rate and material keeping in compaction zone length.

In influence of the matrix channel compaction pressure P_p the granulated substance is exposed to the compressive strength, which vector direction is parallel to the longitudinal axis of symmetry. When compressing powdery substance and when its expansion in the transverse direction is eliminated, then any pressure of the powdery material increase in one direction inevitably leads to a proportional increase in the bulk material pressure in the direction perpendicular to the channel wall.

When pellets exit the matrix channel residual internal stresses within is the main cause for cross-linking between the extruded material particle decline. It is observed that at the same pressure in granulated material the volume mass located in the matrix channel is greater than the extruded matrix channel material (pellet) volume mass. When pellets exit the channel matrix the granular radial expansion results in the stress in the lateral surface of granule layer decline process. From that it can be said that when extruding organic materials it is necessary to create such conditions for the deformation process, which would allow to reduce the pressure on the side walls of the channel matrix [5-7]. For reducing internal stress and increasing the relationship between the matter particles various matrix channel design decisions can be implemented (Fig. 1).



a) **b)** **c)**

Fig. 1. **Matrix compression channel schemes:** a – cylindrical continuous; b – with creating, calibrating parts; c – with forming, calibrating and relaxation components

Matrix channels provide a single constant granule deformation in the radial direction. Granule quality in such channel is mainly determined by the geometric parameters: diameter and length. Granule strength is determined by time that the granule stays in the matrix channel, which depends on the length of the channel and the channel side surface finish.

While analyzing different geometric shape matrix channels and taking into consideration organic compost structural – rheological properties it can be concluded, that the most acceptable channel would be one which has forming and calibrating parts. That way the above named factors and

processes in the matrix channel enable the evaluation of the pelletizer operating modes from which the most important are the pressurized mode and high-speed mode.

The objective of the studies – to evaluate organic compost, cattle litter and feed residue granulation process capabilities while keeping the value of the product intact with ecological and product qualitative requirements.

The objects of the investigation – beef cattle litter and feed residue compost granulated organic fertilizer.

The work tasks – to investigate the granulation process parameters effect on the properties of the granular product.

Materials and methods

The research was carried out with beef cattle litter manure and feed residue compost, made by special technology for granules. Such compost in a mill – drying machine is mechanically grinded and dried with hot air. Bulk granulated product is made as a result. Additional material for the granulation technological process is not used, so this granule production technology is new.

The studies have shown that depending on the granulator diameter of the matrix channel and length. Two types of granules for organic fertilizers were produced: 4 mm diameter, 40 mm length and 6 mm diameter, 30 mm length. Research of chemical composition was carried out under laboratory conditions and the following chemical structure in the granulated organic compost was shown: 2.76 % of nitrogen, 1.34 % of phosphorus, 5.44 % of potassium, 0.58 % of manganese, 2.07 % of calcium, 0.16 % of iron and other microelements needed for plants.

Weighted method was used to define the pellet bulk density and the test was repeated five times. The fertilizer granulometric contents were determined using a sieve "Retsch HS200. The sieves were used with the following diameter pouring holes: 7.1 mm; 5.6 mm; 5.0 mm; 4.0 mm; 2.0 mm; 1.0 mm; 0.5 mm; 0.25 mm.

The dynamic friction coefficient of the granules was determined according to the pellet mass movement velocity with friction that acts on the steel surface. The dynamic friction coefficient was determined according to the equation [8]:

$$f_1 = \frac{P_t}{N}, \tag{1}$$

where P_t – resistance to friction, $N \cdot cm^{-2}$;
N – normal pressure, $N \cdot cm^{-2}$.

For investigation of the dynamic friction coefficient the stand, which is described more in another article, has been used [8].

In matrix with channel cylindrical forming and calibrating parts (Fig. 1) the granule-making process goes as follows. In the granulation process the material falls in a conical matrix channel part where it gets initial compression in the radial and axial directions. At the same time the internal stress reduction process is taking place at the expense of the bigger surface contact area between the granulated material particles and thus the number of communications increases.

Results and discussion

The pelleted organic compost fertilizer pellet moisture content was 24.4 %. The pellet bulk density was influenced by the diameter of the channel matrix pelletizer. 6mm diameter channel granular bulk density was 803 $kg \cdot m^{-3}$ and the diameter of 4 mm – 818 $kg \cdot m^{-3}$. It can be concluded that with smaller diameter granulated channel matrix the pellet density is higher

When investigating granular organic fertilizer granulometric content it was found that 6 mm diameter matrix channel produced in compost fertilizer is dominated by 5.5-7.1 mm fractional part (88.4 %) granules (Fig. 2).

Granulometric compost fertilizer composition changes depending on the diameter of the pelletizer matrix channel. In fertilizer granules produced with 4 mm diameter matrix channel 3.15-4.0 mm fractional part (73.0 %) of granules (Fig. 3) dominated.

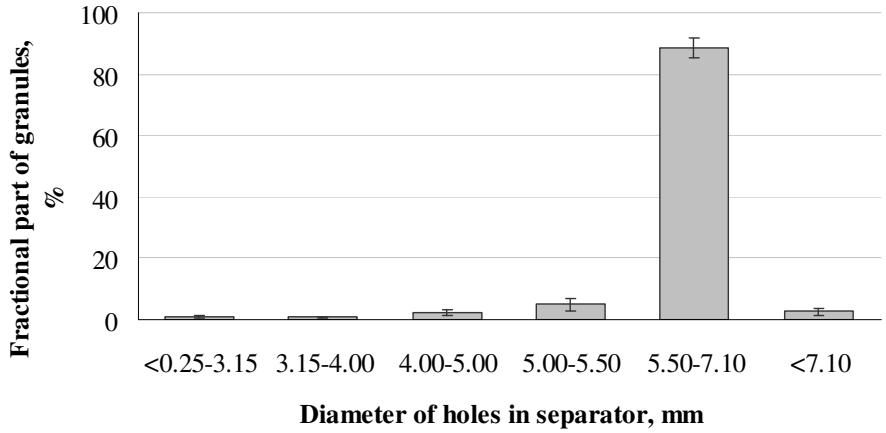


Fig. 2. **Fraction part (%) of granules (diameter – 6 mm) dependence on separator holes diameter (mm)**

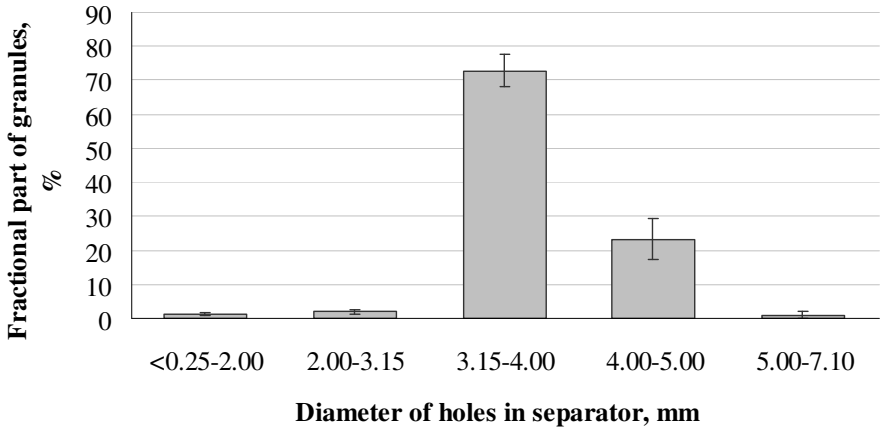


Fig. 3. **Fraction part (%) of granules (diameter - 4 mm) dependence on separator holes diameter (mm)**

The dynamic coefficient of friction was determined depending on the pellet mass velocity on the steel friction surface. The results of the studies showed that the dynamic friction coefficient tends to decrease. For the steel friction surface the granular dynamic friction coefficient numerical value of the considered velocity range respectively changed from 0.67 to 0.45 (Fig. 4.)

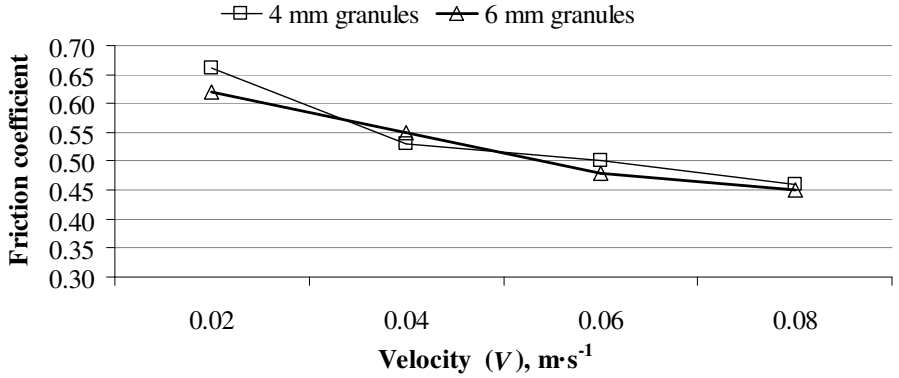


Fig. 4. **Dependence of the granule dynamic friction coefficient (f_t) on the velocity (V), when the friction surface is steel**

The dynamic friction coefficient is directly related to the slope angle of the friction surface which is characteristic to technological machinery, such as dispensers, storage tanks, transportation and handling chutes, etc.

The theoretical study of the granulation process showed that the pelletizer operating mode is strongly influenced by the granulated material rheological properties.

Granulator main working mode selection, material compression and speed modes define the process energetic and resulting production qualitative indicators.

Time, which the granulated material is under a load in the matrix channel, has the greatest impact on the desired density pellet quality. Potential energy accumulates while compacting bulk materials and when the load of the pellet ceases to exist elastic deformation in the pellet is beginning to show its signs. For these relaxation process consequences lowering, granulated compost holding in a compressed state time is needed, which depends on the matrix channel length and granulation speed. Otherwise, surface cracks appear during the granule transversal elastic deformation on the lateral cylindrical surface, because the relaxation process is not over yet. The pellets are produced friable, and do not meet the agro-technical requirements.

Lateral expansion is not possible while extruding powdery organic material in the matrix channel, therefore, any increase in the granule pressure in one direction causes a proportional increase in the pressure to the matrix channel wall. Because lateral pressure on the channel wall increase in pressure appears, and in the result pellets are forming. The matrix channel layout size depends on the longitudinal and transverse pressure distribution character.

When the matrix channel length shortens, the granulated material time in it also shortens. In this case in the formed granules throughout the volume it does not have time to end stress in granule reaction.

When pellets spend shorter time in the matrix channel, their fragility increases. This phenomenon can be explained by the fact that when leaving the matrix channel, the extruded material is exposed to volumetric stress and because of that it relaxes. Cracks appear in the granule, surface roughness increases on the side of the granule and strength decreases. When the length of the matrix channel increases, the pellet qualitative indicators are improving, but the energy costs increase in order to overcome the friction forces, because the matrix material shunt channel area gets larger.

The relaxation process takes place when granules pass through the matrix channel calibrating part. When leaving the channel matrix pellets are monolithically durable and have compacted peripheral layer.

Conclusions

1. Grinded bulk beef cattle manure compost is a high quality organic fertilizer. It can be the raw material for other organic and organic mineral fertilizer production.
2. When pelleting recycled pure compost it is possible to fully preserve its nutritional potential for plants, significantly reduce the fertilizer quantity in the fertilization process and reduce the cost of storage, handling, transportation, by injection into the soil.
3. The material prepared for the granulation process physical-mechanical properties, the qualitative composition of the mixture and extruding pressure have big influence on the compost pellet physical-mechanical properties.
4. The research results of the determined dynamic coefficient of friction showed that for the steel friction surface the granular dynamic friction coefficient numerical values of the considered velocity range respectively changed from 0.67 to 0.45.
5. When investigating granular organic fertilizer granulometric content it was found that when was used 6 mm diameter matrix channel for compost fertilizer granules production were dominated 5.5-7.1 mm fractional part (88.4 %) of granules, when was used 4 mm diameter matrix channel were dominated 3.15-4.0 mm fractional part (73.0 %) of granules.

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