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Investigation of the influence of humidity during granulation of organomineral fertilizer based on poultry manure

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Abstract

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The process of granulation of organomineral fertilizer, created on the basis of poultry manure, with a horizontal flat matrix, was investigated. The influence of the humidity of the organomineral fertilizer on the studied parameters of the granulation process was determined: the power consumption, output of the granulation machine, the specific energy consumption and PDI. The optimal humidity of the organomineral fertilizer is determined, at which the granulation process proceeds with lower energy consumption. We have obtained granules having a diameter of 6 mm and strength of the granules 95-96%, which are suitable for mechanical fertilization.

Keywords: granulation; organomineral fertilizer; horizontal flat matrix; humidity of organomineral fertilizer; power consumption; productivity; specific energy consumption; PDI

Introduction

With the chemicalisation of agriculture over the last three decades, the use of organic fertilizers based on poultry manure has become particularly relevant. They contain a balanced composition of the main components and trace elements, which rapidly dissolve in water and are absorbed easily. They contain significant amounts of beneficial microorganisms and biologically active substances that enrich the soil microflora (Markov et al., 2007). All this has a beneficial effect on the plants, contributes to increasing crop yields and improving soil structure and its fertility. Maintain a favorable balance of humus, create a beneficial reaction of the soil solution and eliminate excess acidity, bring nutrient stocks to an optimal level (Kuncheva & Dimitrov, 2015).

Organic mineral fertilizer based on bird manure has a number of advantages over mineral and organic fertilizers. The minerals in them ensure their fast action, and the organic ones supply the plants with nutrients throughout the growing season (Mitrovska et al., 2009; Enakiev et al., 2016).

Each year, around 1 million tons of poultry manure is produced in Bulgaria. It is a valuable product of the poultry, rich in nutrients and biologically active stimulators for growth of plants. Avian fertilizer contains 3-4 times more nitrogen, 3 times more phosphorus and 2 times more potassium compared to fertilizer from other farm animals (Assenov et al., 2011).

There are many proposals with various economic justifications for the utilization and processing of poultry manure in biogas, electricity, fuel briquettes, feed additives, California worm cultivation, burning, fertilizer production and more. One of these numerous proposals for the disposal of waste products existing in poultry farms is the production of organic mineral fertilizers (Komitov & Kehayov, 2016b). The granule

as a source of concentrated nutrients in the soil acts for an extended period of time. The granular fertilizer stimulates the development of soil microflora and enhances mobility of the nutrients from the soil compound (Beloev et al., 2011a, 2015). Along with the full spectrum of mineral elements in the soil, organic substances rich in humus-like substances are imported, which stabilize the long-term fertility of the soil (Komitov & Kehayov, 2016a; Kehayov & Komitov, 2017).

Granulation of organic fertilizer is necessary to allow the resulting fertilizer to be introduced into the soil mechanically, as existing means of mechanization do not allow it to be introduced into the soil in a loose and powder-like state (Todorov & Assenov, 2008a; Assenov & Todorov, 2008b). In addition, the volume of fertilizer decreases, allowing it to be stored in smaller areas and the cost of transportation reduced. In granulation, the physico-chemical composition does not change and the fertilizer retains its properties for a longer period of time (Gadjalska et al., 2014, 2015).

Materials and Methods

One of the essential factors that determine the granulation mode is the humidity of the material. The amount of moisture that must be added to the starting material during granulation depends on the type of material, its equilibrium moisture, its absorption capabilities, the pressure of the working bodies, the temperature of the working process and the particle size of the material (Kuncheva & Dimitrov, 2015).

The humidity of the granular material significantly affects the energy consumption for the granulation process and the quality of the obtained granules. Depending on its physical state, water acts as a plasticizer and a binder, which helps to bring the particles together and form the corresponding bonds. The contact time of the particles with the moisture determines the type of bond and is one of the main factors in the process of granule formation. In order for the granulation process to proceed better, it is necessary for the contact duration to be minimal in order for capillary condensation of moisture and particle growth to take place. The duration of capillary condensation is determined by the physical and mechanical properties of the material, namely: moisture absorption, physical condition and temperature (Beloev et al., 2011b; Enakiev et al., 2018).

The duration of the contact of the particles with the moisture starts from the moment of mixing the material with the water and is formed by the time for transporting the material and the time of its supply to the granulating chamber. In order to obtain quality granules and to reduce the energy consumption during granulation, the duration of interaction of moisture with the particles of the material must be minimal.

Not only the absolute amount of water is important, but also the condition in which it is. The strength of the granules obtained by wetting the material before granulation is greater than the strength of the granules, which are made of dry material. In addition, when granulating dry material (with an equilibrium humidity of about 8-10%), the separation of this moisture from the capillaries requires a significant energy consumption due to the higher load on the pressing roller (Markov et al., 2007; Enakiev et al., 2010).

The main requirement for wetting is the occurrence and action of adhesion forces between the particles of the material. The particle that is moistened needs to be coated with water molecules for a minimum period of time. Penetration of water into the particle itself (adsorption) is undesirable, because when the particle swells, it is more difficult to granulate, i.e. water acts as a "wedge" body. For this it is necessary to moisten the material immediately before feeding it to the granulation chamber.

The granulation process proceeds with lower energy consumption and higher productivity of the granulating machine at a specific humidity of the material, called optimal humidity w_{opt}. At this humidity, the compaction of the material is the easiest, which means that energy consumption is minimal. At lower humidity of the material than w_{opt} it is not enough to show a lubricating effect of water in the channel of the matrix. At higher humidity than w_{opt}, the water fills the pores of the material and because it is practically incompressible, it prevents granulation. The compacted material at this humidity is more brittle, i.e. has less strength (Todorov & Assenov, 2008; Enakiev et al., 2017).

The produced granules have relatively high humidity, which is less than the humidity of the granulated material. The granules are brittle, fragile, and easily damaged. Manipulating with them is practically impossible, and their accumulation in piles is inexpedient. For this, it is necessary to dry them, which removes excess moisture and eliminates residual stresses in the pellet.

When the surface of the granule is dried, a thin cover is formed which protects the granule from mechanical action and the penetration of water and air. The surface of the granule rapidly loses moisture; the capillaries shrink, dry and lose their elasticity (Assenov & Enakiev, 2012).

The purpose of the study is to determine the effect of humidity of organomineral fertilizer created on the basis of poultry manure on the quality and energy performance of the pelletizing process with a horizontal flat matrix.

Granulating machine

Horizontal flat matrix granulating machines for extruding bulk materials have been widely used in recent years. It

is due to the fact that they operate at relatively low power consumption, and the replacement of the matrix and the adjustment of the gap between the die and the rollers is carried out quickly and easily (Enakiev et al., 2016).

The joint scientific team of ISSAPP „Nikola Poushkarov" and the company „Bimeta DID" Ltd. has determined the basic design parameters of a pelletizing machine in which the pelletizing process is performed with minimal specific energy consumption. For this purpose, preliminary experiments were conducted. The study of the granulation process was carried out in the laboratory of the Institute of ISSAPP "N. Poushkarov".

For carrying out the experimental studies, a pelletizing machine was used, working on the principle of compression through a horizontal flat matrix with a pressure roller, which was developed by the company Bimeta DID Ltd. (Figure 1).

Fig. 1. Horizontal flat matrix granulation machine for pressing bulk materials

Granulating machine consists of frame, fitted in reducer motor, feed hopper and housing, which houses two pressure rollers and a matrix, Drive shaft and blade for cutting granules. For the experiments, a three-phase active and reactive power meter "Vektor" was used. The operating principle is: gear motor transmits torque to the drive shaft, which in turn rotates the matrix. It drives a pair of pressure rollers which, due to their grooved surface and friction forces, rotate about their axes.

The material comes from the hopper and fills the granulation chamber. Press rollers grip the material and feed it to the groove of the die. Rollers pumped material being compressed passes through the channels of the matrix and out of the lower part in the form of granules, which are cut off by means of built-in cutter and discharged through a chute into a collecting vessel (Figure 1).

Table 1 shows the technical characteristics of a horizontal flat matrix pelletizing machine.

Table 1. Technical characteristics of the horizontal flat matrix granulating machine

Type of granulating machine	With horizontal flat matrix
Power	7.5 kW
Productivity	150-200 kg/h
Type of press rolls	Cylindrical
Number of rollers	2
The diameter of the channels of the matrices	6 mm
Diameter of the inlet of the feeder part of the channels of the matrix	8 mm
Angle of the conical misleading part of the channels of the matrix	30°
Weight	230 kg

Data processing and analysis of the obtained results were performed according to developed and approved methodologies of ISSAPP "N. Poushkarov" (Enakiev, 2013).

The strength properties of granular organomineral fertilizer are determined by their resistance to destruction and crushing. The criterion for the strength of the granules is the percentage of the mass of the whole granules from the total mass of granules rotated in a drum of precisely defined dimensions. A methodology for assessing the strength of the obtained granules was developed by the American Association of Agro- and Bioengineers (ASABE) and introduced as standard S 269.4/1991 (ISO 17831-1).

The experiments were performed with three replicates. The average particle size of the fertilizer for granulation was 1.55 mm.

Measuring equipment:

1. Three-phase electricity meter for active and reactive power "Vektor".
2. Ammeter.
3. Electronic scale with range 0 – 6000 g and accuracy 0.1 g.
4. "UMLAUFE" tachometer.
5. Mechanical stopwatch with an accuracy of 0.1 sec.
6. Industrial scale with range 0 – 100 kg and accuracy 0.05 kg.
7. Set of sieves.
8. Dryer.
9. Beaker.

Results and Analysis

Preliminary experiments were performed to establish the limits of variation of the moisture content of the organomineral fertilizer before the planned experiment. In them the studied factor is changed in a wide range. From the preliminary experiments it was found that the process of granulation of organomineral fertilizer with the granulating machine with a horizontal flat matrix proceeds stably at humidity of the fertilizer for granulation – from 25% to 33%. At lower humidity of the material, there is a danger of sealing (or clogging) of the channels of the matrix, which leads to stopping the granulation process. At humidity of the material over 33%, it sticks to the working bodies, which leads to uneven supply to the granulating chamber. As a result, productivity is reduced and the specific energy consumption is significantly increased.

A production experiment was conducted in which 300 kg of granular organomineral fertilizer with a flat horizontal matrix were produced. The influence of the humidity of the organomineral fertilizer on the studied parameters of the granulation process was determined: power consumption, the performance of the pelletizing machine, the specific energy consumption and strength of the granules obtained.

In Figure 2 the influence of the humidity of the fertilizer on the power consumption of the pelletizing machine is shown. With the increase in the humidity of the organic fertilizer from 25 to 33%, the power consumption of the machine decreases from 8.25 kW to 4.3 kW.

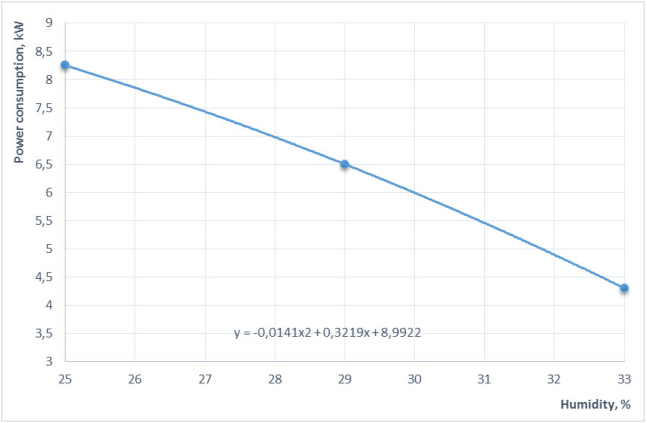

Fig. 2. Effect of humidity of the organomineral fertilizer on power consumption

This is explained by the fact that the higher humidity of the material up to 33% increases lubricating ability of the material. This effect reduces the friction on the walls of the ducts of the matrix and consequently reduces the required power for the process. Power consumption for the process reaches its minimum value – 4.3 kW, with a material humidity of 33%.

In Figure 3 the effect of the humidity of the fertilizer on the performance of the pelletizing machine is shown. By increasing the humidity of the organic fertilizer from 25 to 33%, the productivity of the pelletizing machine decreases from 199 kg/h to 154.3 kg/h. The maximum productivity of a pelletizing machine is 199 kg/h with a material humidity of 25%.

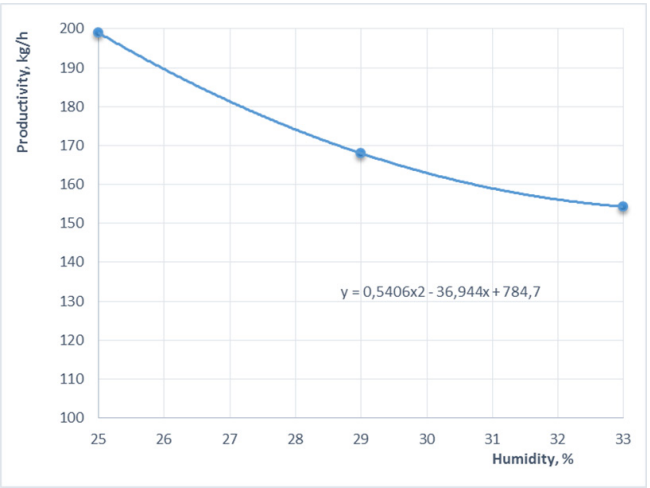

Fig. 3. Effect of humidity of organomineral fertilizer on the performance of a pelletizing machine

In Figure 4 the influence of the humidity of the fertilizer on the specific energy consumption of the pelletizing machine is shown.

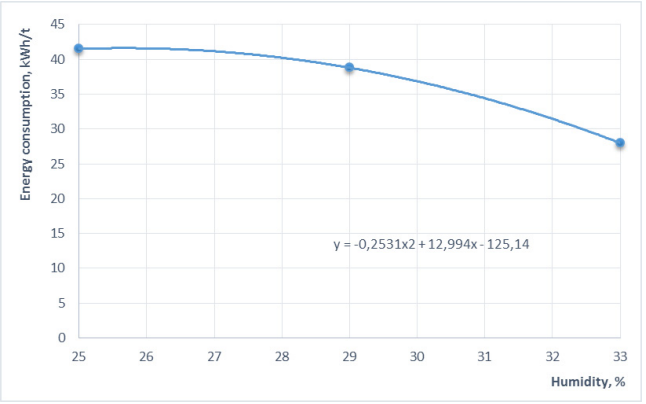

Fig. 4. Effect of humidity of the organomineral fertilizer on the specific energy consumption of the pelletizing machine

With the increase in humidity of the fertilizer from 25 to 33%, the specific energy consumption decreases from 41.5 kWh t to 28 kWh/t. This is mainly due to the fact that the friction in the ducts of the matrix is reduced, which results in a significant reduction in the power consumption of the process with a slight decrease in productivity. This in turn contributes to the reduction of specific energy consumption.

By increasing the humidity of the organic fertilizer from 25 to 33%, the productivity of the pelletizing machine decreases from 199 kg/h to 154.3 kg/h, which equals 22% in relative units. In addition, the power consumption of the machine is reduced from 8.25 kW to 4.3 kW, representing 48%. It is this difference that leads to a reduction in the specific energy consumption of the pelletizing machine, which is a percentage of 33%.

In Figure 5 the effect of the humidity of the fertilizer on the strength of the granules obtained is shown.

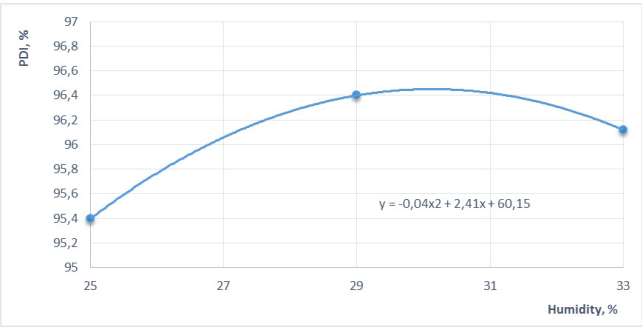

Fig. 5. Effect of humidity of organomineral fertilizer on the strength of the granules obtained

With the increase of organomineral fertilizer humidity from 25 to 29%, the strength of the obtained granules increases from 95.4% and reaches its maximum of 96.4%, and the next material humidity range from 29% to 33% decreases to 96.1 %. The results show that in the investigated area of change of humidity of the organic-mineral fertilizer the pellet strength over 90% was achieved, which completely fulfills the condition for obtaining pellets, which are suitable for mechanized soil application.

In Figure 6 shows a granulated organomineral fertilizer created on the basis of a bird's fertilizer with a horizontal flat matrix.

The obtained organomineral fertilizer in granular form was analyzed to determine its agrochemical value. The macronutrient content in 1 ton of organomineral fertilizer is 14 kg/t nitrogen, 7 kg/t phosphorus and 5 kg/t potassium. These elements are in organic form and mineralization is carried out gradually, without any risk of soil and crop contamination.

Fig. 6. Granular organomineral fertilizer created on the base of bird manure

Conclusion

The process of granulation of organomineral fertilizer created on the basis of poultry manure by pressing through a horizontal flat matrix with a pressure roller is investigated.

The granule acts as a source of concentrated nutrients in the soil for a long period of time. Granular organomineral fertilizer stimulates the development of soil microflora and enhances the mobility of nutrients from soil compounds.

The effect of fertilizer humidity in the region of change from 25 to 33% of the studied parameters was investigated when granulating with a horizontal flat matrix with a pressure roller. The lowest specific energy consumption – 28 kWh/t and the minimum consumed power for the process – 4.3 kW were obtained with humidity of the organic fertilizer – 33%. The highest productivity – 199 kg/h was obtained with a humidity of the fertilizer – 25%, and the maximum strength of the granules – 96.4% was obtained in the humidity of the organic fertilizer – 29%.

In the studied area of change in humidity, granules with a diameter of 6 mm and granule strength in the range of 95.4% to 96.4% were obtained, which fulfills the condition for obtaining granules that are suitable for mechanized introduction into the soil.

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