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Innovative Soil Liming and Fertilizer Means Production Technology

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Abstract

In addition to numerous factors, organic waste has a significant impact on increasing environmental pollution, which is an imperative for its solution. The goal of the work was to use the by-products of biogas production plants and cogeneration plants for soil fertilization, which allows to create a new innovative product from their mixtures. The preparation of the best mixtures applied and evaluated in greenhouses under production conditions was carried out at the companies JSC "Ziedi JP" and "Pampali". The production scheme of soil liming and fertilizer was developed and approved at both companies. The effectiveness of the composition of the mixtures was first tested on soils of different acidity in a greenhouse. The set of machines and aggregates required for the preparation and spreading of the new type of fertilizer on the field was made. Digestate, after complete development in bioreactors, is fed to the mechanical screw press separator, where it is divided into solid (dry matter 25 %<) and liquid (dry matter 3%>) fraction. The digestate of solid fractions is mixed with wood ash in portions in a screw-type mixer equipped with electronic scales. The ingredients are poured in parts so that the mixer mixes a uniform mass. After mixing, the new fertilizer is discharged from the mixer onto a conveyor belt and then into a pile, which is covered with a cover to reduce ammonium emissions. The use of the innovative soil fertility enhancer can be an effective way of recycling both products and can also be an environmentally friendly alternative to mineral fertilizers.

Keywords: digestate, wood ash, mixtures

1. Introduction

Anaerobic digestion and biogas production plants are considered the center of the circular economy, where anthropogenic organic residues previously considered as waste can be converted into energy, organic fertilizers and other value-added components and materials (Adekunle et al., 2019).

The post-fermentation residue is called digestate and spreading the digestate on fields is a common practice in agricultural enterprises. Digestate spreading norms in nitrate-sensitive areas are limited to 170 kg N ha-1 per year. (Commission of the European Communities, 1991). Phosphorus spreading norms are not directly included in the Nitrates Directive, but many European countries have different phosphate spreading limits. Depending on the species of cultivated plants, the amount of phosphorus in the soil, and other variable factors, its spread is in the range of 0 - 250 kg P2O5 ha-1 per year (Amery et al., 2014). If there are already enough nutrients in the soil, but the amount of digestate is more than necessary, it may be necessary to transport the digestate to further fields. Long transport distances justify economic investments in mechanical separation of the digestate. During separation, the digestate is divided into solid and liquid fractions. Sometimes the liquid fraction still contains high solids (up to 10% dry matter) and the solid fraction still has high moisture (15-45% dry matter) (Guilayn et al., 2019). Dividing the digestate into fractions allows to reduce the moisture content in the solid fraction, thereby reducing the costs of transporting and storing the solid fraction. The liquid fraction is easy to pump and can be easily incorporated directly into the soil in the fields, thus significantly reducing nitrogen losses (Fuchs et al., 2013).

In the mechanical separation of digestate, nitrogen usually remains more in the liquid fraction, while phosphorus and potassium remain in the solid fraction. This leads to better nutrient management (Möller et al., 2012).

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Burning woody biomass for energy is of interest to many countries as they want to reduce their consumption and dependence on fossil fuels (Perkiomaki et al., 2005). Wood-fired cogeneration plants and other biomass-fired boiler houses generate more and more ash. Ash in wood cogeneration plants is a by-product (Silva, 2018). Wood ash consists of inorganic compounds from burned biomass, sand and very small, incompletely burned organic parts (Ingerslev, 2011). As a by-product of burning wood, phosphorus (P), potassium (K) is retained in the ash, but most of the nitrogen (N) is lost during combustion in the form of NOx compounds, while the remaining N is strongly associated with organic, unburned residues and is in a non-absorbable form for microorganisms. During the combustion of biomass, various oxides are formed and the subsequent aeration leads to the formation of carbonates in the wood ash, making the ash very alkaline with a pH of 8 to 13 (Augusto, 2008). If the ash is not disposed of in landfills, but processed into plant fertilizers, all the ash is returned to the soil existing nutrients, and the pH of the soil is increased (Pittman, 2006).

The aim of this research was (I) to create a technology to prepare an innovative fertilizer using two production by-products, biogas post-fermentation digestate and biomass cogeneration ash, (II) determine the efficiency of novel mixture fertilizer creation by available agricultural tools on the experimental farm

2. Materials and Methods

The initial stage of the research is to check the chemical composition of the digestate and wood ash of different origins. Wood ash was mixed with digestate according to certain proportions, which are based on laboratory studies guided by the chemical composition of the raw materials.

The preparation of the best mixtures applyed and evaluated in greenhouses under production conditions was carried out at the companies JSC "Ziedi JP" and "Pampali" in Latvia. The production scheme of soil liming and fertilizer was developed and approved at both companies. The effectiveness of the composition of the mixtures was first tested on soils of different acidity in a greenhouse, using fast-growing plant species lettuce and cucumber. The set of machines and aggregates required for the preparation and spreading of the new type of fertilizer on the field was made.

Biogas post-fermentation digestate from cattle dung obtained by JSC "Ziedi JP" and "Pampali" was used for the experiments. Digestates were separated into solid and liquid fractions before preparing the new fertilizer mixtures. Wood ash from the cogeneration stations of LLC "Gren Jelgava" and LLC "Dobeles Eko" was used for the experiments analyses. The characteristics of solid fractions of separated digestates and wood ash are presented in Table 1.

TABLE 1 THE RESEARCH USED THE COMPOSITION OF DIGESTATE AND WOOD ASH

Indicators	Cattle manure digestate		Wood ash	
	From JCS "Ziedi JP"	*From JCS "Pampali'*	*Table column subhead*	*From JCS "Ziedi JP"*
Moisture, %	74.3	76.7	0.16	0.14
Total nitrogen, %	0.57	0.48	0.00	0.00
Total phosphor, %	0.46	0.53	3.50	3.46
Total potassium, %	1.24	1.47	11.6	8.52
pH	9.05	9.03	13.9	13.5

The content of macronutrients and heavy metals was also tested using standard methods and analyzed. The macronutrient content of the soil was also tested The tests were carried out before and after the use of the digestate. The analyzes were carried out by the Latvia University of Life Sciences and Technologies Biotechnology Scientific Laboratory (LBTU BZL).

3. Results and discussion

So far, only a few studies have been conducted to mix biogas digestate with wood ash in a specific ratio.

To prepare the new fertilizer from biogas digestate and wood ash, the equipment available on farms was used. After the correct technology, the number of days the digestate is kept in fermenters is long enough so that the digestate is fully developed and, leaving the post-fermentation, biogas is no longer released or comes close to it. An innovative technological scheme for the preparation of digestate and wood ash mixtures is shown in Fig. 1.

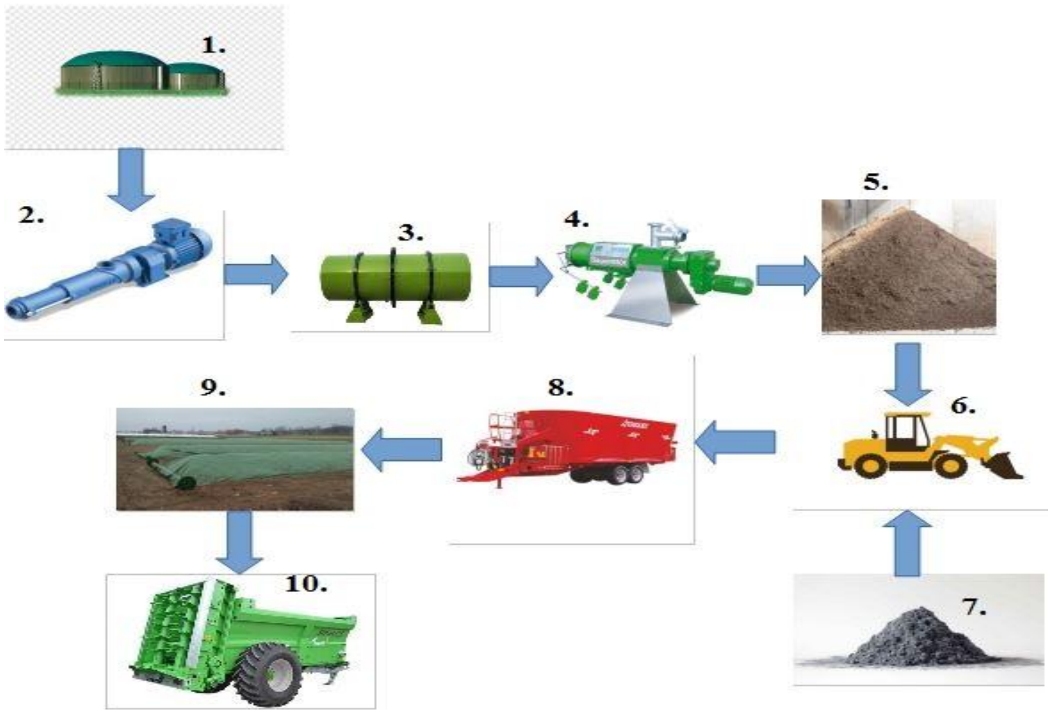

Fig. 1. Scheme of the new fertilizer preparation technology, where 1. Biogas fermenters; 2. Digestate pump; 3. Digestate intermediate storage; 4. Separation of digestate into fractions; 5. Digestate solid fraction storage; 6. Digestate and ash loading; 7. Ash storage; 8. Mixing machine Trioliet with scales and tractor; 9. Application of mixed fertilizer in stirring and covering; 10. Spreading the new fertilizer on the field.

The post-fermentation digestate, which has a dry matter content of up to 7.5%, is pumped with a VANGEN screw-type pump. Pumping takes place through a 150 mm pipeline for optimal digestate flow. The digestate is pumped to the 10m3 intermediate storage of the digestate separator. The buffer acts as a buffer to ensure a steady and continuous supply of digestate to the separator, as well as to prevent the siphon effect. The liquid manure separator EYS SP600 operates in continuous operation mode, as it is equipped with a liquid digestate intermediate storage in a volume of 10 m3, which is always in level.

A single-stage sieve with a holes size of 0.75 mm was used in the separator. After separation, the liquid fraction of the digestate, in order not to consume additional energy, flows to the liquid digestate storage. In the liquid fraction, the dry matter content remains within 2%, because they are particles with a size smaller than 0.75 mm and the separator sieve cannot retain them. The solid fraction of the digestate from the separator falls into a warehouse created under the separator room, so that the digestate is sheltered and easily collected. This is necessary so that in the event of precipitation, another fraction of the digestate does not change the dry matter content, which after separation is 25.7%.

After separation, the solid fraction of the digestate was loaded into the Trioliet mixing machine with the bucket of the front loader. The mixing machine is equipped with electronic scales so that it is possible to observe the proportions of the mixture. The Trioliet mixing machine used is equipped with 3 augers, placed 1 meter apart from each other, which ensure uniform mixing of the ingredients throughout the volume. It is possible to prepare 8 t of mixture in each mixing portion of the new fertilizer. The agitator is driven by gimbal transmission from the tractor PTO. A 130 PS John Deere 6430 is used to drive the PTO. Digestate with wood ash should be added to the mixer alternately to make the mixture faster. After filling the entire preparation dose of fertilizer into the mixer, the mixing process takes place for 15 minutes. The operator carefully watches the process to ensure that the ingredients are thoroughly mixed. During the mixing process, the operator uses personal protective equipment to protect himself from physico-chemical damage.

After mixing, the new fertilizer is discharged from the mixer into the stirrups with the help of an integrated conveyor. The height and width of the stirrups are designed in such a way that the maximum bevel angle is formed. The stirrups are quickly covered with a gas-tight cover to delay ammonia emissions. The pH of the new fertilizer is 11.5, so nitrogen release is rapid. Due to the high pH, the resulting mixture neutralizes the microorganisms present in the digestate. Without a long wait, the mixed mixture is loaded into the JOSKIN manure spreader with the front loader. The spreader is equipped with accurate dosing of fertilizer from the tractor cab and also has its own scales. Spreading width is 24m. The basic elements of the technology are visually shown in Fig. 2.

Preparation of raw materials for mixtures - digestate and wood ash, using front loader JCB 434S.

Loading the raw materials of the mixtures into the mixer.

Mixing raw materials of mixtures in a mixer.

Unloading the digestate and wood ash mixture mixed in certain proportions from the mixer.

Loading prepared means for improving soil fertility into transport.

Spreading of digestate and wood ash mixture on the field.

Fig.2. Production technology of soil liming and fertilizer (some elements of technology).

To prevent the fertilizer from compacting after transportation to the fields, the spreader has 2 auger conveyors and a conveyor belt.

4. Conclusions

Wood ash is a by-product from biomass cogeneration plants and boiler houses, while digestate is a by-product from biogas plants. Together, this is a valuable mixture of nutrients that add value to production by-products. Wood ash is produced by burning wood, while digestate is produced in the biogas fermentation process. The choice of such fertilizer raw materials is based on solving the problems related to reducing waste accumulation and more efficient use of existing resources. As a result, the benefit is not only from the environmental aspect, but also from the operation of farms in the circular circulation economy or bringing them closer to working in accordance with the environment.

The rational use of such by-products was realized by the application of the used technology.

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