Study of the possibility of using meat and bone meal ash for the production of granular fertilizers

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Propagated and implemented in practice the idea of sustainable development promotes a sustainable and eco-friendly model of waste management. Waste are generated in various branches of the economy, which should be managed in accordance with the applicable legal regulations. Particularly due to the increasingly loud request for a sustainable development, this waste should be treated as a source of raw materials for the production of new, fully valuable products. The forecasts developed at the end of the last century indicate that over 50% of the phosphorus resources currently used in the world will be consumed in the next 60-70 years, which will undoubtedly contribute to the growth of market prices of phosphorous products, and also to their deficit over time (Jasinski, 2018). Due to the gradual depletion of phosphorus raw materials and the increase in the demand for phosphate fertilizers, the search for new, alternative sources of this raw material has begun. In addition to the progressive depletion of these deposits, the concern of the European Union to introduce restrictive regulations limiting the permissible content of cadmium in phosphate fertilizers is also worrying (Chaney 2012, Roberts 2014). In view of the prospect of limiting the access to phosphoric raw materials from which fertilizers comply with the provisions of fertilizer law. In accordance with the principles of sustainable development, the search for substitute sources of phosphorus, and in particular the possibility of recycling from waste, should be included among the priority issues of the phosphorus industry. One of the potential sources of phosphorus, apart from municipal and industrial wastewater and sewage sludge, is meat industry waste (Coutand et al., 2008).The possibility of using ashes generated by the thermal utilization of such waste as meat and bone meal was assessed as a potential phosphoric raw material that can be used in the production of phosphate fertilizers.

The following raw materials were used for laboratory and semi-technical tests of fertilizer production:

- ash from the burning of meat and bone meal (MBMA),
- dried phosphate sludge from the production of food phosphates,
- sulfuric acid,
- ammonium sulfate,
- potassium sulfate
- potassium salt,
- dolomite,
- magnesium sludge from the production of magnesium sulfate,
- bentonite.

Table 1 Analyses of the main components of meat and bone meal ash.

Total wt%	P_2O_5	$P_2O_{5\,(ws+c)}$	$P_2O_{5\,(ws)}$	K_2O	MgO	CaO	SO_4	Fe_2O_3	Al_2O_3	Na_2O	H_2O
MBMA	27.60	2.93	0.12	2.80	0.89	45.14	0.86	1.44	0.50	3.91	1.44

Table 2. Heavy metal content analyses of meat and bone meal ash (by ICP-OES and CV-AAS).

Total mg/kg	As	Cd	Pb	Hg
MBMA	0.70	0.11	0.12	0.003

The ash from meat and bone meal used in the research is very similar to regular phosphate rock in terms of its chemical composition. Also the content of heavy metal is very low, as can be seen in Table 2.

MBMA has a chemical composition similar to hydroxyapatite, i.e. it contains hardly available phosphorus for plants. In order to process the insoluble form of phosphates contained in the ash in the form easy absorbed by plants (mono and dicalcium phosphates), it is necessary to conduct the reaction of ash with sulfuric acid as it is in the manufacture of single supherphosphate according to the equation:

$$2Ca_5OH(PO_4)_3 + 7H_2SO_4 \rightarrow 3Ca(H_2PO_4)_2 + 7CaSO_4 + 2H_2O$$

For the manufacture of single superphosphate, the theoretical wetting is calculated from the chemical composition of the ore and the empirical formula below (Hakam et al. 2012):

$$M = 1.75\%\ CaO + 2.46\%\ MgO + 1.58\%Na_2O + 1.22\%\ Fe_2O_3 + 1.92\%\ Al_2O_3 – 0.69\%\ P_2O_5 – 1.22\%\ SO_3 – 1.55\%\ F$$

Where M is the amount of H_2SO_4 in grams necessary for the -decomposition of 100 g of phosphorites.

Based on the stoichiometry of the above reaction, it was assumed that the weight ratio of ash to sulfuric acid in the decomposition process will be 1:0.7, and the product will have a chemical composition similar to single superphosphate.

In the course of these tests, several laboratory tests were carried out. Initially the ash was mixed with the acid periodically (ash in the tray was flooded with a 65.5% concentration of hot sulfuric acid at 70-80°C and then thoroughly mixed), the temperature of the mixture during this operation increased above 100°C and the release was observed significant amounts off-gases with an unpleasant odor, which also indicated difficulties in the development of ash processing technology. The residence time to cool the mix in the tray was about 2 hours. the next two tests were carried out continuously in a set of devices (sulfuric acid dosing system, ash dosing system, pug mill). During the continuously test, as before, there is still a large amount off-gases, the main component of which is hydrogen sulfide, but the emission is not so intense and it could probably be mastered by the absorption node. The temperature of superphosphate falling out of the mixer remained at 30ºC. In this way, processed MBMA after milling was used to prepare powdery fertilizer mixtures, which were then granulated on the semi-technical plant of INS. The results of chemical analyzes of meat and bone meal based superphosphate (MBMA-SSP) are presented in Table 3.

Table 3. Analyses of the forms of phosphorous in the final products.

Total wt%	P_2O_5	$P_2O_{5\,(ws+c)}$	$P_2O_{5\,(ws)}$	H_2O	pH
MBMA – SSP (batch system)	18.60	15.21	12.20	7.9	3.1
MBMA-SSP (continuous system)	17.21	14.20	1.82	9.62	2.64

The analyzes show that the content of particular forms of phosphorus is not fundamentally different from each other in various ways of decomposing ash, which proves that the elevated temperature has little effect on the degree of ash decomposition.
The aim of this part of the research was to determine the effective method of production based on the aforementioned raw materials of multi-component fertilizers, type: PK (10-20) and NPK (4-9-20; 5-9-20; 6-10-20). Technological research on a semi-technical scale was carried out in the INS experimental installation, which includes a pug mill and pan granulator, a drum dryer, screens, and conveyor system and dosing equipment. Seven tests were carried out on the semi-technical scale. Six tests were performed at which the pan granulation was carried out using water and steam as the main granulation agent. The seventh trial was carried out on granulation node comprised of pug mill and pan granulators using the phosphate pulp as a granulating agent. For all obtained products, analyzes of compositions, physico-mechanical properties and derivatographic analyzes of DTA and TG, were carried out.

Conclusions

The conducted research confirmed the possibility of producing multi-component fertilizers with assumed compositions using ashes. In the proposed technological process of producing compound fertilizers, ash treatment with sulfuric acid is planned in order to increase the degree of phosphorus absorption in the product.
The proposed process of producing fertilizer with the use of MBMA, phosphate and magnesium sludge as a source of nutrients is an example of producing a full-value product from raw materials formed as a by-product in other processes. This way of proceeding is in line with the set trends both in the field of waste management and in the chemical industry, in which the aim is to minimize the generated waste and maximize the potential of by-products.
The conducted research extends the scope of knowledge about ash from meat and bone meal as a source of phosphorus for fertilizing purposes. The obtained results indicate the possibility of producing valuable multi-component fertilizers based on ashes with meat and bone meal. In the future, this type of waste may become a valuable phosphorous resource for producers of this type of fertilizers particularly that in the new draft of Fertilizers Regulations that type of phosphorous source is permitted to use to produce fertilizers.

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