Production of NPK-type mineral fertilizers from meat bone meal ash

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The agricultural sector is facing increasing challenges. These include dynamic global population growth, significant economic development, and an increasing standard of living. The current population is about 8 billion, and forecasts predict that in 2050 the world's population will be over 9.8 billion (United Nations, 2017). This results in a constant increase in food consumption and forecasts an intensely increasing demand for agricultural raw materials. With an ever-increasing population, it is estimated that there is an urgent need to increase food production by up to 70% by then (van Dijk et al., 2021). Therefore, it is necessary to increase the efficiency of agricultural production by increasing the level of fertilization. Due to population growth, urbanization or industrialization, this growth must be effective enough to compensate for the constantly decreasing area devoted to cultivation (Almutari, 2023).

Taking into account the geopolitical situation, high prices of fertilizers and the European Union's policy aimed at the sustainable use of key natural resources, the issue of replacing conventional fertilizers with alternative fertilizers is very topical. One of the wastes with fertilizing potential is the ash after burning meat and bone meal, which contains mainly calcium (33.8-36.6%) and phosphorus (14.5-15.0%), occurring in the form of hydroxyapatite (Krupa-Zuczek et al., 2010).

The aim of the study was manufacturing and characterization of NPK-type mineral fertilizers based on meat bone meal ash (MBMA). Five fertilizer formulations with a composition approximately 4-16-18 have been produced, which can be intended for all crops such as cereals, potatoes, sugar beets, as well as for cruciferous vegetables, spinach, cucumbers and lettuce. In order to obtain the appropriate NPK ratio in fertilizers, simple fertilizers (K_2SO_4, KNO_3, NH_4NO_3, $(NH_4)_2SO_4$, CH_4N_2O) were added to the fertilizer mixtures.

The obtained products were analysed for the content of main and secondary nutrients, micronutrients and heavy metals. Nutrient release tests and 2-week germination tests on cucumber seeds (*Cucumis sativus*) were also carried out.

The chemical characterization of fertilizers based on MBMA are presented in table 1. The content of N in fertilizers varied from 4.21% to 7.16%, which is a slightly higher than expected. Also in the case of phosphorus, fertilizers 1-4 were characterized by a slightly higher content of this element (17.4-18.7% P_2O_5) than assumed (14% P_2O_5). These differences result from the type of raw materials from which the fertilizers were produced. Due to this it was not possible to obtain exactly the same composition. The content of potassium in fertilizing products was in the range of 16.9-18.5% K_2O. Fertilizers were rich in calcium, which comes from meat bone meal ash. Taking into account the content of heavy metals in the fertilizers produced, it can be seen that they were at a similar level in each fertilizer produced. The content of Cr and Pb fulfilled the requirements according to (EU, 2019).

Table 1. Characterization of obtained fertilizers

		Fertilizers				
		1	2	3	4	5
Main nutrients	N (%)	7.16	6.22	6.90	4.21	5.56
	P_2O_5 (%)	18.7	17.7	18.0	17.4	16.1
	K_2O (%)	17.8	18.5	17.9	17.2	16.9
Secondary nutrients and micronutrients	Ca (%)	15.2	13.2	13.4	13.3	13.0
	Fe (mg/kg)	1664	1546	1592	1480	1371
	Mg (mg/kg)	4845	4481	4200	4750	4321
	Cu (mg/kg)	25.5	20.2	20.9	19.2	18.1
	Zn (mg/kg)	6.63	4.04	6.70	1.96	3.27
Heavy metals	Cd (mg/kg)	3.44	4.09	4.64	5.23	5.72
	Cr (mg/kg)	51.8	55.1	54.6	53.8	51.0
	Ni (mg/kg)	22.4	23.8	22.6	22.9	22.7
	Pb (mg/kg)	20.2	23.2	16.8	17.3	16.2

Table 2 presents the results of germination tests. In the case of PMMK and fertilizers 1-4, the number of sprouted plants was the same or slightly higher compared to the control sample. However, for fertilizer 5 this result

was much lower. Fertilizers 1-4 contributed to the greatest average length of the above-ground parts of cucumber. It was a 2-3 times increase compared to the control sample and ash from meat and bone meal. In the case of fertilizer 5, this parameter was the lowest (1.5 cm). The negative effect of fertilizer 5 on cucumber germination and growth may be related to the high content of sulphates in this fertilizer.

Table 2. The results of germination tests

Fertilizers	Average number of sprouted plants	Average length of the above-ground part of plants (cm)	Average wet weight of the above-ground parts of plants (g)	Average dry weight of the above-ground parts of plants (g)
Control	21	2.0	4.02	0.30
MBMA	24	2.6	5.87	0.43
1	23	6.4	9.60	0.63
2	20	4.8	5.53	0.48
3	21	5.3	7.73	0.58
4	24	5.0	6.53	0.60
5	8	1.5	0.80	0.13

Based on the results obtained, it was concluded that the ash after burning meat and bone meal is suitable for the production of fertilizers. Due to its high phosphorus content, it can successfully replace natural sources of phosphorus used in the fertilizer industry. The germination tests carried out showed a significant increase in the above-ground part of the plants compared to the control sample, which proves the positive effect of fertilizers produced using PMMK. The use of PMMK for the production of fertilizers would have a positive impact on the natural environment, thereby contributing to the reduction of the amount of landfilled waste.

These studies may be an introduction to further research on the production of fertilizers using PMMK as a phosphorus source. In the future, it is necessary to research the production of fertilizers on a larger scale and conduct field tests.

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