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Research article

Obtaining of granular fertilizers based on ashes from combustion of waste residues and ground bones using phosphorous solubilization by bacteria *Bacillus megaterium*

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ABSTRACT

The article presents research results on obtaining phosphorus granulated fertilizers on the basis of microbiologically activated sewage sludge ashes, ground bones and dried blood from meat industry. Granulation tests were carried out using a laboratory pan granulator as well as on an experimental pilot plant. The aim of the studies was to select the proper composition of the mixture of raw materials and binding agents to obtain granulated fertilizers from waste materials such as MSSA and MBM and bacteria lyophilisate. Obtained fertilizer samples were subjected to physical tests (granulation tests etc.) and quality assessment. The tests confirmed that it was possible to produce granulated phosphate fertilizers using the *Bacillus megaterium* for solubilization of phosphorus in a simple process.

1. Introduction

In last decades, consumption of fertilizers have been steadily growing (Fig. 1). This growth concerns all macronutrients (Fig. 2) (FAO, 2016). Phosphate rocks, which are the basic raw materials used in phosphorus fertilizers production, are non-renewable resources. That is why the necessity to recycle phosphorus for the further reuse is important issue for agro-industrial management and environmental control (Johir et al., 2016). Therefore, attempts to obtain phosphorous from renewable resources including wastes e.g. bone waste, fishbone, and ashes from biomass combustion from waste treatment plants became increasingly significant (Saeid et al., 2014; Stamford et al., 2008).

Nowadays, many studies focus on the phosphorus recovery from different waste materials like wastewater (Johir et al., 2016), swine slurries (Taddeo et al., 2016), sewage sludge and sewage sludge ashes (Herzel et al., 2016; Kalmykova and Fedje, 2013; Smol et al., 2016).

The application of fertilizers from sewage sludge ashes (SSA) to agricultural land is generally considered to be the good way to recycle phosphorus because they usually contain high amounts of P_2O_5. The phosphorus present in SSA exist in a water-insoluble form, mainly as iron, aluminum, and calcium phosphates, therefore it must be converted into an available form for plants.

SSA are widely used as a components for solid fertilizers production because their use for liquid fertilizes is problematic. Liquid fertilizers usually contain low amounts of P_2O_5 and are expensive because of the necessity of solids' separation from liquid phase. Suspension fertilizers based on SSA have also low content of P_2O_5 and are difficult to stabilize. In contrary to above, it is possible to produce granulated fertilizers based on SSA with a higher P_2O_5 concentration. In this case, drying of the final products is required. (Donatello and Cheeseman, 2013; Herzel et al., 2016; Rolewicz et al., 2016). Previous studies of phosphorus recovery from SSA were focused on acid or base leaching. According to these studies, acid leaching is more effective than base one (Kalmykova and Fedje, 2013; Ottosen et al., 2013). The use of sulfuric acid for phosphorus extraction is not always commercially preferable. The use of a strong acid leads to expenditures due to corrosion protection and the necessity of adding the substances to increase the pH value. With regard to above mentioned drawbacks, it is an interesting idea to conduct bioleaching process using microorganisms that produce organic or mineral acids (Chen et al., 2006; Khan et al., 2014). In particular, addition of microorganisms to soil leads to solubilization processes (Sharma et al., 2013).

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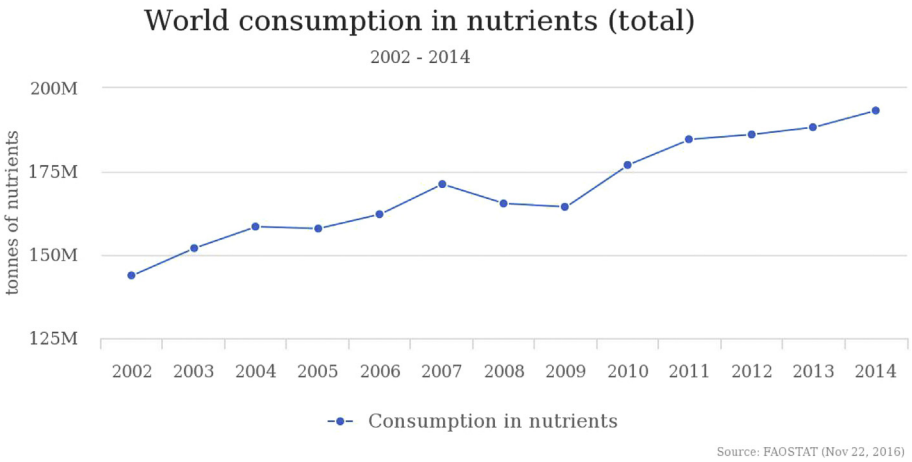

Fig. 1. World consumption in nutrients (total) in years 2002–2014 (FAO, 2016).

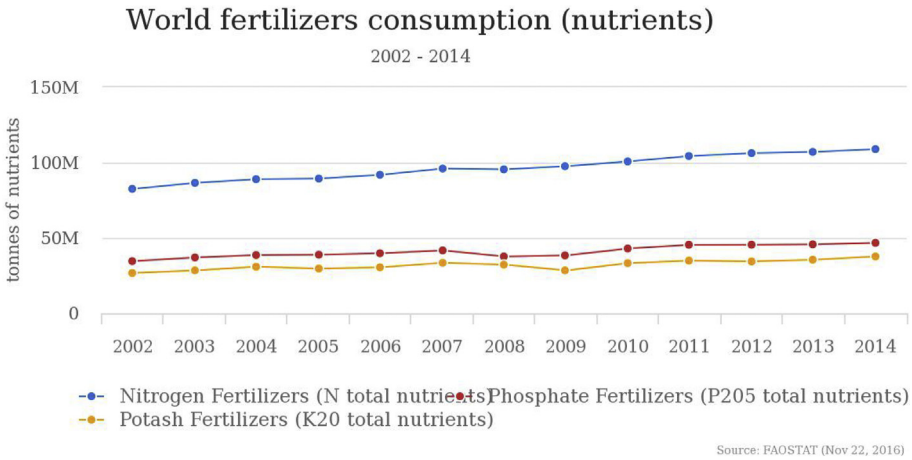

Fig. 2. World fertilizers consumption (nutrients) in years 2002–2014 (FAO, 2016).

One of the possibilities is the use of a natural ability of some microorganisms (bacteria and fungi) for solubilization of phosphates (Saeid et al., 2014). The insoluble forms of P such as tricalcium phosphate, aluminium phosphate, iron phosphate, etc. may be converted to soluble P by P-solubilizing organisms inhabiting different soil ecosystems. Soil microorganisms in this regard have generally been found more effective in making P available to plants from both inorganic and organic sources by solubilizing and mineralizing complex P compounds, respectively (Khan et al., 2014). The effectiveness of activation (solubilization) processes of phosphorus from mineral resources and different types of wastes, depends on numerous essential factors, i.e. the type of phosphorus raw material subjected to solubilization, types of the microorganisms, inorganic additives, as well as a method of preparing the products and conducting the process. Bacteria (Phosphorus Solubilizing Bacteria-PSB) and fungi (Phosphorus Solubilizing Fungi—PSF) can be used for the process. In total, both of the microorganism groups that activate phosphorus are defined by the term Phosphate Solubilizing Organism- PSO (Górecki et al., 1990; Saeid et al., 2012). Two groups of processes are realized in practice:

- composting of organic waste with an optional addition of phosphorus raw materials (activation of phosphorus contained in raw materials takes place during the composting processes) (Eghball and Power, 1999),
- activation of phosphorus compounds contained in high quality raw materials and in waste raw materials using microorganisms (fungi and bacteria) and optionally elementary sulphur (Saeid et al., 2014).

Bacillus megaterium and *Acidithiobacillus ferrooxidans* (Labuda et al., 2012; Sundara et al., 2002) bacteria or *Aspergillus niger* (Omar, 1998) fungi are examples of strains of bacteria and fungi that allow the microbiological solubilization process to happen. *Bacillus megaterium*, which were used in this study, produce the mixture of organic acids mainly citric, lactic and propionic acids which react with phosphorus compounds present in SSA, converting them to available form (Saeid et al., 2014; Chen et al., 2006).

The aim of the study was to obtain granulated fertilizers on the basis of phosphorus waste materials (municipal sewage sludge (MSSA) and meat and bones meal (MBM)) and *B. megaterium* for the field experiments conducted by University of Warmia and Mazury in Olsztyn, Poland.

2. Material and methods

2.1. Materials

MSSA originated from incineration of municipal sewage sludge from Łyna sewage–treatment plant near Olsztyn were used as a

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