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A novel microbial-mineral preparation for the removal of offensive odors from poultry manure

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ABSTRACT

This paper describes the research performed to develop a novel microbial preparation for deodorization of poultry manure. Three forms of the preparations were investigated: microorganisms (*Pseudomonas fluorescens, Enterococcus faecium, Bacillus subtilis, Bacillus megaterium, Leuconostoc mesenteroides* and *Lactobacillus plantarum*) on the mineral carrier (PBM), microbes in the form of spray-dried microcapsules (SDM) and freeze-dried powder (FDP). The experiments were performed in an installation consisting of four chambers, each with a working volume of 8 dm^3. Each chamber was filled with a 0.5 kg of fresh poultry manure, onto which the tested preparations were sprinkled. The deodorization efficiency of the preparations was evaluated by passing air through the reactors and measuring odorants in the exhaust air. In the course of the experiments, the final formula of the preparation was established. It consisted of a perlite-bentonite mixture (20:80 by weight) as a sorbent, and mineral carrier to which 20% of SDM was added. The new preparation applied to poultry manure was particularly active against ammonia and hydrogen sulfide, which were reduced in the exhaust air by 94% and 60%, respectively, after 2 days of deodorization. The experiments also showed that the preparation can be stored for at least 5 months at both cooling (4 °C) and room (22 °C) temperatures with no decrease of its microbial activity.
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1. Introduction

The operation of each poultry farm is associated with the formation of odor nuisance, which poses substantial problems for the local community. Odor can be defined as a physiological stimulus of olfactory cells by a specific compound called an odorant (Rappert and Müller, 2005a; Schiffman et al., 2001). There are plenty of different inorganic and organic odorants arising from livestock farming including alcohols, aldehydes, ammonia, amines, hydrogen sulfide and organic sulfides, carboxylic acids, esters, ketones, terpenes, and aromatic compounds (Blanes-Vidal et al., 2009; Rappert and Müller, 2005b). Odors emitted from poultry breeding farms are regarded as the most unpleasant by many people, equal with fattening pig facility odors (Nimmermark, 2011). Substantial odor nuisance of poultry manure as well as other manure types may result from the variety and complexity of the released odor-causing compounds. There is also a synergistic or additive effect by which even low levels of several odorants create a mixture, which is much more offensive than individual compounds present in the air at much higher concentrations (Fournel et al., 2012; Schiffman et al., 2001). Hence, an effective odor removal technique should be directed at reducing odorants of different chemical classes. There are many ways to reduce odor nuisance arising during livestock farming, including:

- modification of diet to improve nutrient retention by animals and decrease their excretion in excrement (Hayes et al., 2004; Petersen et al., 2007),
- impermeable and permeable covers, which trap gases released from manure (Funk et al., 2004; Rothrock et al., 2013),
- chemical oxidation technologies including ozonation, photocatalysis, Fenton reaction (Cantau et al., 2007; Hammouda et al., 2016; Wang et al., 2013),

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- biofilters, bioscrubbers and membrane reactors, which trap, degrade or convert entrapped malodorous compounds into their benign forms (Jaber et al., 2014; Mudliar et al., 2010; Van der Heyden et al., 2015),
- chemical and biological amendments, which are directly added to manure to adsorb, oxidize odorants or convert them into odorless forms (Kim et al., 2008; McCrory and Hobbs, 2001).

The latter method seems to be particularly attractive for farmers, from practical and economical point of view, because it does not require any installations for odor treatment and qualified staff to operate them. Various chemical and mineral additives have been applied for poultry manure deodorization (McWard and Taylor, 2000; Moore et al., 1995; Rothrock et al., 2008; Turan et al., 2009), however, the literature concerning the use of biological amendments is scarce. Kim et al. (2008) tested different chemical and biological amendments including tap and salt water, treated manure, soybean, essential oil and randomly selected commercial biopreparations in pig buildings. DeLaune et al. (2004) investigated the effect of a microbial mixture, aluminum sulfate (alum) and phosphoric acid added to poultry litter on ammonia volatilization during composting. Coates et al. (2005) applied several Fe(III)-reducing species belonging to the family *Geobacteraceae* for deodorization of swine manure. They demonstrated that simultaneous use of Fe(III) chelated with nitrilotriacetic acid and selected strains of *Geobacter* sp., *Geothrix* sp. and *Geovibrio* sp. can rapidly remove all volatile fatty acids from swine manure by more than 90%, and enhance methane production by 200%.

The proper selection of microorganism capable to remove odorous compounds, determines quality and quantity of malodorous gases. Many autotrophic and heterotrophic microorganisms are involved in the processes of ammonia and hydrogen sulfide elimination from air in animal farms. In particular, nitrifying bacteria, including *Nitrosomonas europaea*, *Nitrococcus mobiles* strains have been found to efficiently remove ammonia from manure (Hanajima et al., 2008). The in-vitro experiments performed by Kim et al. (2014) demonstrated strong ability of *Bacillus amyloliquefaciens* strains to reduce fecal ammonia, hydrogen sulfide and sulfur dioxide emissions from pig manure. Likewise, Chung et al. (2001) studied biotreatment of ammonia and hydrogen sulfide gas mixtures using biofilters packed with immobilized cells containing heterotrophic bacteria *Arthrobacter oxydans* and *Pseudomonas putida*. The authors achieved greater than 95% and 90% removal efficiencies for ammonia and hydrogen sulfide, respectively. In another study undertaken by Hartikainen et al. (2002), peat biofilter was inoculated with *Thiobacillus* sp. strains. The results revealed a high elimination of hydrogen sulfide, dimethyl sulfide and methanethiol of up to 99% from treated gas. Furthermore, Endoh et al. (2003) as well as Sato et al. (1999) isolated from soil heterotrophic bacteria species of *Bacillus* sp. and *Pseudomonas* sp. active in utilization of hydrogen sulfide, dimethyl sulfide and methanethiol. Regarding biodegradation of nitrogen-containing odorants other that ammonia, various strains of *Arthrobacter* sp., *Bacillus* sp., *Micrococus* sp. *Mycobacterium* sp., *Pseudomonas aminovorans* and *Methylophilus methylosporus* can degrade dimethylamine, whereas the strains of *Aminobacter aminovorans*, *Paracoccus aminovorans*, *Pseudomonas aminovorans*, *Hyphomicrobium* sp. amd *Micrococcus* sp. have been found to efficiently decompose trimethylamine (Rappert and Müller, 2005a). Little is known about microbial degradation of pyrazines, however some strains of *Pseudomonas putida*, *Pseudomonas acidovorans* and *Alcaligenes facalis* are involved in the transformation of pyrazines to other compounds (Rappert and Müller, 2005a). Considering carbon-containing odorants, Bourque et al. (1987) selected various strains of bacteria, including *Acinetobacter calcoaceticul*, *Alcaligenes faecalis*, *Corynebacterium glutamicum* and *Micrococcus* sp., which were active in degradation of phenol, p-cresol and all volatile fatty acids. In another research performed by Huang et al. (2006) the addition of *Lactobacillus plantarum* into manure decreased the concentrations of butyric and valeric acids (as well as their branched forms) but increased the concentrations of acetic and propionic acids. There is still a need to search for microorganisms active in removing odorants generated at poultry farms. Zhang et al. (2006) found that metabolism of aerobic heterotrophic bacteria can contribute to the removal of odorous compounds from manure environment. In our previous research (Gutarowska et al., 2014), we have demonstrated that selected heterotrophic microorganisms may be used for deodorization of poultry manure. The strains, also used in the present study (*Pseudomonas fluorescens, Enterococcus faecium, Bacillus subtilis, Bacillus megaterium, Leuconostoc mesenteroides* and *Lactobacillus plantarum*), were isolated from natural environments (soil, poultry manure and silage). Apart from their deodorization properties, they are found to inhibit the growth of potentially pathogenic microorganisms in poultry manure (Matusiak et al., 2016).

Two common methods of drying are used in biotechnology to provide durability and stability of biological materials: freeze drying (lyophilization) and spray drying. Freeze drying is a technique based on water removal from a frozen material under reduced pressure based on sublimation. In contrast, spray drying uses hot air to evaporate water from the feed solution sprayed into a drying chamber (Barbosa et al., 2015; Febriyenti et al., 2014). Both methods have their advantages and drawbacks. During freeze drying, materials are not subjected to high temperatures, hence the freeze-dried products maintain their high quality and initial nutritious character. Moreover, with the use of appropriate protectants, lyophilization allows to achieve a high survival of microbial cells in the dried product (Barbosa et al., 2015; Santo et al., 2013). However, freeze drying is an energy and time consuming process and the dried product is porous and hygroscopic. On the other hand, spray drying is a rapid process and its operation is simple and continuous (Barbosa et al., 2015; Santo et al., 2013). Considering the costs, spray drying is about six times cheaper (per kg of water removed from a product) than lyophilization (Castro et al., 1997). The obtained product is composed of spherical microcapsules arising as the sprayed droplets contact with hot air in the drying chamber. Maltodextrin added to the dried material serves as the main building material of microcapsules whereas addition of trehalose protects cell structures under osmotic and thermal stress (Desobry et al., 1997).

The aim of this study was to evaluate the efficiency of three different microbial-based preparations: microorganisms on a mineral carrier, spray-dried microcapsules and freeze-dried powder, on reduction of ammonia, hydrogen sulfide and other odorants in air generated by chicken manure. The effect of different drying processes, i.e. spray drying and lyophilization, on removal of malodorous compounds was also investigated. Additionally, microstructure analysis of mineral carriers and stability tests of microorganisms, which are the components of the preparations, were performed. To the best of the author's knowledge, this study is the first to investigate the microbial-mineral preparation applied for poultry manure deodorization. Moreover, the way the individual components of the preparation are combined (dry mineral carrier with dried microbial encapsulates), has neither been tested nor commercially used.

2. Materials and methods

2.1. Poultry manure

Poultry manure used in the experiments was delivered from a

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