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# Residues from the thermal conversion of waste from the meat industry as a source of valuable macro- and micronutrients

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ABSTRACT

The increased consumption of meat (including poultry) observed over the last decade has led to the intensification of its production. With the production increase, the amount of generated waste also increases. Appropriate disposal of waste from the meat industry will significantly reduce the amount of such waste and its negative impact on the environment.

The paper presents a method for the thermal neutralisation of feathers, poultry litter and meat and bone meal (MBM). Waste incineration was carried out in a stationary electric furnace, at a temperature varying in the range of 600–900 °C. The resulting ashes were characterised by a high percentage of phosphorus (30–170 g/kg ash), calcium (20–360 g/kg ash) and other valuable macro- and micronutrients like copper, iron, manganese and zinc. The ashes produced during the thermal treatment are safe in terms of sanitary and can be used as additives enriching the fertilisers and soil improvers.



## 1. Introduction

A recently observed increase in the consumption of poultry meat in the European Union has led to an increase in the production of such meat. From 2009 to 2013 poultry production has increased by about 7% to 12.7 million tons. For comparison – at the same time the production of pork has increased by 2.6%, whilst beef decreased by 6.2%, and sheep and goat meat by 6.4% (Europa, 2015). With the increase in production, the amount of waste (feathers and poultry litter) also increases, which should be disposed of according to EU regulations.

Trends in the development of the poultry sector may have a significant impact on environmental issues. Waste management is an important aspect of natural environmental protection. The priority tasks are determined to reduce the amount of produced and stored waste, and to develop methods for processing. The choice of disposal methods, resulting in the production of poultry, depends not only on the type and characteristics of the waste, but above all must comply with the requirements of applicable law.

Also, in other sectors of the meat industry, a continuous increase in waste generation is observed. The main waste from the meat industry is i.e. skin, blood, head, legs, horns, bones and hooves collected from healthy animals, which are inedible low risk animal products (category 3) (EC, 2009).

For a long time, animal waste was used by farmers to improve soil fertility. The latest knowledge in the field of agriculture and animal husbandry revealed disadvantages in the direct application of animal waste for such purposes. These defects include the spread of the soil pathogens and disease transmission to animals, as well as water pollution and greenhouse gas emissions. It is therefore important to search for new environmentally safe waste disposal methods.

Waste feathers constitute 5–7% of the total mass of adult chickens. In the course of poultry processing, they are obtained in large quantities as a by-product. The development of the poultry industry in the world has led to the generation of more than 4 million tons of feathers waste each year. This amount of feathers is a problem because it takes a large area of storage. It is therefore important to search for new methods of disposing of this waste (Zaghloul et al., 2011; Vasileva-Tonkova et al., 2009; Sayed et al., 2005; Park and Son, 2009). Currently used method of disposing of feathers is their processing into low nutritious animal feed. The nutritional value of such feed is determined by the content of amino acids such as methionine and histidine. The amount of these amino acids, decreases with the age of the chicken and therefore it is problematic to obtain a product with reproducible characteristics (Onifade et al., 1998). In some countries, regulations prohibit the use of waste feathers for the production of fodder

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and, in most cases, feathers are stored as waste (Barone and Schmidt, 2006; Cheng et al., 2009). The main threat to the storage of feathers are odours resulting from their degradation, as well as the production of greenhouse gases such as methane and carbon dioxide (Roberts et al., 2004). Furthermore, solid, soluble decomposition products can pass along with the water into the soil. Collecting this type of waste is considered a serious source of danger and threat to animal and human life (Sayed et al., 2005).

Waste from the meat industry is mostly processed into meat and bone meal (MBM). This represents a mixture of small pieces of bones and residual fractions derived from production. The composition of MBM is variable and dependent on the raw material used. The raw material has about 40% moisture content. From the dry matter, 2/3 is produced as MBM and 1/3 as fat (EC, 2009; Cyr and Ludmann, 2006). Meat-and-bone meal are mainly exported to European Union countries for energy purposes, as a biofuel. In the past, this material was used for animal feeding. However, since the beginning of bovine spongiform encephalopathy (BSE), the use of animal by-products in animal nutrition was under strict regulation and consequently only low risk material (category 3) is allowed for use in animal feed or as organic fertilisers. The feeding of meals derived from animal by-products to ruminants has been banned in both the EU and other countries (Cascarosa et al., 2012; Bertsch and Coello, 2005; Staroń et al., 2013).

Poultry litter is widely regarded as a natural by-product, which is largely used as a fertiliser. It consists of nutrients essential for plant growth, such as nitrogen, phosphorus or potassium, and a plurality of micronutrients. They are both in the form of organic and inorganic compounds. The nitrogen present in the organic form is more stable than the nitrogen present in mineral fertilisers. Poultry litter fertiliser use is associated with the problem of odours, which are released during manure storage and during the fertilisation of farmland (Kelleher et al., 2002; Badri et al., 2002; Schröder, 2005).

The aim of this study was to investigate the possibility of processing the waste from the meat industry, i.e. feather waste, meat and bone meal and poultry litter by thermal conversion, determination of the physicochemical properties of the ashes after burning and to determine the possibility of using the mineral residue as an alternative source of macro- and micronutrients. Numerous studies presented in the literature show that MBM is mainly used for energy recovery. McDonnell et al. burned pellets obtained from MBM and peat in a fluidised bed combustor (McDonnell et al., 2001). Chaala and Roy presented vacuum pyrolysis as a MBM disposal option. The process generated a combustible gas, a high calorific value oil, a solid residue rich in minerals and an aqueous phase rich in organics (Chaala and Roy, 2003). Conesa et al. studied thermal decomposition of meat and bone meal both in inert and reactive atmosphere (Conesa et al., 2003). Skodras et al. prepared mixtures of MBM with Greek brown coal and studied its behaviour under pyrolysis and combustion conditions (Skodras et al., 2007). Coutand et al. made a characteristic of ashes originating from MBM and suggested its potential use. The ashes obtained from the specific incineration (laboratory) and from co-incineration (industrial process) (Coutand et al., 2008). Deydier et al. evaluated ashes efficiency for in situ remediation of lead-contaminated aqueous solutions and soils (Deydier et al., 2007). Research conducted the incineration of waste feathers, MBM and poultry litter provided for the use of the obtained ash for fertilising purposes. Fertilisation is one of the most important factors of the intensification in crop production. For proper plant development and optimal uptake of nutrients from the soil, it is important to maintain the correct proportions of nutrients on the basis of agro-chemical state of the soil and the needs of the plants. Furthermore, due to the end of phosphorus resources, it is necessary to seek alternative sources. Phosphorus belongs to limited non-renewable resources, and is an essential nutrient for the growth of most organisms in ecosystems and cannot be replaced by other elements. It is very important raw material for many industries (Tan and Lagerkvist, 2011). Mineral apatite the main material used in fertiliser production, which resources in the world are estimated to be only for about 200 years. However the details relating to reserves are both commercially and politically sensitive. The main deposits of phosphate rock resources are relatively in a few countries. The main producers of phosphate rock are China, the United States and Morocco. In the European Union the only operating source is the mine situated in Finland. Therefore, sustainable methods of recycling of phosphorus used in society are necessary (Dawson and Hilton, 2011). The composition of phosphorite largely depends on its nature and origin. Sedimentary rocks contain high concentrations of heavy elements ex. U, Th, REE (rare earth elements), and also they are contaminated by other elements, such as: Cd, As, Sb, V, Cr, Zn, Cu, and Ni. The amounts of these undesirable components vary widely, not only between different sources of phosphate, but also even in the same bed (Sabiha-Javied et al., 2009).

The method of thermal treatment of waste from the meat industry may be an additional source of phosphorus as well as other elements, e.g. sodium, potassium and magnesium. It will also help to significantly reduce the problem of the disposal of such waste.

## 2. Experimental

### 2.1. Materials

The chicken feathers (F) waste and poultry litter (PL) originating from large plant poultry as well as meat and bone meal (MBM) produced in rendering plants were the objects of the research. Chicken feathers were taken from a meat establishment engaged in slaughtering chickens. Sample feathers were taken immediately after slaughter and consisted of whole feathers. MBM was obtained by thermal treatment during which it has been partially defatted. The particle size was 1 mm. Chicken manure came from a production plant employing litter breeding. Manure sample was taken from the warehouse, in which the drying process was carried out. The particle size of the manure is from 0.5 to 10 mm.

### 2.2. Methods

Feathers, meat and bone meal and poultry litter incinerated to ashes in a stationary electric furnace from Czylok Company which was equipped with a microprocessing temperature controller MRT20 at a temperature ranging from 600 to 900 °C, by each 100 °C for 1 and 3 h. The mass of material which was subjected to ashing, 100 g, was the constant parameter. The material was incinerated in ceramic vaporisers that were placed in a cold oven and removed immediately after a period of combustion at the tested temperature.

### 2.3. Characteristics of physicochemical properties

#### 2.3.1. Physicochemical characteristics of research material

Elemental analyses (analysis of the contents of C, H and N) were performed on a type 2400 CHN analyser from Perkin Elmer.

The heat of combustion was determined using a KL-12Mn Precyzja-Bit calorimeter.

Surface analysis was performed on a Hitachi TM-3000 scanning electron microscope equipped with an X-ray EDS microanalyser.