Effect of composted slaughterhouse wastes and meat meal on soil as well as yield and element composition of crops

Thesis of the PhD dissertation

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1. Introduction and main objectives

In the 20th century the meat consumption increased together with the standard of living both in Hungary and in the World. According to predictions, the volume of meat production of 228 million tons in 2000 can be doubled by 2050 (AKI 2007, FAO 2006).

The wastes of the meat processing can be used in many ways. Utilization of animal wastes for the soil productivity was reported even in the 19th century (Thaer 1809 In: Kádár 1996a; Wolff 1872 In: Kádár 2007). In the 20th century most of these wastes were used for fodders.

Fodder use of animal origin wastes has been strictly regulated by EU since BSE (bovine spongiform encephalopathy) disease showed up, so alternative utilities have to be found.

Hazardous wastes from animal bodies reach 200-300 thousand tons per year in Hungary. After heat treatment these wastes become non-hazardous, and other treatments (like composting, drying, grounding) make land application possible (Kiss et al., 2001).

The organic fertilizers made from animal bodies can increase the organic matter and nutrition content of the soil, so soil parameters (structure water holding capacity) can also be improved. An essential aim of the Hungarian waste management regulation (2000. évi XLIII. hulladékgazdálkodási törvény) to reduce the amount and organic matter content of the deposited wastes.

Unfortunately only a few data is available about the effect of different organic fertilizers originating from animal bodies on soil and researches aimed mostly the effects of meat meal, or meat and bone meal. For these reasons the effect of different composts and meat powder originating from slaughterhouse waste were studied in a field experiment.
The main objectives of the study were:
- To identify the basic characteristics, nutrient content, element composition and possible harmful microelement content of the composts and meat powder made from slaughterhouse waste
- To explore the mechanism of action, the effect on soil parameters and soil element content of these fertilizers,
- To follow the development, yield and element composition of plants on treated soils
- To examine the time of decay and the residual effects of these fertilizers
- To identify the optimal doses of application

2. Materials and methods

General introduction
Field experiments was set up with the processed slaughterhouse wastes at the experimental site of the Research Institute for Soil Science and Agricultural Chemistry at Őrbottyán in 2002 and 2003 with the supervision of Prof. Dr. Imre Kádár. Five experiments were set with the five different organic fertilizers:

Mature compost – the fertilizer and the experiment marked as: Ő1
Immature compost – Ő2
Semi-matured compost from meat powder – F1
Semi-matured compost from cooked meat – F2
Pure meat powder – H

Soil characteristics of the experiments
The sandy soil had 0-8% CaCO₃, 0.9-1.1% humus, 10-15% clay fraction; pH(H₂O): 7-8 in average in the 0-20 cm layer. The site was weakly supplied with available P and K. The water table was at 6-8 m. On the eroded and
damaged spots the CaCO₃ content increases and the depth of the humus layer decreases (Klimes-Szmik 1955, Kádár 1999 a, b).

Set up and arrangement of the experiments

Five experiments were set with four different composts and a meat powder processed by ATEVSZOLG Inc. The quality and composition of the composted slaughterhouse wastes also varied. Materials were applied once at 5 different levels in 4 replications making 20 plots for each experiment during 2002 and 2003. The plots had an area of 5x8=40m² and arranged in split-plot design. In each experiment the applied rates were 0, 25, 50, 100, 200 t/ha fresh compost. In case of meat powder the doses were 0, 2.5, 5.0, 10.0, 20.0 t/ha.

Characteristics of the applied organic fertilizers

Table 1 shows the components, application dates and qualities of the composts and meat powder.

<table>
<thead>
<tr>
<th>Mark of experiments</th>
<th>Name of fertilizers</th>
<th>Components of fertilizers</th>
<th>Application date</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>É1</td>
<td>mature compost</td>
<td>slaughterhouse waste and sewage sludge</td>
<td>09 May 2002</td>
<td>inodorous, friable</td>
</tr>
<tr>
<td>E2</td>
<td>immature compost</td>
<td>meat powder, straw</td>
<td>09 May 2002</td>
<td>smelly, rough</td>
</tr>
<tr>
<td>F1</td>
<td>semi-mature compost</td>
<td>meat powder, straw</td>
<td>18 Nov 2002</td>
<td>smelly, rough</td>
</tr>
<tr>
<td>F2</td>
<td>semi-mature compost</td>
<td>cooked meat, straw</td>
<td>06 May 2003</td>
<td>smelly, rough</td>
</tr>
<tr>
<td>H</td>
<td>meat powder</td>
<td>100% meat powder</td>
<td>18 Nov 2002</td>
<td>inodorous meal</td>
</tr>
</tbody>
</table>

The mature É1 compost became friable, inodorous, homogeneous material after 2-month air-exposure and 10-month maturation. Immature É2 compost has a bad smell, was rough, heterogeneous, after 6-week air-exposure and without maturation. Semi-mature F1 compost made with meat powder was the material of immature compost maturing 6 months more, but had still a bad smell and was rough. Semi-mature F2 compost made with cooked meat received 2-month air-
exposure and 8-month maturation, and was also smelly, rough and heterogeneous. The average compositions of the applied composts and meat powder are shown in Table 2.

Table 2: Composition of composts and meat powder in D.M. with cc.HNO$_3$+cc.H$_2$O$_2$ digestion (Analysis: RISSAC lab 2002-2003)

<table>
<thead>
<tr>
<th>Measured parameters</th>
<th>Unit</th>
<th>Average composition in the experiments</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>%</td>
<td>É1 45.8 É2 60.0 F1 55.7 F2 95.0 H 59.1</td>
<td></td>
</tr>
<tr>
<td>Org. Matter</td>
<td>%</td>
<td>É1 41.7 É2 40.3 F1 43.8 F2 58.6 H 42.1</td>
<td></td>
</tr>
<tr>
<td>Organic C</td>
<td>%</td>
<td>É1 24.1 É2 23.3 F1 25.3 F2 33.9 H 24.4</td>
<td></td>
</tr>
<tr>
<td>C/N ratio</td>
<td></td>
<td>É1 7.1 É2 8.8 F1 5.3 F2 7.3 H 7.3</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>%</td>
<td>É1 12.65 É2 11.25 F1 11.68 F2 7.02 H 10.42</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>%</td>
<td>É1 5.56 É2 4.26 F1 5.26 F2 4.06 H 4.27</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>%</td>
<td>É1 3.12 É2 3.26 F1 2.89 F2 6.41 H 4.43</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>%</td>
<td>É1 0.83 É2 0.50 F1 0.41 F2 0.65 H 0.43</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>%</td>
<td>É1 0.37 É2 0.54 F1 0.18 F2 0.43 H 0.43</td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>%</td>
<td>É1 0.79 É2 0.69 F1 0.63 F2 0.45 H 0.62</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>%</td>
<td>É1 0.70 É2 0.36 F1 0.37 F2 0.54 H 0.43</td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>%</td>
<td>É1 0.29 É2 0.29 F1 0.08 F2 0.07 H 0.43</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>%</td>
<td>É1 2.36 É2 0.14 F1 0.52 F2 0.02 H 1.16</td>
<td></td>
</tr>
<tr>
<td>NH$_4$-N</td>
<td>mg/kg</td>
<td>É1 169 É2 3006 F1 941 F2 882 H 167 1033</td>
<td></td>
</tr>
<tr>
<td>NO$_3$-N</td>
<td>mg/kg</td>
<td>É1 2480 É2 1135 F1 61 F2 122 H 760</td>
<td></td>
</tr>
</tbody>
</table>

Experimental plants

In the first experimental year (2002) maize (Zea mays), in the second mustard (Sinapis alba) and from the third year triticale (X Triticosecale) monoculture were grown.

Precipitation

As the water holding capacity of the sandy soil is low, the amount of precipitation has strong effect on yields and the mechanism of fertilizers. The years 2002 and 2003 were dry. The maize received 237 mm and the mustard 52 mm of precipitation during their growing season. Between 2004 and 2008 the triticale had mostly satisfactory amount of precipitation evenly distributed. The year 2009 was again dry but the precipitation was outstanding in 2010.
Samplings and laboratory analyses

Soil samples were taken from each plot to identify the basic characteristics and the ammonium-acetate + EDTA soluble “available” element content. In the next year, besides the basic characteristics and the ammonium-acetate + EDTA soluble element content, the cc.HNO₃+cc.H₂O₂ soluble „total” element content was also measured. The next and last sampling was made in 2008 from each plot, when the same parameters were studied as in 2003.

In every year, during the vegetation period, scoring of the crop stand was made. Plant samples were taken to define the yield and, in some of the years, the element composition of the plants. Analysis of element composition was done in 2002, 2003, 2004, and 2009.

The element compositions of the organic fertilizers were identified the same way as the „total” element content of the soil.

Method of data processing

Data from the observations and analyses were managed with MS Excel computer program. Based on the data, the effects of the different doses of fertilizers were studied on the soil and plants, as it was previously described. The residual effects were also followed during the studied years. One-way analysis of variance was used to evaluate each experiment arranged in randomised block design, where the application dose of the fertilizer was the factor (Sváb 1981).

3. Results and discussion

Evaluation of the analytical data of fertilizers

The composts and the meat meal had high N and P concentration, which basically determines their application doses. It means 8.7-21.4 t/ha fresh (moist) compost (5.2-8.3 t/ha dry matter) or 2.6 t/ha meat meal application on the
nitrate-sensitive areas of Hungary (where maximum 170 kg/ha/year N can be applied) and 10.2-37.8 t/ha fresh compost (6.1-14.7 t/ha dry matter), or 3.1-4.6 t/ha meat meal application on non-sensitive areas. The É1 mature compost had more fold content of some microelements compared to the other composts, which was probably due to the added sewage sludge. The application of É1 compost in 200 t/ha dose made 42 kg/ha Zn load which exceeded the 30 kg/ha application limit of the Hungarian regulations No. 50/2001. (IV. 3.) and 40/2008. (II.26.) for sewage sludge. The element compositions of the composts and meat meal fulfil the limit values of the regulation No. 40/2008. (II.26.) for sewage sludge.

**Effect of fertilizers on soil**

According to the soil analyses, the increasing doses of organic fertilizers resulted in the increment of nutrition and organic matter content, water-holding capacity. The “available” P$_2$O$_5$ content rose considerably. Even due to 25 t/ha compost application the soils had 200-400 mg/kg NH$_4$-acetate+EDTA soluble P$_2$O$_5$ content which was double or triple compared to control. N content also lifted.

The data form 2003 showed, that the lowest doses caused 10-20% non-significant increment in the total N content. The É1 mature and É2 immature composts (applied in 2002 spring) had moderate effect on NO$_3$-N content, however the immature composts increased it by 50-100% and meat meal quadruplicated it even with the lowest application dose. As a result, the soil had 17-38 mg/kg NO$_3$-N on plots treated with semi-mature composts (F1 and F2) or meat meal, which means good or abundant supply. Higher doses of fertilizers caused even 100-200 mg/kg NO$_3$-N content. The data of the sampling form the year 2008 show only slight increasing of NO$_3$-N.

In the early years of the experiment mostly the „available” S and Na contents, and generally the “total” P, S, Ca, Na, Zn and total N contents increased
significantly due to the higher application doses. In 2008, the water-holding capacity and the organic matter content still increased in some cases with the rising of the doses. The “available” P₂O₅, Na, S and Zn contents showed generally significant differences. The „total” P, S and total N also increased.

The treatments caused no harmful microelement contents above the limit values in soil, not even in the case of the É1 mature compost with higher microelement content. The pH and CaCO₃ content of soil did not change considerably in any of the experiments.

**Effects of fertilizers on the yield and element content of crops**

In the first two droughty years of the experiment the composts in 50 t/ha dose and the meat meal in 10 t/ha load caused better stand and higher yields of crops, though the increment was not significant. The highest application rates of compost and meat meal were depressive. The É2 immature compost caused 20-50% destruction of maize.

All of the composts had significant residual effect on triticale in 2004 as the weather was favourable and immature É2 compost could increase straw and grain air-dried yield threefold compared to control plot. Highest load of F1 semi-mature compost caused more than 100% increment, while F2 semi-mature compost and meat meal almost 50% increment. Maximal yields occurred at the maximal compost doses without depression.

In following years residual effects were continuously moderated. The É1 compost lost its effect in 2005, while the meat meal had no more impact after 2007; however the immature and semi-mature compost treatments at higher rates produced significant yield increases even in 2008. The years 2009 and 2010 were unfavourable regarding the weather, but significant differences in the yield still occurred.

The treatments with É2 immature and F1 semi-mature composts produced the highest yields and yield surpluses on the average of the years as well as the
longest residual effects, as they significantly increased the grain yield even in 7-8 years after the application. The F2 semi mature compost had slightly moderated effect compared to É2 and F1. Meat meal had strong influence, as in 2005 meat meal treatment could reach the highest average yields, but its residual effect disappeared by the fifth year. The É1 mature compost had the least impact on yields; statistically verifiable difference occurred only in one year at 100 t/ha dose (Figure 1).

![Figure 1. Effect of the highest loads of fertilizers on the yield of triticale between 2004 and 2010 (Calcareous sand soil, Órbottyán)](image)

Treatments had effect on the element composition of plants. Rising compost doses caused increasing N, NO$_3$-N, K, S, Zn content and decreasing Mg content in maize. Changes were significant mainly in the shoot of the tasseling stage.

In the case of mustard uptakes of N, S, P, Na elements were enhanced, while Mo was hindered. The N and S content of triticale was generally enriched with the rising application rates in 2004 and also in 2009. The other studied elements did not show any consequent and directly proportional changes. Plant analyses
showed no extreme element enrichments, composition remained in the “normal” level.

So the studied fertilizers are generally able to improve soil qualities and nutrient content, which can lead to surplus yields of crops. Generally, they have strong residual effects, the decomposition is gradual, and thus they can evenly supply nutrients for the plants.

4. New scientific results

1. The studied fertilizers had high N and P concentration, which basically determines their application doses. It means 9-38 t/ha fresh (moist) compost (5-15 t/ha dry matter) or 2.6-4.6 t/ha meat meal application depending on the sensitivity of the area and the composition of the organic fertilizer. The element contents of the applied fertilizers do not exceed the limit values.

2. Generally, the composts increased significantly the organic matter content and water holding capacity of the treated soils in the year of application and 5-6 years later as well. The applied fertilizers caused significant increment in the „available” and „total” P-, S-, Na-, and Zn-content, as well as N-, NO₃-N- and NH₄-N-content of the soil. The treatments did not result in harmful microelement levels.

3. In the first two dry years of the experiment the 200 t/ha application rate of composts caused depression. The composts in 25 and 50 t/ha dose and the meat meal in 5-20 t/ha load however caused significantly or tendentiously higher yields of crops. In following years as the precipitation was more favourable, the fertilizers could increase the yield depending on their quality and dose.
4. In the case of immature and semi-mature composts the 200 t/ha treatments resulted in significant yield increases even 7-8 years after the application, while 20 t/ha meat meal lost its effect after 2-3 years.

5. Regarding the composition of plants, in the first 2 or 3 years the treatments increased mostly the nitrogen, sulphur, phosphorus, and in some case the sodium and potassium uptakes significantly or tendentiously due to the treatments. The dry weather made mustard yields low, so concentrations of some elements were 2-3-fold enhanced. The nitrogen and sulphur content of the triticale showed tendentious increment due to increasing compost doses 7-8 years after the application.

5. References

2000 year XLIII. Act About the waste management. (In Hungarian) Magyar Közlöny. 53:3126-3144.

6. Publications

Publications related to the topic of the dissertation

Publications in referred, foreign edition journals

Publications in Hungarian edition journals


Full Text Papers in Conference Proceedings


Publications in other topics

Publications in Hungarian edition journals


Full Text Papers in Conference Proceedings


