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Research Article

FACTORS INFLUENCING COMPOSTING POULTRY WASTE

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ABSTRACT
Organic recycling of waste, taking into account sanitary safety, should be a fundamental method for recovering the nutrients present in the waste for plants and organic matter. It also refers to by-products of animal origin, which are not intended for consumption by humans. In the present research , composting of hydrated poultry slaughterhouse waste with maize straw was carried out. A combination with fodder yeast and post-cellulose lime was also introduced, which modified chemical and physicochemical properties of the mixtures. The experiment was carried out by recording the biomass temperature for 110 days in 1.2×1.0×0.8 m reactors with perforated bottoms enabling active aeration. The following parameters were taken into consideration in the composted material: carbon, nitrogen, sulfur, respiratory activity, microorganisms, fractions of compost obtained after washing on sieves. Small amounts of fodder yeast favoured the development of microorganisms and caused a sanitary risk in the final product. At the initial stage, the temperature of raw compost in that object was several degrees lower than in the case of the composted mass without yeast addition. The addition of post-cellulose lime at ratios 6.5 : 1 : 6.5 (maize straw: poultry slaughterhouse waste: post-cellulose lime) caused a change in the time of microbiological activity, and led to its inhibition in the final process. In comparison to objects with poultry waste, the highest degree of hygienization was found in the compost with post-cellulose lime (with pH close to neutral). By adjusting the ratios of substrates we can influence the microbiological activity, but the amounts of individual substrates should be determined taking into account the quality of the obtained compost.

Keywords: poultry waste, cellulose, yeast, compost, biological activity.

INTRODUCTION

Organic recycling of waste, taking into account the sanitary safety, should be the fundamental method for recovering the nutrients present in the waste for plants and organic matter. It also refers to by-products of animal origin, which are not intended for consumption by humans [Elving et al. 2010, Kopeć et al. 2014]. It results from the need to maintain a favorable balance of humus in cultivated soils. Introdiusing organig mater into the soil causes an increase of compounds rich in humic and preserves the soil structure, water capacity, and many other properties connected with organic matter. The products of organic recycling are also a significant part of carbon sequestration. Balanced development requires retardation of resources. One of multidirectional ways to keep balance in the environment is to return the organic matter that is useless in other technologies.

Positive aspects of organic recycling that is based on waste can be lost by errors in sanitation of waste. Transmission of pathogens between rural and municipal areas may occur not only by using organic waste such as compost in both of the mentioned environments. Pathogens may also be spread on specks of dust, through ground water pollution and contamination of food and fodders. A transfer caused by vector animals such as birds and rodents may also take place. Recycling of organic waste may pose a potential threat to health in a situation of lack of suitable control and management systems [Elving et al. 2010]. Many authors [Kopeć et al. 2014, Saveyn and Eder 2014] confirm that the chemical composition of composts obtained with a share of plant materials and waste from the agri-food industry meets minimum requirements for organic fertilizers. Some categories of animal by-products can be processed during biogasification or composting. Processing technologies must fulfil a series of rules, including maintaining material hygienization. The sanitary risk associated with introducing these products to the environment is high, but the current technique and possibilities of controlling the process make it possible to eliminate this risk. Regulation (EC) No 1774/2002 of the European Parliament and of the Council (Journal of Laws L. 273 of 10 October 2002) assumed that raw materials of category 3 used in composting plants, must fulfil the following requirements:

a) maximum size of particles before inserting them to a composting reactor: 12 mm;
b) minimum temperature of the whole raw material during processing in a reactor: 70 °C; and
c) minimum time of processing in a reactor at 70 °C (the whole raw material): 60 mins.

Elving et al. [2010] draw attention to the secondary threat and to restoring the microbiological potential during the maturation of compost or its application to soil. The_authors believe that the risk is associated with lack of compost aeration and it depends on the ratio of psychrophilic to mesophilic zones in a material, on aeration level or heat loss during the process. In their publications, Czekała et al. [2006] and Wolna-Maruwka et al. [2009] raised the same issues.

The aim of the paper was to verify the microbiological and physico-chemical quality of the composted materials from poultry waste. These materials are difficult to manage due to low dry matter content. The composting process must be carried out with addition of plant biomass as a structure-forming material. In the experiment fodder yeast and waste lime modified process properties to a high degree. In some cases fodder yeast can be regarded as waste (e.g. lost suitability for feeding).

MATERIAL AND METHODS

The composting experiment was carried out within 110 days (from April to August 2014) in 1.2×1.0×0.8 m reactors with perforated bottoms that enabled aeration. The cases were covered against precipitation, but subjected to the effects of outside temperature and of solar radiation, which had an impact on heat exchange of the composted material with the surroundings. Maize straw was the biomass to which the poultry industry waste was introduced (the control object without the addition of waste – M) (Table 1). In terms of dry matter, 15.4% poultry slaughterhouse waste (M+W) was added to the maize straw (M). To such a prepared material, 3 and 9 kg fresh matter of fodder yeast (M+W+Y_1 and M+W+Y_3) and 50 kg postcellulose lime (M+W+L) was introduced, forming further combinations of the experiment. The waste was applied in amounts that resulted from its physical properties, taking into account the structure and humidity of the feedstock.

After mixing the materials, moisture of the mixture was adjusted to 60%. Aeration was conducted in cycles, 6 times a day at a flow of 15 dm^3 for 60 minutes, as well as by manually turning the mass over once a week.

The temperature inside the material was recorded using DT-171 data-loggers with a frequency of every 30 minutes. The ambient temperature was measured in an automatic meteorological station using daily mean values in calculations.

Before and after the experiment, carbon, nitrogen and sulfur contents were determined in the organic material with the use of a Vario Max Cube NCS thermal conductivity detector.

The analysis of microorganisms in the composts was carried out by the serial dilution method. The results were given in $CFU \cdot g^{-1}$, using highly selective substrates [Pepper and Gerba 2005]. The number of index bacteria was estimated: *Escherichia coli,* coliform bacteria, *Salmonella* ssp., Haemolytic staphylococci, Sulphite-reducing *Clostridium* (*Clostridium perfringens*). The analyses were carried out in three replications. The results were calculated on dry matter of compost.

The structure of the washed material left on sieves defined the degree of composting process. Washing 50 g of compost was carried out after shaking the material with distilled water on a rotary agitator for 3 hours (maintaining a 1:10 material: water ratio), followed by washing the skeleton particles off on 1 mm and 0.05 mm sieves. The results were calculated on the dry matter of individual fractions after drying at 105 °C for 12 hours.

Electrolytic conductivity and pH were determined in the composted material treated with water in the 1:2.5 ratio.

Table 1. Amount of dry matter of the substrates in the particular combinations as well as the content of carbon, nitrogen and sulfur in individual mixtures prior to the beginning of the process

Substrat / parametr		Objects				
		M	M+W	M+W+Y_1	M+W+Y_3	M+W+L
Maize straw (M)	kg d.m.	28.12	28.12	28.12	28.12	28.12
Slaughterhouse waste (W)		–	4.32	4.32	4.32	4.32
Yeast (Y)		–	–	2.87	8.61	–
Postcellulose lime (L)		–	–	–	–	28.16
C total	g·kg^{-1} d.m.	407.0	402.7	377.8	338.3	303.0
N total		12.4	12.3	16.2	22.3	11.1
S total		1.5	4.9	4.6	4.1	3.0
C:N		32.8	32.7	23.3	15.2	27.3
C:S		271.3	81.4	81.6	82.1	101.8
N:S		8.3	2.5	3.5	5.4	3.7

Explanation: M – maize straw; M+W – maize straw + slaughterhouse waste; M+W+Y_1 – maize straw + slaughterhouse waste + yeast in a single dose; M+W+Y_3 – maize straw + slaughterhouse waste + yeast in a triple dose; M+W+L – maize straw + slaughterhouse waste + post-cellulose lime.

Along with yeast, significant amounts of nitrogen were introduced to the composted material, and the applied doses changed significantly the C:N ratio; in the case of the triple dose of yeast the C:N ratio was 15.2 (Table 1). Such a value theoretically contributes to the domination of mineralization processes over humification ones. The availability of these elements and the speed of their activation are also important. In the case of yeast, they should be more easily activated and available for plants after application in the form of compost [Botha 2011], and their application to soil speeds up transformation of nutrients [Al-Falih 2006, Al-Falih and Wainwright 1995a,b].

During the 110-day period of the experiment, mean values of outside temperature of 10-day cycles in the period of the experiment were within a range from 11.5 to 21.9 °C, and the range of mean daily temperatures was from 7.2 to 23.8 °C (at the turn of spring and summer).

In the first decade, the temperature of the composted material (Figure 1a), i.e. maize straw with no additions (M) and maize with the addition of poultry slaughterhouse waste (M+W) was similar and amounted to 33–35 °C, but in the second decade of the composting process, the diversification of the temperatures took place.

The difference in the mean temperature was 15 °C and was greater in the waste material from the slaughterhouse (M+W) in which maximum temperature value (62.7 °C) was recorded. In the second decade it was the highest temperature value in the objects. Introducing yeast and lime delayed microbiological processes taking place in the mixtures. The mean temperature (Figure 1b) in the mixture of maize straw, poultry waste and a single dose of yeast (M+W+Y1) in the second decade was 47.5 °C. It was 7.5 °C lower than in the composted mixture without the addition of yeast (M+W). The application of a triple dose of yeast to maize straw and poultry slaughterhouse waste (M+W+Y3) caused the highest microbiological activity (recorded by an increase in temperature) in the third decade, and in the case of the addition of lime (M+W+L) the activity was moved to the next decade. The addition of post-cellulose lime changed the standard course of the process, but maximum temperatures obtained indicate the adjustment of microflora to the environment and an increase in the activity of microflora.

Loses of dry matter depended on the temperature of the composting process. After composting, the greatest losses of dry matter were found in the case of composting of maize straw with no additions (M), and only 28% of the mass remained in relation to the mass at the beginning of the process. It is indicative of the intensity of microbiological processes taking place during composting. Introducing waste poultry decreased mass losses. The addition of post-cellulose lime, with the highest ash content (41.2%), limited dry matter losses approximately 2 times in comparison with the mixture of maize straw and poultry waste.

Figure 2 presents absolute values of residues after the introduction of substrates. This decrease in dry matter losses may be caused by changes in physico-chemical properties of the substrates and a different character of microbiological processes.

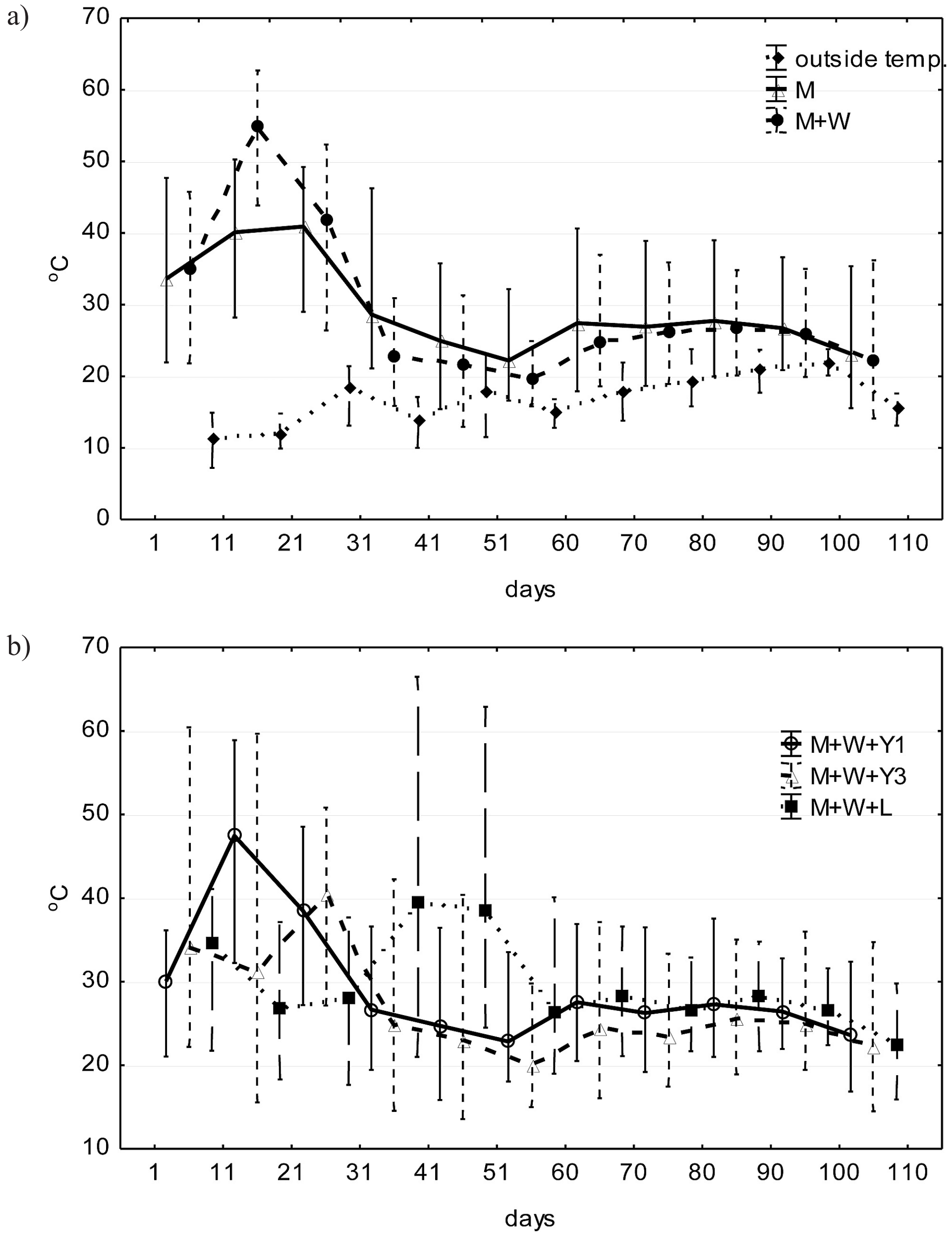

Figure 1. Changes in temperature of: a – composted mass of selected objects as well as ambient temperatures, b – selected mixtures during composting (objects as in Table 1)

The share of fractions left on sieves remains in strong connection with dry matter losses (Figure 3). The skeleton fraction, including water-proof aggregates, was found mostly in the composted material that was obtained from maize straw. The addition of post-cellulose lime caused almost absolute mineralization of the plant material. In this object the fractions below 1 mm constituted 90%. In this experiment and combinations selected in such a way it is difficult to draw an unambiguous conclusion. Comparing the results with dry matter losses during the process, it may be believed that the degree of mineralization and humification of maize straw and poultry waste in the object where post-cellulose lime was added was significant. When balancing the losses in these conditions, with the assumption that carbon in post-cellulose lime did not undergo changes to CO_2, it may be assumed that dry matter losses in the combination of maize straw and after-slaughter waste with the addition of lime would amount to 73.5% and would be 1.5% greater than losses for the composting maize straw alone.

It was organoleptically determined that the composting process diversified the fraction structure in the case of material with addition of triple amount of yeast. The comparison photo (Figure 4) indicates that leaves remained in a form of vascu-

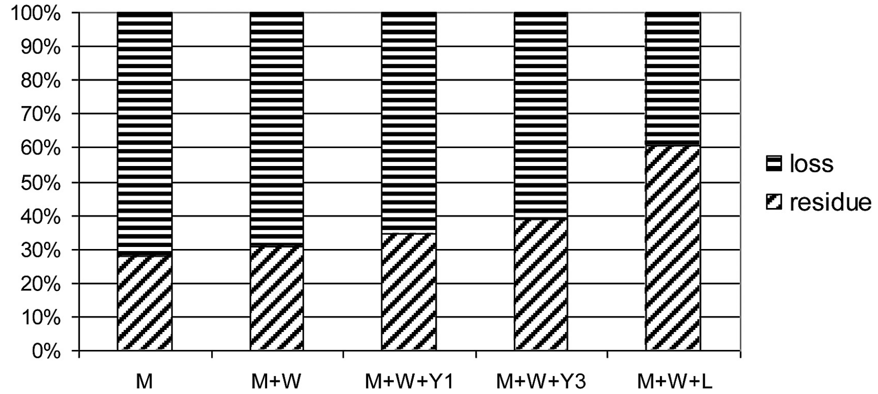

Figure 2. Percentage of dry matter residue after composting (objects as in Table 1)

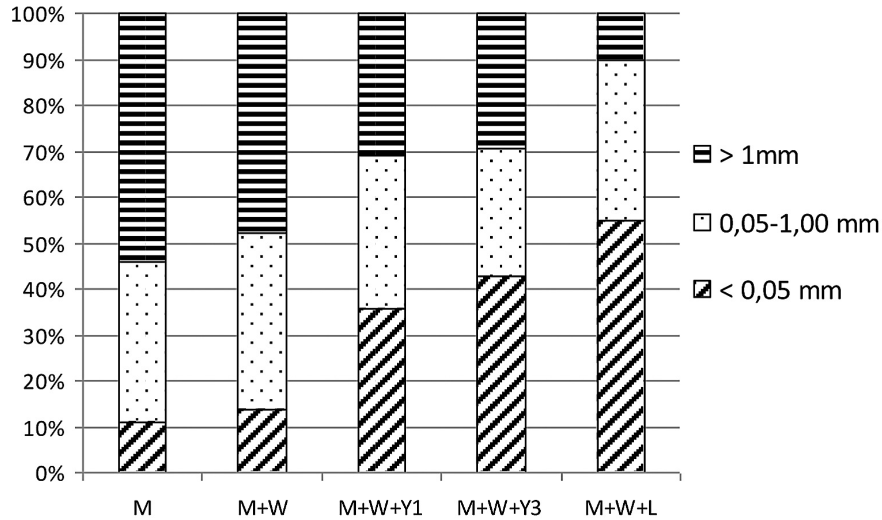

Figure 3. Percentage of selected compost fractions obtained after washing on sieves (objects as in Table 1)

lar bundles, which is indicative of intensive processes of parenchyma decay and inhibition of the process at a given stage. In that object, the highest temperature of the process was recorded in the third decade, but it was significantly lower than in the object where a single dose of yeast was applied. The addition of yeast increased the amount of easily available nitrogen, causing the value of the C:N ratio in the material before the process to narrow. However, the value of the C:N ratio is less important than availability of these two elements and microflora [Botha 2011, Al-Falih 2006].

The additions introduced to the composting process influenced the pH of the composted material and the electrolytic conductivity. Transformations of the composted biomass with addition of yeast caused an increase in the electrolytic conductivity and led to acidification of the material (Table 2).

Respiratory activity of the composts after 110 days was very low (Figure 5). Cumulative value of oxygen consumption in the period of 4 days (AT4) was below 5 mg $O_2 \cdot g^{-1}$ d.m. of the material. This suggests that compost maturity has been reached. Functions of oxygen consumption (y, mg $O_2 \cdot g^{-1}$ d.m.) by the material after composting (x, hour):

- y(M) = 0.023x + 0.23
- y(M+W) = 0.026x + 0.11
- y(M+W+Y1) = 0.041x + 0.22
- y(M+W+Y3) = 0.031x + 0.18
- y(M+W+L) = 0.021x + 0.086

Differences in respiratory activity between the objects were small. The lowest oxygen consumption was recorded in the object with addition of post-cellulose lime (M+W+L). The applied postcellulose lime had alkaline pH, which hygienized the compost mass and caused a decrease in the number of microorganisms [Schmidt and Laurindo 2010, Westholm et al. 2014].

In the case of two objects, i.e. compost from maize straw (M) and maize straw with the addition of poultry waste (M+W), the oxygen consumption was similar (slopes, respectively,

Figure 4. Comparison of the skeleton particles remaining on the 1 mm sieve: 3 - $M+W+Y_1$; 4 - $M+W+Y_3$

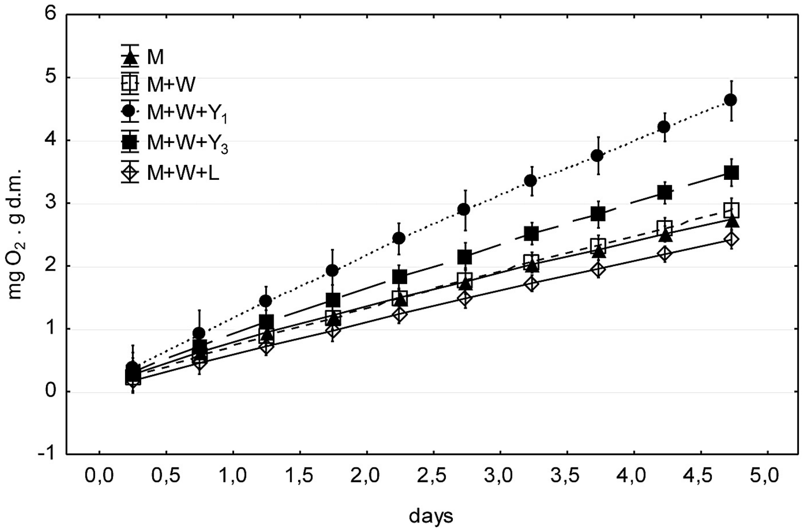

Figure 5. Effect of cumulative increase in oxygen consumption mg $O_2 \cdot g^{-1}$ d.m. in the composted material in the period of 4 days (objects as in Table 1)

0.0234 and 0.0260). Compared to the mentioned objects, the addition of yeast caused a slightly higher respiratory activity of the composted materials, and this effect is greater in case of a single dose (M+W+Y1).

Elving et al. [2010] showed a significant correlation between bacteria content and temperature of the process, as well as the Solvita test that is based on the measurement of CO_2 and NH_3. The results of respiratory activity of the composts were confirmed by the number of microorganisms (Table 3). The greatest amount of organisms from all groups was identified in the compost with the addition of yeast at a single dose, and this material also showed the greatest respiratory activity.

Escherichia coli is the best known and the most common representative of the *Enterobacteriaceae* family, and also probably so far the most widely used indicator of microbiological contamination. The conditions for survival of *E. coli* in the environment are both abiotic factors (availability of nutrients, temperature, pH, humidity) as well as biotic ones (mainly the presence of other microorganisms) [Liang et al. 2011, Van Elsas et al. 2011]. High content of organic matter in the composted material as well as the elevated temperature can help the bacteria survive. *E. coli* may survive in the natural environment for approximately 30–80 days, whereas under favorable conditions this time may significantly lengthen. In extreme cases (tropical soils) re-multiplication of bacteria might occur, which may distort the obtained results [Cools et al. 2001, Topp et al. 2003, Boes et al. 2005, Gondek 2009, Brochier et al. 2012, Oliveira et al. 2012]. A similar phenomenon is probably involved in the studied composts.

Table 2. Selected parameters of the composted materials

Parametr		Objects				
		M	M+W	M+W+Y_1	M+W+Y_3	M+W+L
C total	$g \cdot kg^{-1}$ d.m.	372.1+-1.68	359.2+-3.32	353.2+-2.12	349.7+-3.09	237.3+-1.42
N total		35.31+-0.02	45.62+-0.16	47.26+-1.24	43.68+-0.46	18.12+-0.61
S total		4.16+-0.31	6.96+-0.22	13.53+-0.03	21.52+-1.18	2.36+-0.06
C:N		10.5	7.9	7.5	8.0	13.0
C:S		89.4	51.6	26.1	16.3	100.6
N:S		8.5	6.6	3.5	2.0	7.7
EC	mS cm^{-1}	10.80+-0.11	11.07+-0.36	18.40+-0.01	15.21+-0.11	5.55+-0.58
pH H_2O		7.30+-0.03	6.77+-0.09	6.49+-0.05	6.45+-0.03	7.56+-0.04
pH KCl		6.74+-0.01	6.27+-0.01	6.01+-0.01	6.21+-0.01	7.19+-0.01

Explanation: objects as in Table 1, EC - electrolytic conductivity.

Table 3. Number of index microorganisms in dry matter of the composted material

Sample	*E. coli*	Coliforms	*Salmonella* ssp.	Haemolytic staphylococci	Sulphite-reducing *Clostridium*
	[$CFU \cdot g^{-1}$ d.m.]				
M	<11	320	<11	<11	11
M+W	185	533	62	31	348
M+W+Y_1	736	3852	227	76	93
M+W+Y_3	114	219	<7	<7	122
M+W+L	83	193	5	<5	33

Explanation: objects as in Table 1.

CONCLUSIONS

The smaller dose of fodder yeast favored the development of microorganisms and caused the sanitary risk in the final product. In the initial stage, the temperature of the composted mixture in that object was several degrees lower than the temperature of the composted mixture without yeast addition.

The addition of post-cellulose lime in the ratios of 6.5:1:6.5 (maize straw: poultry waste: lime) changed the microbiological activity, and led to its inhibition in the final stage. In comparison to the object with poultry waste without the addition of lime, the highest degree of hygienization was found in the compost with post-cellulose lime (with pH close to neutral).

The microbiological activity of compost depends on the ratios of substrates, however, the amounts of substrates influence the quality of the obtained compost.

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