Composting of Waste from Poultry Breeding – Biological Analysis

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The objective of this study was primarily to determine the course of biological composition changes of wastes during composting. Here presented are the results of the bacteriological, mycological and parasitological composition analyses of composts consisting of: goose and broiler excrements from ecological farms, remainders of goose intestines from slaughterhouses, goose feather waste collected on the sieves of the farm wastewater treatment plants, as well as sewage sludge from slaughterhouse wastewater treatment plants and poultry processing plants. Ground pine bark, pine shavings and rye straw chaff was used as an addition to the composting mixture. The investigation of the composting process in static piles lasting 120 days was carried out in winter conditions in the area near the aforementioned wastewater treatment plant of an industrial complex situated in Lower Silesia (the south-western region of Poland), the complex specializing in breeding, slaughtering and processing of poultry.

Key words:
Composting, raw sludge, goose excrements, goose feathers, broiler excrements, biological composition

Introduction

Composting of organic wastes is an old practice, developed over the millennia of agricultural history. Undoubtedly, one of the most important inventions in the last century was the processing of organic components so that it was possible to use them in agriculture. Traditional objectives of composting are: stabilization of its chemical composition and destruction of pathogenic organisms. If it is necessary to process wastes of high humidity, the additional objective of composting is to remove excessive water. In the history of highly developed societies, waste composting was accepted and rejected alternatively. It was only at the beginning of the 1970s that the process of composting gained support thanks to an elaboration of the technology of composting municipal sewage sludge.[1–3] For now it is safe to say that there is some stagnation in the development of composting techniques and that probably there is no country where this process could be considered as significant in the technology of removing organic wastes, both municipal or industrial.[4–7] Nowadays, the exception is Austria where the process of composting is best mastered from the technological and organizational point of view; it is guaranteed thanks to the legislation constantly modified in order to keep developing technologies for collecting and processing organic waste. The whole matter is confirmed by the fact that only in Vienna, within a year about 100 000 t of organic fraction released from the municipal waste are composted.[8] Composting industrial waste coming from animal and poultry farming, as well as animal and poultry processing remains an open issue,[9–11] because in this case it is possible to utilize different components in proportions depending on the parameters necessary in the composting process, such as: humidity, temperature, amount of oxygen, porosity, and the mole ratio $r_{C/N}$. Poultry excrements contain pathogens like: *Salmonella* sp., *Campylobacter* sp., and bacteria which constitute an indicator of fecal contamination: different species of *coli, Escherichia coli* and fecal intestine streptococcus.[11,12] At the same time, it is known that poultry waste contains large amounts of proteins and fat that cause their intense odor particularly during storage and utilization as fertilizer. Like elsewhere, in Poland it is generally considered that the process of composting farm wastes, and wastes from slaughterhouses and meat processing plants is the simplest method of stabilizing them and securing a satisfactory degree of decontamination.[6,13,14] Together with the aforementioned wastes, it is also possible to compost sewage sludge from the industrial branches presented in this study.

Research methodology and scope

The aim of the research was neutralization and stabilization of waste generated in poultry breeding and processing. As a method of processing such

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Table 1 – *Fraction of particular components in the piles*

Waste component	Amount and humidity of wastes	
	pile 1	pile 2
broiler excrements	200 kg (51.1 % H_2O)	450 kg (52.4 % H_2O)
goose excrements	1000 kg (58.2 % H_2O)	3000 kg (57.6 % H_2O)
sludge from the drying beds	300 kg (50.6 % H_2O)	250 kg (50.7 % H_2O)
mixed raw sludge	–	200 kg (98.2 % H_2O)
mature compost	500 kg (69.2 % H_2O)	–
intestine remainders	300 kg (69.4 % H_2O)	–
goose feathers	300 kg (76.6 % H_2O)	400 kg (73.3 % H_2O)
pine sawdust	–	50 kg (12.1 % H_2O)
milled pine bark	–	50 kg (6.1 % H_2O)
rye straw chaff	–	50 kg (8.7 % H_2O)
rye straw	200 kg (9.1 % H_2O)	100 kg (9.1 % H_2O)

waste, the composting process in static piles was proposed.

The research was carried out in the area of a wastewater treatment plant of a poultry works, which was quite comfortable because of the availability of the basic components such as sludge, goose feathers, intestine remainders and excrements. Additional elements (bark, sawdust and straw) were brought from the neighbouring sawmill and farm. Initially prepared substrates were mixed together and stored in piles of volume of $V = 4$ to 6 m^3. During the process, the temperature in the piles and the external temperature were taken and registered permanently. Rainfall and snowfall as well as the course of pile compression (reduction in height) were recorded.

Chemical and biological analysis of particular constituents was carried out before, during and after the composting process. The chemical analysis consisted of determining the contents of organic mass, organic (elementary) nitrogen, humidity and pH of the water extract. Bacteriological analysis consisted of determining the general number of bacteria on the nutritious agar and the general number of bacteria on the selective bases.

After completing the composting process, the full identification of bacteria from *Enterobacteriaceae* was also carried out.

The mycological analysis consisted of determining the presence of fungi in the samples sowed on the bases Sabouraud (37 °C) and Czapek (20 °C).[15]

The parasitological analysis consisted of determining the number of protozoa cysts, ova of parasite worms and ova of arthropoda. The analysis was carried out based on the Mac Master method.[16]

Table 1 shows the results for two compost piles of different component mass fractions.

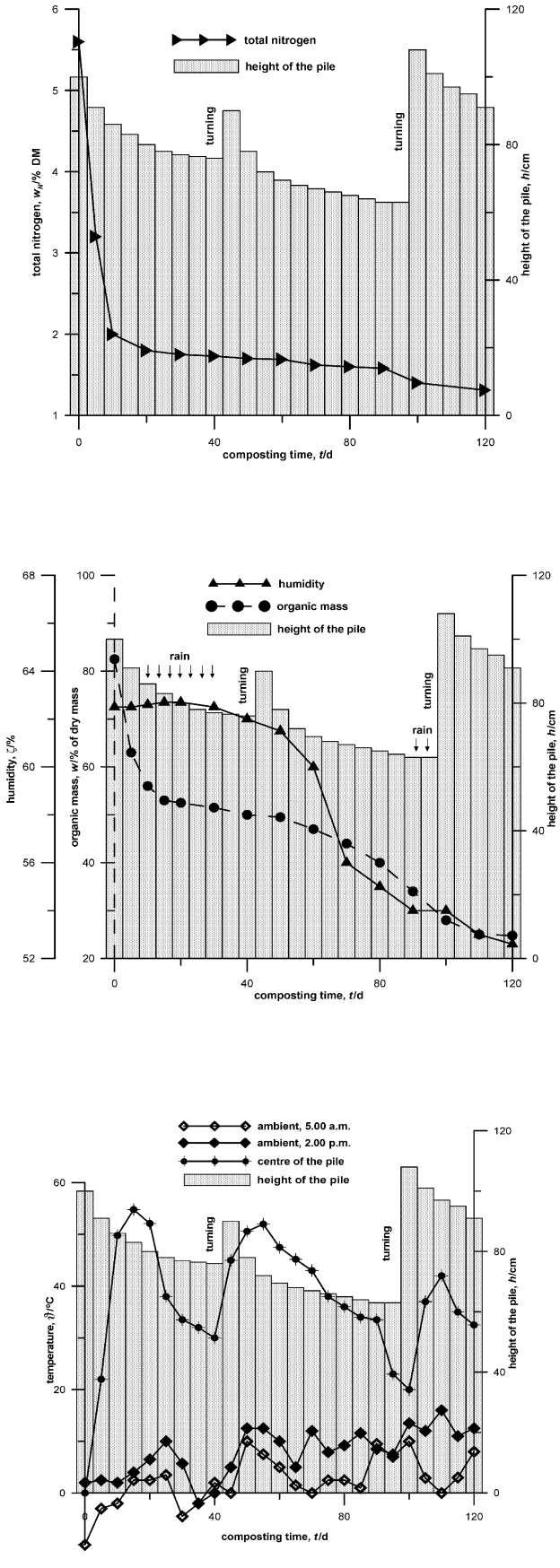
The main difference between the contents of the components in the two piles described in the table was that, first, pile No. 1 contained the remains of poultry bowels that were absent in pile No. 2 and, second, raw municipal sludge was applied in pile No. 2 that was not applied in pile No. 1. Besides, pine bark and pine sawdust were applied in pile No. 2 – in pile No. 1 matured compost was applied instead.

The investigation of composting for the series described here was carried out between January and April, meaning practically in winter conditions. Rye straw was used ($\delta = 15 – 20$ cm thick layer) as a thermal isolation; such straw was also used as an interlayer between the layers of raw compost. The task of this interlayer was to enable the oxygen to penetrate the composting mass.

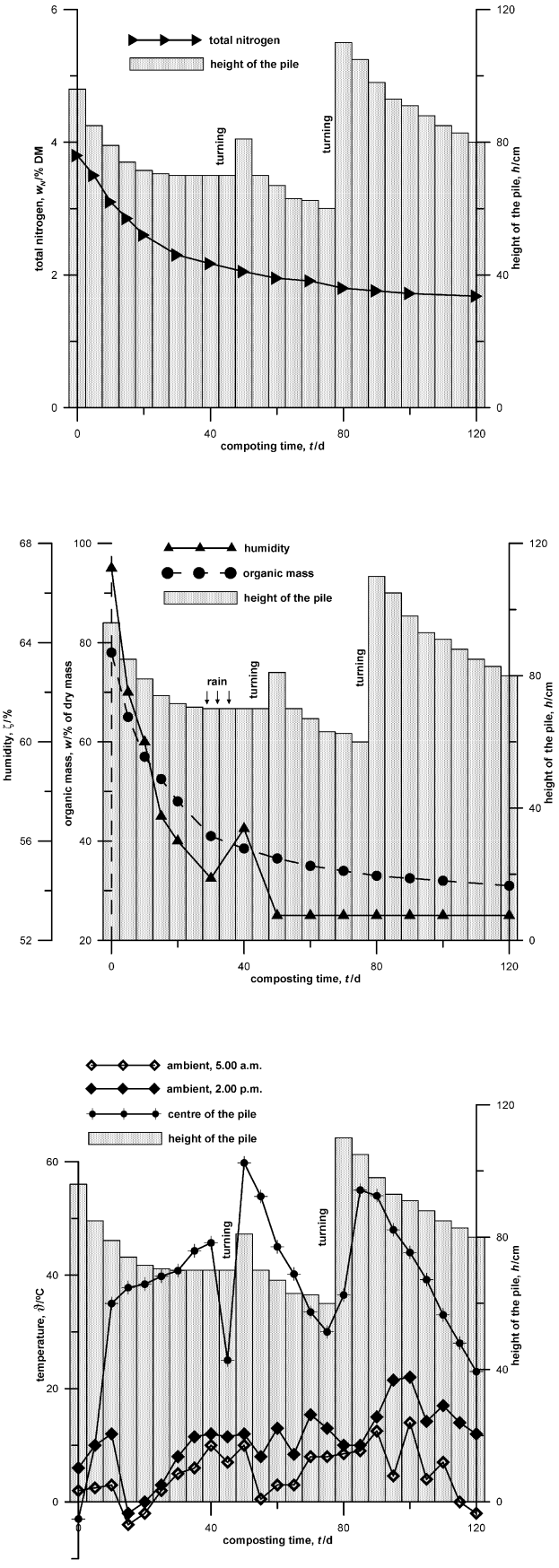
During the process, the piles were thrown over twice.

Results and discussion

The analysis of the chemical composition of the compost components is shown in Table 2. Changes in the humidity of the piles, consistence of total nitrogen, organic mass, and the process of pile compression, as well as the changes in temperature in the piles, the changes in external temperatures over 120 days of the process are shown in Fig. 1 for pile 1, and in Fig. 2 for pile 2.



F i g . 1 – *Course of the changes in total nitrogen content, organic mass, humidity, temperatures in pile, and height of the pile, as a function of composting time. Pile No. 1.*



F i g . 2 – *Course of the changes in total nitrogen content, organic mass, humidity, temperatures in the pile, and height of the pile, as a function of composting time. Pile No. 2.*

Table 2 – *Chemical composition of particular compost components*

Waste type	Humidity (w_{H_2O}/%)	Organic mass (w_{DM}/%)	$r_{C/N}$	pH of the water extract
broiler excrements	51.1–52.4	79.22	17	8.34
goose excrements	58.2–57.6	83.36	42	7.02
sludge from the drying beds	55.6–56.3	50.24	14	7.36
mixed raw sludge	98.2	68.32	18	6.92
mature compost	69.2	54.68	11	7.26
intestine remainders	69.4	94.32	4	8.12
goose feathers	73.3–76.6	91.94	3	7.92
pine sawdust	12.1	93.20	560	6.26
milled pine bark	6.1	90.92	320	6.62
rye straw chaff	8.7–9.1	96.22	110	7.38

The results of the bacteriological composition analysis (the general number of bacteria) for particular components of the composts, and also for the raw composts and mature composts are shown in Table 3. For samples of mature composts, full quantitative analysis (Table 4) and qualitative analysis for the bacteria from *Enterobacteriaceae* family (Table 5) was carried out.

The results of the bacteriological analysis indicated that total elimination of bacteria in the composts did not occur. A large population of mesophile and psychrophile bacteria was shown. Most of them were resting spores (see: Table 3). Therefore, the elimination of resting forms from the compost is difficult to achieve because of their great resistance to physical and chemical factors. An accurate analysis of bacteria from the *Enterobacteriaceae* family was carried out because there was the greatest possibility of finding pathogenic bacteria among them. A quantitative analysis of

Table 3 – *Bacteriological composition of particular components of raw composts and mature composts*

Waste type	General number of bacteria on the agar in 1 g of the sample			
	mesophiles 37 °C	psychrophiles 20 °C	resting spores	
			37 °C	20 °C
broiler excrements	$2.1 \cdot 10^6$	$7.9 \cdot 10^7$	$1.3 \cdot 10^6$	$9.7 \cdot 10^7$
goose excrements	$3.4 \cdot 10^9$	$9.2 \cdot 10^9$	$2.2 \cdot 10^8$	$9.2 \cdot 10^8$
goose feathers	$2.4 \cdot 10^7$	$8.8 \cdot 10^8$	$5.4 \cdot 10^8$	$7.1 \cdot 10^8$
intestine remainders	$2.1 \cdot 10^7$	$7.2 \cdot 10^7$	$3.6 \cdot 10^7$	$4.6 \cdot 10^8$
sludge from the drying beds	$8.6 \cdot 10^9$	$6.8 \cdot 10^{10}$	$7.2 \cdot 10^8$	$1.8 \cdot 10^{10}$
mixed raw sludge	$8.0 \cdot 10^9$	$3.2 \cdot 10^{10}$	$8.2 \cdot 10^7$	$3.6 \cdot 10^9$
pile 1				
raw compost	$3.3 \cdot 10^9$	$3.6 \cdot 10^{10}$	$2.8 \cdot 10^8$	$3.2 \cdot 10^8$
compost after 120 days of the process				
a) internal layer	$1.6 \cdot 10^7$	$4.2 \cdot 10^7$	$1.6 \cdot 10^6$	$2.2 \cdot 10^6$
b) external layer	$3.2 \cdot 10^8$	$1.6 \cdot 10^9$	$5.2 \cdot 10^6$	$1.2 \cdot 10^7$
pile 2				
raw compost	$1.2 \cdot 10^9$	$2.8 \cdot 10^{10}$	$8.8 \cdot 10^7$	$2.8 \cdot 10^8$
compost after 120 days of the process				
a) internal layer	$9.6 \cdot 10^6$	$8.8 \cdot 10^6$	$3 \cdot 10^5$	$1.8 \cdot 10^5$
b) external layer	$7.2 \cdot 10^8$	$3.6 \cdot 10^8$	$6.6 \cdot 10^6$	$1.6 \cdot 10^7$

Table 4 – *Number of bacteria from the Enterobacteriaceae family in 1 cm³ of mature composts. Inoculation on selective bases.*

Base type	Marking of the sample of mature compost			
	external layer	internal layer	external layer	internal layer
	pile 1		pile 2	
MacConkey	$8.0 \cdot 10^5$	$7.5 \cdot 10^4$	$2.2 \cdot 10^6$	$4.2 \cdot 10^4$
SS	$8.0 \cdot 10^5$	$5.4 \cdot 10^4$	$2.8 \cdot 10^6$	$2.8 \cdot 10^5$
Sołtys	$2.6 \cdot 10^6$	$3.6 \cdot 10^5$	$6.8 \cdot 10^6$	$2.2 \cdot 10^5$

bacteria from the *Enterobacteriaceae* family was carried out on the bases of different selectivity. They were: MacConkey's base, SS base and Sołtys base (Table 4). It was shown that the population of the bacteria *Enterobacteriaceae* was on a high level in all samples of the composts ranging from $4.2 \cdot 10^4$ to $6.8 \cdot 10^6$ cfu. The amount of *Enterobacteriaceae* in the compost of "pile 1" and "pile 2" were on a similar level. For samples described here, qualitative analyses were also carried out (Table 5); they confirmed that pathogenic forms for people and animals are present in composts. It seems that the reason for the presence of numerous pathogenic bacteria from the *Enterobacteriaceae* family in the compost after four months of maturation is secondary contamination with wastewater aerosols. They could have got to the compost piles from the wastewater aeration tanks because the distance between those objects was about 10 m; moreover, the level of waste in the aeration tank was about 6 m higher than the area of the composting plant.

The mycological investigation (Table 6) showed that during the composting process a significant decrease occurred in the amount of fungi of the group *Mucor* sp., *Penicilium* sp. and *Trichoderma*. Fungi of group *Aspergillus* and *Candida* were exterminated.

Then, the results of parasitological analysis revealed (Table 7) that during the process, the ova of *Ascaridia* and *Capillaria* present in the raw compost had been destructed. In the mature compost, only single ova of arthropoda were present, which is typical for the composting process.

Conclusions

1. Wastes from industrial farming and poultry processing are easily susceptible to stabilization of their chemical composition during the composting process. They undergo self-heating easily in spite of the fact that the process was carried out in winter conditions even at external temperature of −10 °C.

Table 5 – *Pathogens and relative pathogens bred in mature composts*

Species of bacteria	Presence of certified strains in the sample			
	pile 1		pile 2	
	external layer	internal layer	external layer	internal layer
Enterobacter amylovara	+	–	+	+
Escherichia coli	+ + +	–	+ +	+
Klebsiella pneumoniae	+ +	+	+ +	–
Serratia filaria	+ +	–	+	–
Serratia odorifera	+	–	–	–
Xenorkabdus luminescens	–	–	+	+
Xenorkabdus sp.	+ + +	+ +	+	+

Note: (+) single, (+ +) numerous, (+ + +) large number.

Table 6 – *Mycological composition analysis of particular components of fresh compost and mature compost*

Sample type	Sabouraud base (37 °C)	Czapek base (29 °C)
pile 1 raw compost	*Mucor* sp. (+ + +) *Aspergillus niger* (+) *Penicillium* sp. (+ +) *Candida* sp. (+) *Trichoderma* (+ + +)	*Mucor* sp. (+ +) *Penicillium* (+ +)
mature compost internal layer	*Mucor* sp. (+ +) *Penicillium* (+ +) *Trichoderma* (+ + +)	not found
mature compost external layer	*Mucor* sp. (+) *Penicillium* (+ + +) *Trichoderma* (+)	not found
pile 2 raw compost	*Aspergillus niger* (+ +) *Penicillium* sp. (+ + +) *Trichoderma* (+)	*Mucor* sp. (+ +) *Penicillium* (+ + +) *Aspergillus niger* (+)
mature compost internal layer	*Penicillium* (+ +) *Trichoderma* (+)	not found
mature compost external layer	*Trichoderma* (+)	not found

Note: (+) single, (+ +) numerous, (+ + +) large number.

Table 7 – *Parasitological composition of the wastes and the raw and mature composts*

Sample type	Protozoa cysts	Helminth ova	Arthropoda ova
broiler excrements	(+)	*Capillaria* (+)	(+ +)
goose excrements	(+)	*Ascaridia* (+)	(+ +)
feathers	(−)	(−)	(+)
fermenting sludge	(+)	*Ascaridia* (+ +) *Capillaria* (+)	(+ + +)
pile 1 raw compost	(+)	*Ascaridia* (+) *Capillaria* (+)	(+ + +)
mature compost (centre of the pile)	(−)	(−)	(+)
pile 2 raw compost	(+)	*Ascaridia* (+) *Capillaria* (+)	(+ + +)
mature compost (centre of the pile)	(−)	(−)	(+)

Note: (+) single, (+ +) numerous, (+ + +) large number, (−) not found.

2. As a result of composting, the numerous arthropoda ova decreased and helminth ova (*Ascaridia* and *Capillaria*) were eliminated.

3. In mature composts, a large number of psychrophile and mesophile bacteria was found; among them resting spores were found.

4. Temperatures in the piles were close to pasteurization conditions; in spite of this, it was impossible to obtain a significantly decontaminated product. This could be due to the fact that the compost piles were situated in the close neighbourhood of a wastewater aeration tank. As there was a possibility of secondary contamination of the composts with the wastewater aerosols, it would be better to carry out the process far from the wastewater treatment plants or in closed reactors. This also might be the effect of insufficiently precise turning of the piles.

5. No parasites such as *Ascaris* sp., *Trichuris* sp. and *Toxocara* sp., or *Salmonella* bacteria were found in the waste after the composting process. In case of composts being applied in agriculture, the presence of *Enterobacteriaceae* bacteria, as well as fungi and arthropoda eggs, is not a subject of legal regulations. Therefore, composts having parameters such as those measured in this study, fulfill Polish and European Union legal requirements with reference to sanitary assessment, and their application in agriculture is permitted.

List of symbols

h – height, cm

$r_{C/N}$ – mole ratio

ζ – humidity, %

t – time, d

V – volume, m^3

w – mass fraction

δ – thickness, cm

ϑ – temperature, °C

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