Management of distillery stillage by composting process

Agnieszka Piotrowska-Cyplik, Jacek Dach[*], Katarzyna Czaczyk[**], Paweł Cyplik[**], Zbigniew Czarnecki
Institute of Food Technology of Plant Origin, Faculty of Food Technology,
Wojska Polskiego 31, 60-624 Poznan, POLAND
e-mail: apio@au.poznan.pl
[*]Institute of Agricultural Engineering
[**]Department of Biotechnology and Food Microbiology,
The August Cieszkowski Agricultural University of Poznan

Summary

This study undertook investigations on the elaboration and determination of the utilisation efficiency of distillery stillage composting process using structure-forming materials (straw and farmyard manure). The objective of the performed investigations was to ascertain possibilities of obtaining in short time stable compost intended for non-industrial use. Therefore, during the 180-day period of experiments established in 2 compost-pile variants (each in 3 replicates), changes in the temperature, humidity and pH were monitored. In addition, the level of mineralization of the composted organic matter as well as changes in the ash content, mass balance of piles and bulk density in the piles were also determined. The authors also analyzed changes in the content of total C, N and P as well as the mutual ratios of these macro-elements C:N and C:P and changes in their $N\text{-}NH_4^+$, $N\text{-}NO_3^-$ and $P\text{-}PO_4^{-3}$ ion forms in the water extracts from compost heaps in relation to the composting time. It was found that the addition of structure-forming organic materials, especially farmyard manure, exerted a significant influence on the intensification of the composting process of distillery stillage. The performed comparative studies on the effect of the addition of two different structure-forming materials on an intensification of mineralization process in a pile with addition of manure was evaluated. The reduction of C:N rate from 40 to 22 in this pile was established.

Introduction

The potato stillage, a by-product of the process of alcohol production, which remains after the separation of crude alcohol from the distillery beer in small farm and industrial distilleries processing starch raw materials (potatoes, grain) and molasses to manufacture ethyl alcohol are treated as a waste exceptionally difficult to utilise (Banerjee and Biswas, 2004; Manisankar et al. 2004). The main purpose of waste composting is the production of organic fertilisers (composts), while the secondary objective of this process is to diminish the arduousness of organic wastes for the environment (Fauci et al., 1999; Giusquiani et al. 1995). Composting is a biotechnological process, which can be justified if the manufactured product in the form of compost is utilised as a fertiliser to improve and fertilise soil or ameliorate degraded areas (Eghball, 2002). This application exerts a positive impact on, among others, the improvement of soil structure, reduction of the utilisation of mineral fertilisers, which is one of the main principles of rational management.

Materials

The experimental material for investigations was a distillery spent wash obtained from a distillery in Siekierki Wielkie near Swarzędz as well as wheat straw and farmyard manure. The experimental compost piles were composed on the basis of weight ratios calculated per the amount of carbon and nitrogen brought into the compost volume in each of their components.

The prepared piles had the following weight composition (in kg DM)
Pile I – potato distillery stillage (120 kg) + farmyard manure (31.2 kg) X 3 replicates.
Pile II – potato distillery stillage (120 kg) + straw (15.1 kg) X 3 replicates.

Analytical methods

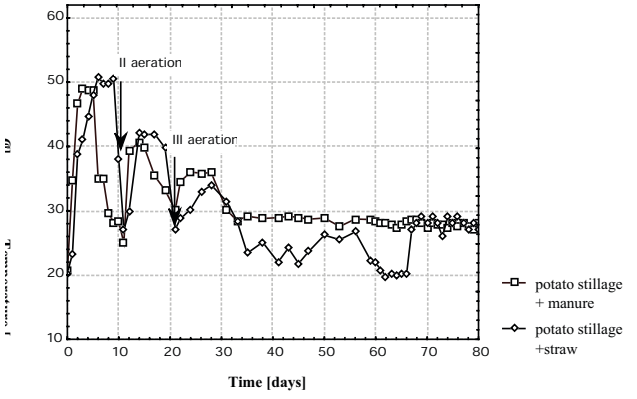
The total nitrogen was estimated by the Kjeldahl method Kjeltec System 1026 Distilling Unit Tecator. Total carbon was assessed by the Tiurin method. The total phosphorus -by the titrimetric method (BN-88 9103-06/02). Ammonium ion concentrations were determined by Waters liquid chromatographer with a UV detector. A Transgenomic ICSep CN2 (Merck) column equipped with a pre-column was used. The concentrations of anions (nitrates and phosphates) in water extracts were determined using the HPLC (Merck-Hitachi) with a UV detector. The ions discharge column Polyspher IC AN – 1 (Merck) with a pre-column.

Results and discussion

Influence of the duration of the composting process on changes in the total carbon, nitrogen and phosphorus concentrations in the composted piles

Carbon and nitrogen are the most important components both determining and limiting the microbiological waste decomposition (Iglesias-Jimenez and Perez-Garcia, 1992; Eiland et. al., 2001). The supplementation of the stillage with structure-forming materials enhanced the intensity of mineralization processes which, in turn, led to the reduction in the carbon content by 35% in the pile supplemented with manure and by 23% - in the pile with straw supplementation ($p<0,01$) (Tab. 1). The nitrogen content in stillage piles with the addition of structure-forming materials did not change considerably, whereas the phosphorus content increased in the pile with straw from 15 to 26 g $\cdot$g^{-1} dry matter, and in the pile with manure - from 18 to 27 g $\cdot$g^{-1} dry matter. Changes in the C, N, and P content resulted in a systematic narrowing of the C:N and C:P ratios in the composted material.

Fig. 1. Temperature changes in distillery stillage composting piles



The temperature changes in distillery stillage composting piles did not change after 80 days. The temperature after this time was evaluated at the 30^{O}C (Fig. 1).

In the pile with straw, the C:N ratio decreased from 42 to 29 and that of C:P - from 18 to 9, whereas in the “stillage+manure” compost, the C:N ratio decreased from 40 to 22 and that of C:P-from 17 to 8. In literature (Chanysak and Kubota, 1981; Iglesias-Jimenez and Perez-Garcia, 1992), it is generally accepted that the value of C:N ratio at the level of about 15 indicates the stabilization of the composting mass. The calculated C:N values in this study show that composts supplemented with manure reached sufficient maturity on the 60th day of the experiment. At that time, the organic matter was found to decrease which was accompanied by the decrease of carbon and nitrogen compounds. From the above-described research, it is evident that the piles with the manure supplement

were characterised by a stronger narrowing of the C:N and C:P ratios, which resulted in obtaining more mineralized composts. On the other hand, the piles with straw showed a lower reduction in the C:N and C:P ratios giving compost with higher organic matter content.

Influence of duration of the composting process on changes in $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{-3}$ ions content in water extracts from composted piles

During the composting, processes leading to significant changes in the concentrations of the examined ions in water extracts from the composts took place. In the course of distillery stillage composting process, it was possible to observe changes in nitrate, phosphate and ammonium nitrogen concentrations occurring during the mineralisation process of organic substances. In all experimental treatments, a significant increase in the ammonium ion concentrations in water extracts was observed. Rapid changes in the concentration of $N\text{-}NH_4^+$ ions occurred in the piles with the addition of straw and manure, where on day 10 of the process, in case of the pile with manure, the $N\text{-}NH_4^+$ ion concentration reached 127 mg·dm^{-3} and in the pile with straw – 89.5 mg·dm^{-3}. From then on, the ammonium ion concentration decreased following the nitrification process, which ran more intensively in the pile with the manure supplement. The concentration of nitrates manufactured during nitrification was about 24% higher in water extracts from the pile with the manure addition than in the pile with straw. In both stillage piles, the phosphate concentration in water extracts did not change during the entire process. It is evident from the presented results that the ammonium and nitrate ion concentrations in water extracts from piles were positively correlated with pH changes. During the composting process, the ammonium ions were released resulting in the pH increase but later on the nitrification processes resulted in the pH decrease. The observed low concentration of phosphate ions was caused by the formation of poorly soluble calcium salts.

Table 1. Changes of selected physico-chemical parameters in compost piles of distillery stillage with manure and straw

	Days					
	0	10	20	45	90	180
distillery stillage+manure pile						
C (g•kg^{-1} dm)	307±11	268±14	238±8	230±11	224±8	205±9
N (g•kg^{-1} dm)	7,6±0,8	8,4±0,5	9,25±0,6	9,25±0,9	9,24±0,8	9,4±0,5
C:N	40	32	26	24	24	22
P(g•kg^{-1} dm)	18±0,4	16,2±0,2	18,6±0,6	21,8±0,8	24,6±0,9	27±0,5
$N\text{-}NO_3^-$ (mg•kg^{-1} dm)	95±0,8	330±0,7	505±0,6	618±0,7	691±0,6	736±0,5
$N\text{-}NH_4^+$ (mg•kg^{-1} dm)	1139±11	1260±15	1270±18	745±21	301±20	198±12
$P\text{-}PO_4^{3-}$(mg•kg^{-1} dm)	29,7±0,7	33,1±0,4	22,5±0,6	12,8±0,7	13,3±0,6	12,7±0,5
pH	5,9	7,1	8,3	8,8	8,4	8,3
distillery stillage+straw pile						
C (g•kg^{-1} dm)	306±16	281±13	246±11	248±10	247±14	236±14
N(g•kg^{-1} dm)	7,43±0,6	7,78±0,8	8,91±0,5	8,04±0,2	8,13±0,4	8,30±0,6
C:N	41	36	34	30	30	28
P (g•kg^{-1} dm)	17,04±0,9	16,7±0,6	19,72±9,0	20,81±10	21,97±0,7	26,11±0,6
$N\text{-}NO_3^-$ (mg•kg^{-1} dm)	4,4±0,2	21±0,6	33±0,4	44±0,8	48±0,9	51±0,8
$N\text{-}NH_4^+$ (mg•kg^{-1} dm)	92±5,0	890±14	860±12	590±11	267±10	112±9,0
$P\text{-}PO_4^{3-}$(mg•kg^{-1} dm)	32,2±0,5	25,3±0,4	14,3±0,6	13,7±0,7	12,6±0,9	13,0±0,8
pH	5,4	6,3	7,5	8,5	8,3	8,2

Conclusions

The manure supplement allowed to obtain highly-mineralized compost, which, in turn, reduced the arduousness of the waste material.
The mineralization process of the stillage with straw was slower, which allowed to obtain the compost richer in organic matter of better fertilizing values.

The effects of mineralization processes taking place in the composted piles included losses of carbon and nitrogen leading to the reduction of the C:N and C:P ratios.

It was found that changes of pH, anion and cation contents observed in this study and caused by the mineralization and nitrification processes may constitute good indicators, which can be applied for the evaluation of the appropriate progress of composting processes.

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