NITROGEN CONVERSIONS DURING THE COMPOSTING OF MANURE/STRAW MIXTURES

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ABSTRACT

Hot composting of mixtures of straw and manure almost always leads to considerable NH_3 losses by volatilization and relatively small gains in organic nitrogen which was shown by periodic determination of different forms of N during composting and mushroom growing.

INTRODUCTION

In the Netherlands there are locally large surpluses of manure, particularly of swine liquid manure (SLM), causing nuisance by malodour due to anaerobic protein degradation and high ammonium content. In cooperation with colleagues of the Mushroom Experimental Station and the Institute for Mechanization, Labour and Buildings, we investigated the aerobic composting of mixtures of straw and SLM, and of the fibrous part of SLM obtained by sieving. In this way we tried to transform SLM into a more manageable product without nuisance complaints, and to utilize the ammonia for microbial protein production. The advantages of straw as a carbon source for such a process (and the disadvantages of an easily degradable carbon source) are discussed by Grabbe (1978). Wheat straw is composed of about 43% cellulose, 23% pentosans, 8% other carbohydrates, 16% lignin, small amounts of protein and fat and 6% ash.
Composting could possibly result in a product which is composed of about 22% cellulose, 12% pentosans, 25% lignin, 28% biomass, small amounts of other carbohydrates and fat and 9% ash (total weight loss 35%). In this process lignin has not been used as a carbon source, but it can bind a certain amount of nitrogen. Mushrooms, however, are able to utilize this nitrogen-enriched lignin (Gerrits, 1969), so an obvious purpose for the compost is the use as a substrate for mushroom growing. If a biomass content of about 28% could be achieved, use as a roughage might be considered. Important parameters for composting are water and NH_4-content and pH (Gerrits, 1974). Therefore, questions to be answered by our experiments were: How will increasing amounts of moisture and NH_4-N from SLM, when added to straw, affect composting and the composition (quality) of the resulting composts for further use?

MATERIALS AND METHODS

Compost was prepared from fresh wheat straw, soaked with SLM for 3 days in containers. The SLM had the following composition:
Untreated 8% d.m., 4.9% o.m., 8.5 g/l Kjeldahl-N and 6.6 g/l NH_4-N.
Aerated 7% d.m., 4.9% o.m., 4.8 g/l Kjeldahl-N and 2.3 g/l NH_4-N.
The straw had 82.6% dry matter, the nitrogen content of which was estimated to be 0.5%. The following amounts of SLM were added to 200 kg chopped straw:

1. 400 liter SLM and 260 liter water (C_1)
2. 800 liter SLM (C_2)
3. 1200 liter SLM (C_3)
4. 800 liter SLM from an aerated storage (C_4)

Coarse fibre was separated from SLM with an AZO-sieving machine (180 μm mesh). Two composts F_1 (+) and F1 (-) were prepared from 400 kg coarse fibre each, one with (+) and one without (-) gypsum ($CaSO_4 \cdot 2H_2O$; 25 g/10 kg). To prevent too much loss of heat, the materials were incorporated as vertical segments in a 1 m high ridge of a conventional mixture. The pile was turned on days 3 and 7. Two nylon bags with coarse fibre from other origins, F_2 and F_3, were buried in conventional heaps in this way following normal composting temperatures. Composting for 8 days was followed by peak-heating (i.e. pasteurization and conditioning) for 10 days, spawning and mycelium growth for 12 days.
Small samples of coarse fibre F_1 in nylon bags were buried in compost that underwent conditioning in a tunnel with forced aeration, for 10 days at 50°C (F_1t(+) and F_1t(-)). Here, conditioning was directly followed by spawning and mycelium growth for 10 days.
Mushroom production on the composts was tested on a small scale.
In fresh samples of compost pH was measured and NH_3 was distilled off in the presence of MgO to determine the NH_4-N content. In dried, ground samples ash was determined by ashing at 600°C. Samples dried at 70°C were analysed for Kjeldahl-N, crude fibre (Van de Kamer, 1952) and lignin (organic matter nonhydrolysable with 72% H_2SO_4). Filtrates of samples hydrolysed with 6 N HCl by heating for 9 h in closed tubes at 120°C were analysed for Kjeldahl-N, NH_4-N and α-amino-N.

RESULTS AND DISCUSSION

From the composition of SLM and of aerated SLM it is clear that by aeration the SLM has lost much of its NH_4-N. However, organic-N (= Kjeldahl-N - NH_4-N) has increased, probably as a result of an increase in microbial biomass.
The rise of temperature at composting occurred most rapidly with mixture C_4 of straw and aerated SLM (figure 1). This can be explained by the presence of a large microbial biomass, adapted to aerobic conditions. The temperature of the straw/SLM mixture C_3 increased least rapidly. Heap C_3, with the highest moisture content (80%) may have had a limited oxygen supply. The heat capacity of the heaps also increases with the amount of SLM added to straw.
Temperatures of only 50°C were reached by composting F_1 coarse fibre.

Here the presence of only small amounts of easily degradable carbon compounds probably is the limiting factor.
Odour control was achieved except for NH_3, of which large amounts escaped, every time the heaps were turned.

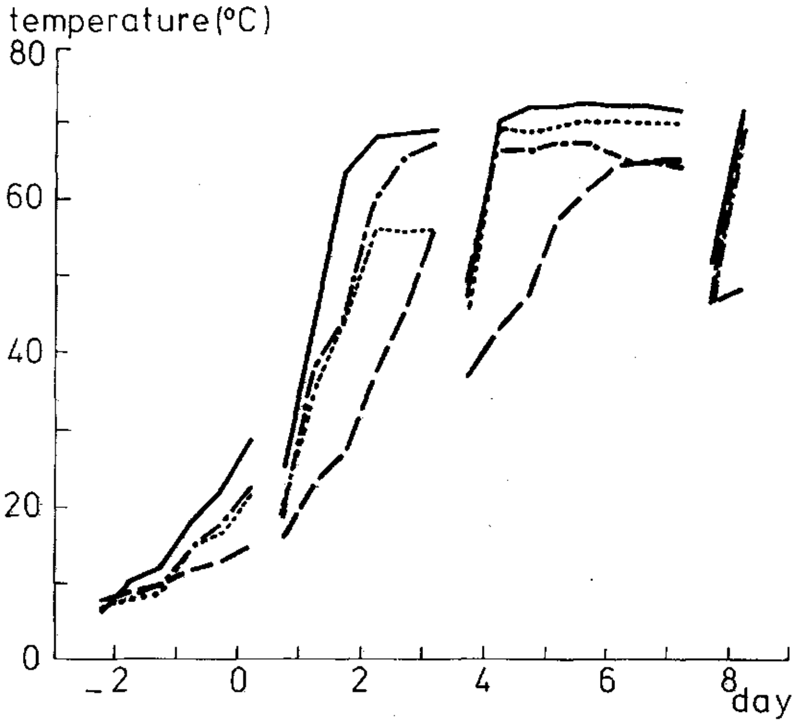

Fig. 1. Temperatures during composting of manure/straw mixtures. —·— = 1. ----- = 2. — — = 3. —— = 4.

Carbon and Nitrogen Transformations. Because C- and N-transformations occur together and are interrelated, both are discussed here. Table 1 shows how the amounts of dry matter, organic matter, crude fibre, lignin and various nitrogen fractions change during the process. This table was made by recalculating the contents at different times, assuming that the amount of ash is constant. Section I of table 1 presents amounts of components at day 8 (end of composting), day 18 (end of peak-heating) and day 81 (end of mushroom cropping) in % of those at day 3. (At day 1 no samples were taken because of heterogeneity). Ash content for C_I at day 8 strongly deviated and, therefore, was estimated by interpolation. Complete balance sheets could be calculated for the coarse fibre samples, which were conditioned in an aerated tunnel, on the basis of weight times content. Contents at day 10 (end of conditioning) and at day 20 (end of mycelium growth) are compared with those at day 1 (table 1 section II).

TABLE 1. Amounts of components in composts at different times, in % of those at day 3 (section I) or day 1 (section II and III)

		day	d.m.	o.m.	NH_4-N	Kjeldahl-N	α-NH_2-N_h	NH_4-N_h	crude fibre
I	C_1	8	87	84	38	156	126	165	-
	C_2	8	86	82	40	100	95	66	-
	C_3	8	92	89	59	102	101	70	-
	C_4	8	95	93	61	106	138	89	-
	C_1	18	71	65	8	141	109	167	51
	C_2	18	69	61	20	100	69	61	59
	C_3	18	77	70	24	94	103	67	73
	C_4	18	77	71	22	104	136	95	63
	C_1	81	59	51	15	139	105	153	-
	C_2	81	52	40	16	106	88	57	-
	C_3	81	56	44	7	93	78	61	-
	C_4	81	59	48	27	97	109	89	-
II	F_1t(-)	10	77	73	19	97	91	126	66
	F_1t(+)	10	76	68	26	90	91	111	57
	F_1t(-)	20	74	69	7	99	76	118	55
	F_1t(+)	20	76	68	14	99	78	141	54
III	F_2	8	94	93	56	108	109	146	104
	F_3	8	95	94	76	91	133	188	92
	F_2	18	69	63	1	141	124	97	37
	F_3	18	75	69	1	124	158	184	45
	F_2	30	63	56	3	150	118	85	23
	F_3	30	74	68	3	138	139	123	42

I and III conventional composting; II tunnel with forced aeration; for details, see text.

Table 1 section III gives data for the coarse fibre samples F_2 and F_3. Contents at day 8, at day 18 and day 30 (after 12 days of mycelium growth) are compared with those at day 1. In table 1 no data for the coarse fibre heaps F_1 (+) and F_1 (-) are given, because of unaccountable large ash fluctuations.
In figure 2 nitrogen balance sheets are shown for the composting of manure/straw mixtures C_1-C_4. Initial amounts of total nitrogen are calculated from the sum of nitrogen in straw and SLM (weight times N-Kj. in fresh samples). NH_4-N initially originates almost completely from SLM. At the end of composting on day 8, "total" nitrogen is

approximated by the sum of N-Kjeldahl (weight times N-Kj. in dried samples) and NH_4-N (weight times NH_4-N in fresh samples). The difference in total nitrogen thus calculated approximately gives the N-loss during composting in the form of NH_3. Figure 2 also shows that N-loss by C_1-C_4 increases with the amount of NH_4-N present at the start. The coarse fibre samples in the tunnel with forced aeration rapidly lost NH_4-N, as could be expected. NH_4-N levels in coarse fibre F_2 and F_3 are very low after 18 days, but not yet after 8 days (table 1).

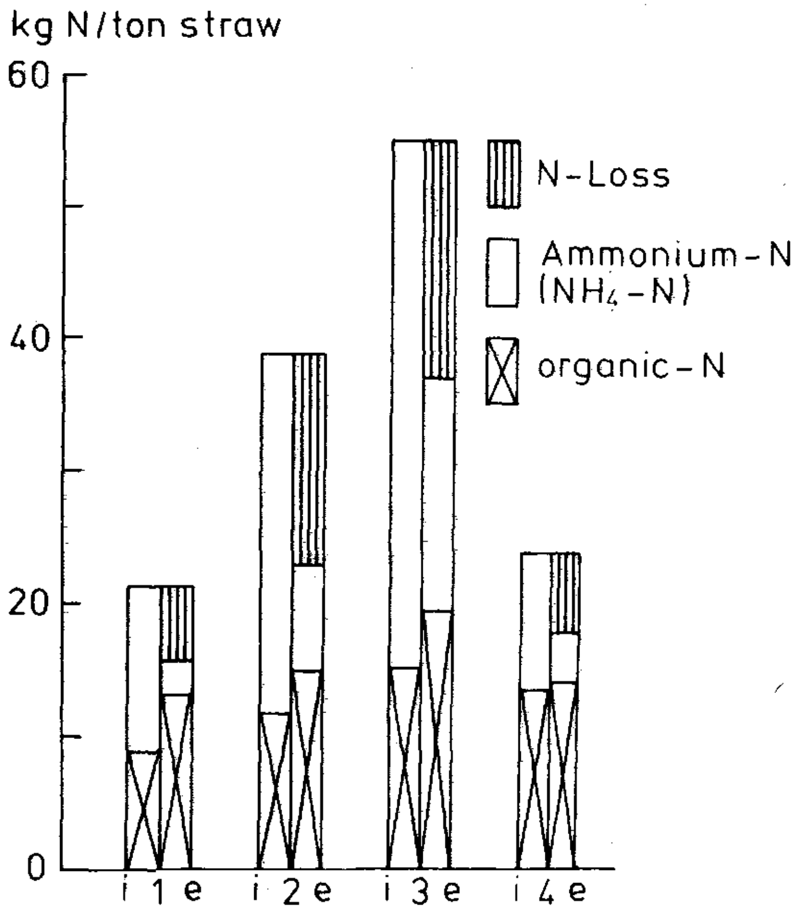

Fig. 2. Gain of organic nitrogen and loss of ammonium nitrogen during 8 days of composting. i = initial, e = end, 1-4 = different manure/straw mixtures (see text).

Figure 2 also shows that by composting the amounts of organic N in heaps C_1-C_4 increased only little. The increases are the net result of microbial synthesis and breakdown of organic N compounds. In C_1-C_3 this increase was about 4 kg N and in C_4 less than 1 kg N per ton of fresh straw. Clearly, hot composting of straw/SLM mixtures does not

favor the net production of a large amount of microbial biomass. (Since easily degradable carbohydrates are lost at the same time, the use of compost as a roughage hardly seems profitable.)
Table 1 confirms this view for C_1. Compared with day 3, the Kjeldahl-N content of C_1 has increased at day 8 and day 18, while C_2-C_4 show no large differences. Increases in organic N of C_2-C_4 as shown in figure 2, therefore must have occurred in the first 3 days, a situation similar to aeration of SLM where increases in organic N are only shown at retention times of less than 4 days.
Kjeldahl-N in the coarse fibre samples hardly changes in $F_1t(+)$ and $F_1t(-)$, while it increases in F_2 and F_3. More important than an increase in organic N per se is whether this increase reflects an increase in protein or only of other less valuable organic N-compounds. Some indication of this can be obtained from further analysis of acid hydrolysates.
α-amino-N in acid hydrolysates gives an estimate of the protein part of the samples. Gains in α-amino-N_h are noted for manure/straw mixtures C_4 and C_1 and for the coarse fiber samples F_2 and F_3; the other samples show losses. Even where gains are noted, protein content of the samples is only about 6 to 9% of organic matter. With time, gains become smaller or change into losses. Addition of large amounts of SLM obviously unfavourably affects the net amount of protein by composting.
NH_4-N in acid hydrolysates shows increases as well as decreases with time. With most samples this component tends to reach a value of about 0.6% of organic matter at spawning. Thus this analysis hardly discriminates among composts.
Increasing the amount of SLM added to straw decreases the percentage crude fibre breakdown. "Tunnel" samples show crude fibre losses already during the first 10 days, where the temperature permits fungal cellulolytic activity in contrast to hot composting. Crude fibre losses are considerable during peak heating of coarse fibre samples F_2 and F_3, leaving only little carbohydrates for the mushroom.
The lignin content (% of o.m.) increases during processing of all coarse fibre samples, although some lignin is degraded in the "tunnel" samples.

Yield of Mushrooms. Only with straw-SLM mixture C_1 so much NH_4-N had been lost on day 18 that free NH_3 was below the toxic level for the mushroom. Composts C_4, C_2 and C_3 had NH_4-N contents at spawning of 0.19, 0.47 and 0.73 with pH of 8.7, 9.0 and 9.0 respectively, resulting in toxic levels of free NH_3 for the mushroom. As a result no mushroom could be cropped from C_2 and C_3 and only 1.2 kg/m^2 from C_4.
In table 2 the different composts are given in order of decreasing yield with some data of their composition at the moment of spawning. A normal control compost yielded 19.1 kg/m^2. From table 2 it is clear that coarse fibre conditioned by forced aeration and compost of straw plus a small amount (2 m^3/ton) of SLM may be used for mushroom cultivation if some improvements can be made. Note that coarse fibre samples can be prepared for spawning by forced aeration in only 10 days. From table 2 it is clear that no single factor can fully explain differences in yields, but only a combination of factors.

TABLE 2. Composition of compost at spawning and mushroom yields

	Moisture content % of wet weight	NH_4-N % of d.m.	pH	Kjeldahl-N	α-NH_2-N_h	Crude fibre	Lignin	Mushroom yield kg/m^2
				% of o.m.				
$F_1t(+)$	63	0.23	7.2	2.62	1.28	25.4	31.7	15.4
$F_1t(-)$	66	0.14	7.3	2.49	1.12	25.9	31.6	13.5
C_1	73	0.08	8.2	2.42	0.81	28.4	-	11.6
$F_1(-)$	68	0.06	7.0	3.19	1.13	19.0	30.3	8.6
$F_1(+)$	67	0.51	7.5	3.23	1.12	20.5	31.8	7.6
F_3	56	0.02	7.5	3.18	1.49	16.6	34.2	6.2
F_2	54	0.03	6.7	3.42	1.41	14.3	32.7	3.2
C_4	75	0.19	8.7	2.65	1.17	30.3	-	1.2
normal (+gypsum)	63-68	<0.23	7.5	~3.2	1.0-1.3	~25	~32	18-22
		<0.023	8.5					

CONCLUSIONS

1. Only small increases in protein result from hot composting of straw/SLM mixtures or coarse fibre from SLM. The process does not hold a prospect for preparing a roughage.
2. Nitrogen losses during hot composting in the form of NH_3 are inevitable and increase with the amount of nitrogen-rich SLM added to the straw.
3. It is likely that by composting straw/SLM mixtures, followed by peak-heating, a product can be obtained suitable for mushroom growing, if no more than 2 m^3 SLM is added per ton of fresh straw.

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KEYWORDS

Composting, nitrogen loss, liquid manure, straw carbohydrates, microbial protein, mushroom.