ELSEVIER

Bioresource Technology **62** (1997) 37–42

Printed in Great Britain
0960-8524/97 $17.00

PII:S0960-8524(97)00080-1

EFFECTS OF TURNING FREQUENCY ON COMPOSTING OF SPENT PIG-MANURE SAWDUST LITTER

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(Received 10 February 1997; revised version received 26 May 1997; accepted 2 June 1997)

Abstract
Spent pig-manure sawdust litter (spent litter) disposed of from the pig-on-litter (POL) system was collected to investigate the effects of turning frequency on composting. Three heaps of the spent litter were piled up coinciding with the three turning frequency treatments: Pile A = turned every 2 days; Pile B = turned every 4 days; pile C = turned every 7 days. Turning frequency appeared to affect a number of important composting parameters; temperature, pH, NH_4^+*-N, humic acid and ATP content, and germination index. On the whole, piles A and B had a faster rate of composting and took a shorter time (two months) to reach maturity than did pile C. The phytotoxicity in piles A and B was also eliminated more efficiently than in pile C. These results suggest that turning every 2 or 4 days is the more suitable turning frequency for composting of spent litter. At this turning frequency, composting of spent litter will proceed at a faster rate, thus reaching maturity quicker (74 days). Furthermore, this turning frequency will help eliminate the phytotoxins in the spent litter much faster than turning every 7 days. However, since turning the piles every 2 days is more labour intensive, it is suggested that turning every 4 days be the practical turning frequency for composting of spent litter. © 1997 Elsevier Science Ltd.*

Key words: composting, turning frequency, temperature, pig manure, phytotoxicity.

INTRODUCTION

Wastes generated from pig farms are highly polluted and, if discharged directly onto land or into water-bodies, can cause undesirable effects such as unproductive crops, dissolved oxygen depletion and eutrophication (algal blooms) (Polprasert *et al.*, 1994). In Hong Kong, agricultural wastes, particularly pig manure, have been shown to be the major contributor to stream pollution, especially in the New Territories and in Urban parts of Hong Kong (Hodgkiss and Griffiths, 1987). Several methods have been evaluated for pig waste treatment and one of them is the pig-on-litter (POL) system. The POL system is a pig production method where pigs are reared on a litter bedding, which contains a mixture of sawdust and bacterial product, and the pig excreta (both faeces and urine) once deposited are quickly mixed with the litter bedding and decomposed *in-situ*. The nitrogenous compounds decompose rapidly leading to the eradication of the offensive odour of ammonia. Moreover, there is no unpleasant sight of the faeces, and the discharge of effluent is unnecessary (Tam and Vrijmoed, 1990). After 10–13 weeks, the pigs are removed from the pig pen and what is left is the spent pig manure sawdust litter (spent litter).

The spent litter from the POL system contains high concentrations of organic matter, N, P, K and trace elements, and also a significant amount of active microbial biomass, which is similar to an immature compost (Tam and Vrijmoed, 1993; Tiquia *et al.*, 1996a). The negative effects of applying immature compost to the soil–plant system have been discussed in the literature. Immature compost induces high microbial activity in the soil which reduces soil oxygen concentration and blocks existing soil-available N, which then gives rise to serious N-deficiencies in crops (Jimenez and Garcia, 1989). Application of immature compost as soil fertiliser and/or conditioner causes negative effects on seed germination and plant growth and development (Zucconi *et al.*, 1981a,b). Tam and Tiquia (1994) found that spent litter, removed from the POL system after being used for 6 months, inhibited seed germination and root elongation of some local vegetables. Therefore, in order to avoid these risks, the spent litter must undergo further composting and achieve full maturation before utilisation for crop production.

The spent litter from the POL system is a relatively new material for composting (Tam and

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Vrijmoed, 1993; Tiquia, 1996; Tiquia *et al.*, 1996a). For successful composting of spent litter, the optimum environmental factors such as aeration, moisture and temperature must be determined. Turning frequency is commonly believed to be a factor which affects the rate of composting as well as compost quality (Golueke *et al.*, 1954; Tiquia, 1996). Turning is often cited as the primary mechanism of aeration and temperature control during windrow composting (Gray and Biddlestone, 1973; Golueke, 1977; Michel *et al.*, 1996a,b; Tiquia, 1996). However, optimum turning frequencies for different materials vary widely and the effects of turning on various compost parameters are not well understood. In this study, the effects of turning frequency on composting of spent litter were examined by measuring the temperature, pH, moisture content, different forms of N, humification, ATP content and germination index.

METHODS

An ordinary pig pen was set up at the Ta Kwu Ling Pig Breeding Centre, New Territories of Hong Kong, employing the POL system. After 13 weeks of pig raising, the pig pens were left idle and the spent litter was collected and piled up in an open shed on the farm for further composting. Three heaps of spent litter were set up. The turning frequencies of these piles were every 2 days (Pile A), 4 days (Pile B) and 7 days (Pile C). Each pile was triangular in shape, about 2 m in width at the base and 1.5 m in height. The total weight of each pile was approximately 2000 Kg. The heaps were turned over using a truck and front-end loader. The moisture content was adjusted to 50% at the beginning of composting and no moisture adjustment was done thereafter. During the composting process, the ambient temperature and the temperature within each pile at a depth of 60 cm towards the central part of the pile were measured before turning.

Samples collected at five symmetrical locations in the pile were combined and mixed to give one composite sample. Triplicate composite samples were collected from each pile at day 0 and then weekly until the end of the composting trial. The spent litter was analysed for moisture content (105°C for 24 h); pH (1:10 w/v extract) using a pH meter (Hanna HI 8424); NH_4^+-N and $(NO_3^- + NO_2^-)$-N using the distillation method (Keeney and Nelson, 1982); cation-exchange capacity (CEC) (Harada and Inoko, 1980); humic (HA) and fulvic (FA) acid (Schnitzer, 1982); ATP content using the luciferin–luciferase method and a luminometer (Monolight 1500); and, the seed germination index of two local vegetables, Chinese cabbage (*Brassica parachinensis*) and tomato (*Lycopersicon esculentum*) using the methods described by Tam and Tiquia (1994) and Tiquia *et al.* (1996c).

RESULTS AND DISCUSSION

Turning frequency affected the rate of composting, time required to reach full maturation and elimination of phytotoxicity of the spent litter during composting. The changes in physical (temperature), chemical (pH and, concentrations of NH_4^+-N and HA) and biological (GI) properties revealed that composting of spent litter with a 2 or 4-day turning frequency had a faster composting rate than turning the spent litter pile with a 7-day turning frequency.

Temperature

At the beginning of the composting process, the temperatures of piles A (turned every 2 days), B (turned every 4 days) and C (turned every 7 days) were significantly higher than the air temperature (11°C) at between 47 and 52°C (Fig. 1). As composting proceeded, the temperatures of these three piles further increased, reaching a peak value of 66°C during the second week of composting and they were maintained at that high level until day 21 (thermophilic stage). After the thermophilic stage, the temperatures of all piles decreased gradually until they reached ambient temperature (around 27–30°C). The temperature of piles A and B reached ambient level at day 74 (2.5 months) while that of pile C took a much longer time (about 4 months). Previous studies on composting have shown that temperature can be used as a parameter to indicate the rate and extent of composting and maturity of composts (Golueke *et al.*, 1954; Tiquia, 1996; Tiquia *et al.*, 1997). They pointed out that a compost material could be considered mature when the temperature in the pile had cooled to the ambient level. Studies on composting of spent litter showed a positive correlation between temperature and microbial parameters such as total aerobic heterotrophs, O_2 consumption rate, ATP content and dehydrogenase activity (Tiquia, 1996; Tiquia *et al.*, 1996b; Tiquia *et al.*, 1997) indicating that temperature is an important and simple composting parameter.

ATP content

The pattern of change in ATP content of the piles was similar to that of temperature. The ATP contents of piles A and B rose to a peak of 0.27 μmol g^{-1} on day 14 from initial values of 0.05 and 0.07 μmol g^{-1}. This high level was maintained until day 25. After that, the ATP contents of piles A and B dropped rapidly to 0.08 and 0.12 μmol g^{-1} by day 42, further dropped to 0.01 and 0.02 μmol g^{-1} by day 60 and then maintained at these values until day 74 (Table 1). Pile C followed the same trend of

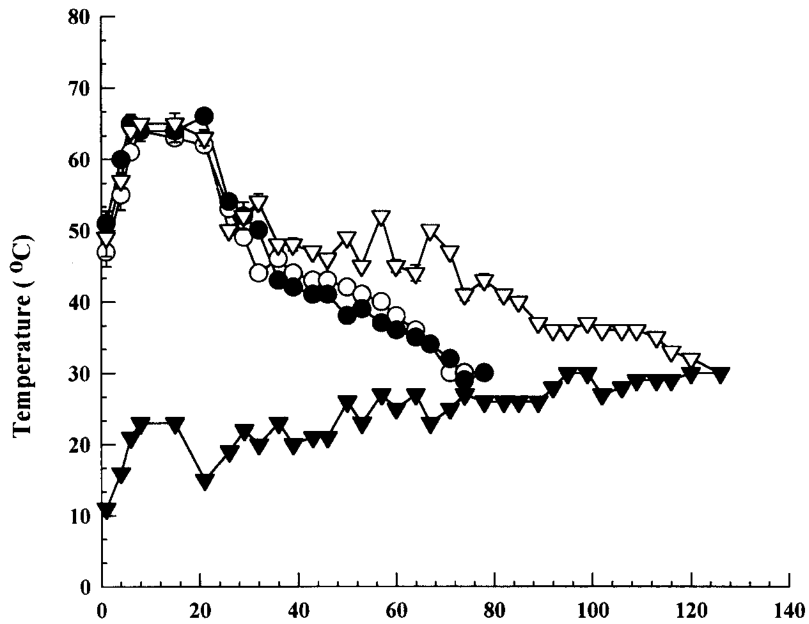

Fig. 1. Changes in air temperature and temperature within each pile of the spent litter during the composting process (○ = Pile A; • = Pile B; ▽ = Pile C; ▼ = air temperature; means and standard deviations of the three replicates are shown).

Table 1. Changes in chemical properties of the spent litter during composting[a]

Parameters	Treatments	Time (days) Day 0	Day 60	Day 74	Day 126
Physical parameter					
Temperature (°C)	Air	11	25	27	30
	Pile A	47	38	30	*ND*
	Pile B	51	36	29	*ND*
	Pile C	49	45	41	32
Chemical parameters					
pH	Pile A	8.52	6.00	5.35	*ND*
	Pile B	7.95	6.05	5.10	*ND*
	Pile C	8.09	7.88	5.92	4.84
Total N (%)	Pile A	1.86	1.90	1.66	*ND*
	Pile B	2.13	1.80	1.89	*ND*
	Pile C	2.36	2.19	2.31	2.26
NH_4^+-N (mg g^{-1})	Pile A	6.04	0.67	0.12	*ND*
	Pile B	6.56	0.96	0.13	*ND*
	Pile C	6.77	3.69	3.29	1.36
(NO_3^+ + NO_2^-)-N (mg g^{-1})	Pile A	0.08	0.12	0.08	*ND*
	Pile B	0.12	0.99	1.42	*ND*
	Pile C	0.08	1.24	1.87	4.36
HA (g Kg^{-1} O.M.)	Pile A	31.58	43.97	41.08	*ND*
	Pile B	34.73	41.99	42.76	*ND*
	Pile C	38.74	35.69	34.96	39.81
FA (g Kg^{-1} O.M.)	Pile A	109.23	101.14	109.86	*ND*
	Pile B	113.46	98.18	103.88	*ND*
	Pile C	118.11	103.68	98.95	99.84
HA:FA ratio	Pile A	0.29	0.44	0.37	*ND*
	Pile B	0.31	0.43	0.41	*ND*
	Pile C	0.33	0.34	0.35	0.40
Microbial parameter					
ATP content (μmol g^{-1})	Pile A	0.08	0.02	0.01	*ND*
	Pile B	0.06	0.01	0.01	*ND*
	Pile C	0.03	0.14	0.09	0.05

[a]Means of the three replicates are shown.
Pile A = pile turned every 2 days; pile B = pile turned every 4 days; pile C = pile turned every 7 days; *ND* = not determined as the piles had already reached maturity.

ATP changes as piles A and B until day 40. After day 40, the ATP content of pile C rose to a second peak of 0.15 μmol g^{-1}, but then fell to a final ATP value of 0.05 μmol g^{-1} by day 126, which was higher than piles A and B at the end of composting, suggesting that the spent litter in this pile was still biologically unstable after two months of composting.

Chemical parameters

The pH values of all piles were high (8–8.42) at the beginning of composting process. A very obvious drop in pH was observed on day 11: from between 8.0 and 7.3 for all piles. This coincided with a decrease in the NH_4^+-N and an increase in (NO_3^-+NO_2^-)-N content of the spent litter pile on day 11. The pH of piles A and B dropped rapidly between 5.10 and 5.35 by day 74 while that of pile C dropped to 5.92 (Table 1).

The NH_4^+-N content of all piles decreased from an initial value of 6.0–6.7 mg g^{-1} to 5.2–5.5 mg g^{-1} by day 11. This fall may have been due to the rapid conversion of NH_4^+ to NO_3^- and/or NO_2^-; which actually increased on day 11. After the initial drop, the NH_4^+-N content of piles A and B rose again to as high as 7.2 mg g^{-1} then dropped to a very low NH_4^+-N level (0.10 mg g^{-1}) by day 74, while that of pile C declined, but to a higher level (1.36 mg g^{-1}) by day 126 (Table 1). It has been noted that the absence of, or decrease in, NH_4^+-N is an indication

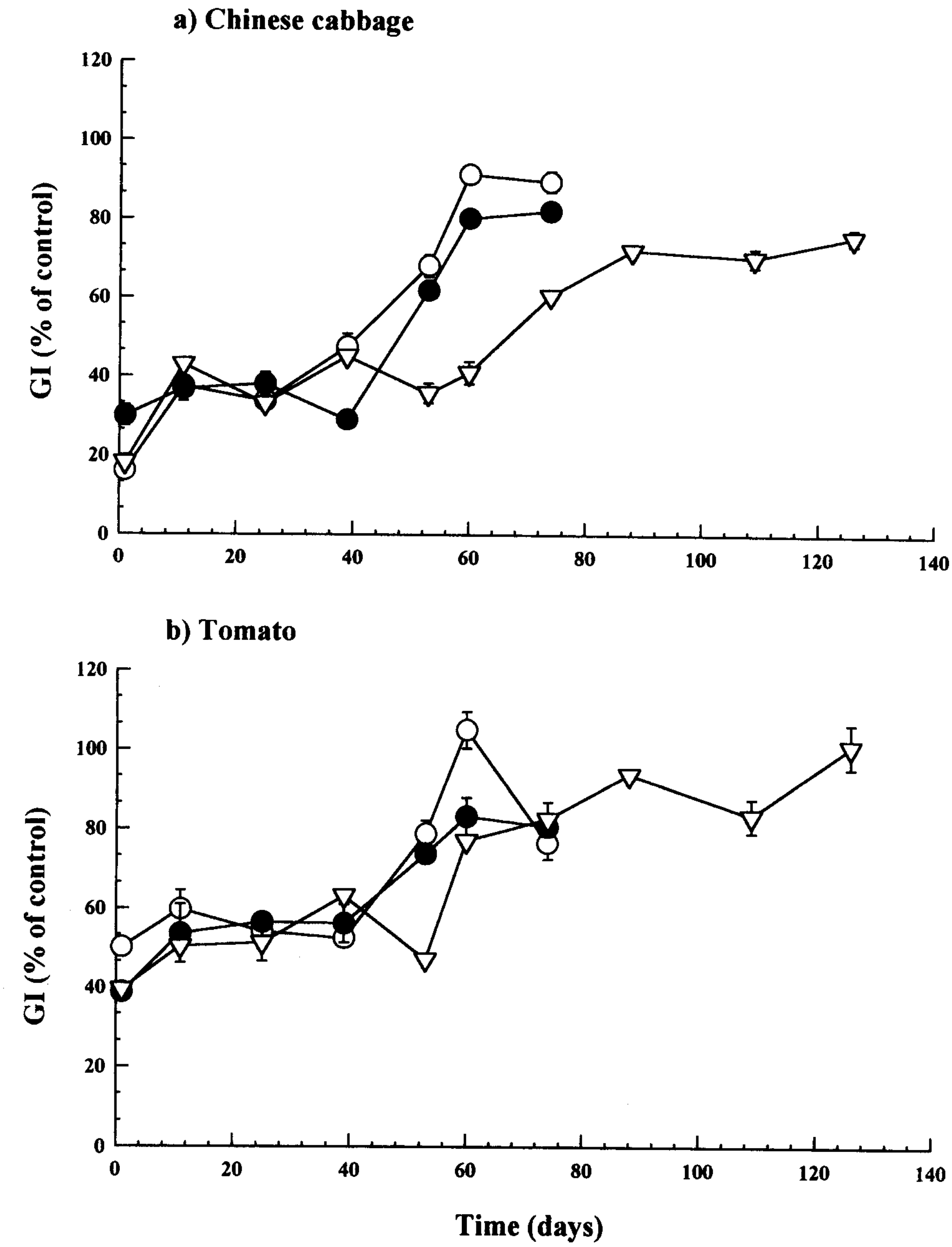

Fig. 2. Germination indices of two plant species on the spent litter. (○ = Pile A; • = Pile B; ▽ = Pile C; means and standard deviations of the three replicates are shown).

both of good composting and maturation process (Hirai *et al.*, 1983; Riffaldi *et al.*, 1986; Tiquia, 1996). Tiquia (1996) suggested that the drop in NH_4^+-N content of spent litter to 0.5 mg g^{-1} indicates maturity. In the present study, this value was reached in piles A and B at day 60 (Table 1).

The initial (NO_3^-+NO_2^-)-N contents of all piles were around 0.1 mg g^{-1}. These values rose to as high as 0.5–1.0 mg g^{-1} by day 11 and were maintained at this level until day 40. After day 40, they rose again to about 1.4 mg g^{-1}. The (NO_3^-+NO_2^-)-N contents of piles A and B were maintained at 1.0 mg g^{-1} and 1.4 mg g^{-1}, respectively from day 46 onwards, while that of pile C rose rapidly to 4.4 mg g^{-1} by day 126 (Table 1).

Piles A and B had very similar HA contents during the whole composting period. The HA content in these two piles increased rapidly to around 41 and 46 g Kg^{-1} O.M. (organic matter) during the first 18 days of composting and then stabilised to around 41 and 42 g Kg^{-1} O.M. from day 39 to day 74. The HA content of pile C increased sharply to about 43 g Kg^{-1} O.M. by day 25 but decreased to 38 g Kg^{-1} O.M., and then fluctuated in the range between 34 and 41 g Kg^{-1} O.M. until day 126 (Table 1).

Phytotoxicity assay

The germination index (GI), which combines measures of relative seed germination and relative root elongation, has been used to evaluate the toxicity of spent litter (Tam and Tiquia, 1994; Tiquia *et al.*, 1996c). At the beginning of composting, the GI of Chinese cabbage and tomato was very low (Fig. 2), with initial readings of 18–33% and 37–49% (% of control using distilled water), respectively but as composting proceeded, the GI values of both Chinese cabbage and tomato increased. A GI value of 80% has been used as an indicator of the disappearance of phytotoxicity in composts (Zucconi *et al.*, 1981a,b). Tiquia *et al.* (1996c) used this value not only as an indication of the disappearance of phytotoxicity but also as an indication of the maturity of spent litter. In this study, a GI value about 80% (for Chinese cabbage) was never reached in pile C, while for tomato, this GI value was reached only at day 74, demonstrating that the turning frequency affected the elimination of phytotoxicity from the spent litter. This finding was in agreement with Zucconi *et al.* (1985) who reported that aeration (such as turning) is the most important factor in the metabolic destruction of phytotoxins.

ACKNOWLEDGEMENTS

The authors express their thanks to Mrs. Christina Lo and all the staff of Ta Kwu Ling Pig Breeding Centre, Agriculture and Fisheries Department, Hong Kong Government for their technical assistance. This work was funded by the Research Committee of the City University of Hong Kong and the University Grants Committee.

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