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Composting of poultry manure and wheat straw in a closed reactor: optimum mixture ratio and evolution of parameters

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Abstract The main objectives of this work were to investigate the evolution of some principal physico-chemical properties (temperature, carbon dioxide, oxygen, ammonia, pH, electrical conductivity, organic matter) and microbial population (mesophilic and thermophilic bacteria and fungi) during composting poultry manure with wheat straw in a reactor system, and to evaluate the optimum mixture ratio for organic substrate production. The experiments were carried out in four small laboratory reactors (1 l) and one large reactor (32 l) under adiabatic conditions over 14 days. During the process the highest temperature was 64.6°C, pH varied between 7.40 and 8.85, electrical conductivity varied between 3.50 and 4.31 dS m^{-1} and the highest value of organic matter (dry weight) degradation was 47.6%. Mesophilic bacteria and fungi predominated in the beginning, and started the degradation with generation of metabolic heat. By increasing the temperature in reactors, the number of thermophilic microorganisms also increased, which resulted in faster degradation of substrate. The application of a closed reactor showed a rapid degradation of manure/straw mixture as well as a good control of the emissions of air polluting gases into atmosphere. The results showed that the ratio of manure to straw 5.25:1 (dry weight) was better for composting process than the other mixture ratios.

Keywords Composting · Microbial population · Organic waste · Poultry manure · Reactor · Wheat straw

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Introduction

Pollution caused by animal wastes has become a great problem in many countries. Composting is one of natural processes capable of stabilizing organic wastes. The stabilization process considerably reduces odour emissions, and dries up the waste making it easier to handle and transport. Also, proper composting effectively destroys pathogens and weed seeds due to high temperature (55–65°C) achieved through the metabolic heat generated by microorganisms. Because animal waste possibly contains viral, bacterial, and protozoan pathogens, the application of untreated livestock wastes could be a hygienic risk for humans. Composting is an effective and safe way for reduction of the manure's mass and volume, destruction of pathogens, and stabilization of nutrients and organic matter in it (Michel et al. 1996; Tiquia et al. 2000).

Poultry manure is a significant source of nitrogen, but small amount of carbon needs to be added for faster degradation of organic matter in composting processes. Type of amendments/ bulking agent in poultry manure has statistically the most significant effect on the composting rate (Hansen et al. 1989a) and on the loss of carbon and nitrogen as well (Barrington et al. 2002).

The main objectives of this work were to investigate the evolution of some principal physico-chemical properties and microbial population during composting poultry manure with wheat straw in a closed reactor, and to evaluate the optimum mixture ratio for organic substrate production.

Materials and methods

Experimental material

Poultry manure and wheat straw (Table 1), mixed in different ratios (Table 2), were used as experimental material. The straw was cut on pieces 2.5 cm long. Poultry and straw were mixed manually in plastic boxes for 30 min, by hands, in order to achieve better homogenization of material. Initial content of moisture in the first mixture was about 69% and other mixtures were amended with water in order to achieve the same percentage.

Experimental apparatus

Figures 1 and 2 show the schematic diagrams of the systems, one with the small and one with the large reactor.

Four thermos bottles (0.20 height × 0.08 internal diameter m) made of stainless steel with volume of 1 l (Pengo, Italia) were modified and used as laboratory reactors (R1, R2, R3 and R4). This modification included the rubber stopper with holes for inlet of air, for thermocouples, and for outlet of gas mixture (Fig. 1). Reactors were additionally insulated with polystyrene foam. Additionally, one large laboratory designed reactor with volume of 32 l (0.48 height × 0.30 internal diameter m) (Fig. 2), made of high-density polyethylene, was also used (R5). This reactor was insulated with a layer of polyurethane foam (1 cm of thickness).

Aquarium pumps CX-0098 (Champion, China) were used to blow the air with a constant flow (0.9 l min^{-1} kg^{-1} OM) into four small reactors, while an air compressor EURO 8/24 (Einhell, Germany) was used for constant aeration (0.9 l min^{-1} kg^{-1} OM) of the large reactor. Measurement of airflow was carried out using airflow meters (Valved Acrylic Flowmeter, Cole-Parmer, USA).

Table 2 Ratios of poultry manure to straw

Reactor	Poultry manure:straw ratio (dw)
R1[a]	8.09:1
R2[a]	5.25:1
R3[a]	1.33:1
R4[a]	2.03:1
R5[b]	5.25:1

[a] small reactors; [b] large reactor

Table 1 Characterization of poultry manure and straw before mixing (three measurements, mean value ± standard deviation)

Material for composting	Dry matter (% ww)	Organic matter (% dw)	pH	EC (dS m^{-1})
Manure	27.41 ± 0.97	78.07 ± 1.83	7.71 ± 0.06	3.34 ± 0.10
Straw	89.13 ± 0.95	87.91 ± 1.11	7.11 ± 0.05	1.91 ± 0.03

ww, wet weight; dw, dry weight

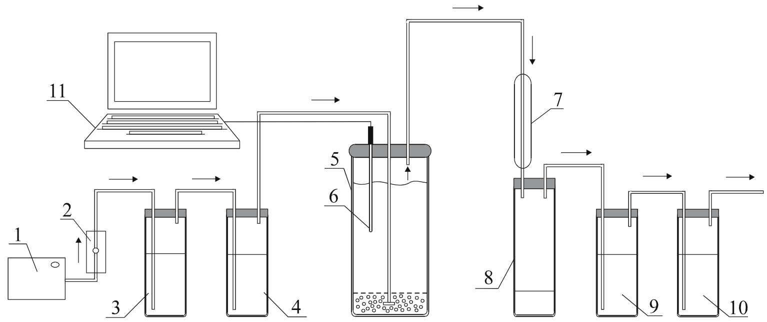

Fig. 1 Schematic diagram of one small reactor with experimental apparatus. (1. aquarium pump, 2. airflow metre, 3. gas washing bottle with solution of sodium hydroxide, 4. gas washing bottle with distilled water, 5. small reactor, 6. thermocouple, 7. condenser, 8. graduated cylinder, 9. gas washing bottle with solution of sodium hydroxide, 10. gas washing bottle with solution of boric acid, 11. laptop)

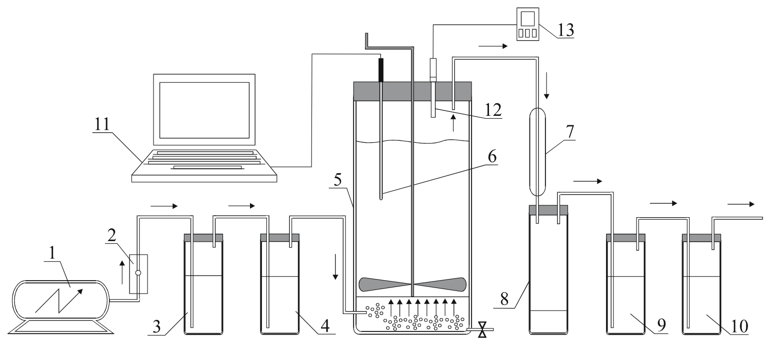

Fig. 2 Schematic diagram of the large reactor with experimental apparatus. (1. air compressor, 2. airflow metre, 3. gas washing bottle with solution of sodium hydroxide, 4. gas washing bottle with distilled water, 5. large reactor, 6. thermocouple, 7. condenser, 8. graduated cylinder, 9. gas washing bottle with solution of sodium hydroxide, 10. gas washing bottle with solution of boric acid, 11. laptop, 12. sensor for carbon dioxide, 13. datalogging carbon dioxide metre)

Before inlet to reactors, the air had been introduced into solution of sodium hydroxide in order to remove traces of carbon dioxide. Then, air passed through the gas washing bottle with distilled water in order to maintain the humidity at reactor inlet. At outlet, the gas mixture passed through a condenser, a gas washing bottle with 1 M sodium hydroxide and a gas washing bottle with 0.65 M boric acid, in order to remove the condensate, carbon dioxide and ammonia, respectively. The gas washing bottles were changed daily for determination of carbon dioxide and ammonia.

Monitoring of the process and physico-chemical analysis

In all reactors, temperature was measured in the intervals of 15 min through thermocouples type T (Digi-Sense, Cole-Parmer, USA), placed in the middle of the substrate. This is their optimal location considering the maximum dry matter loss corresponding to energy use per initial mass of the compost dry matter (Ekinci et al. 2004). Thermocouples were connected through the acquisition module Temperature Data Acquisition Card Thermocouple CardAcq (Nomadics, USA) on a laptop. Automatic registration of data for temperature was performed over the whole period of the experiment, using special software (Nomadics, USA). The temperature in the laboratory was also measured.

The oxygen in the exit gas mixture was measured by an Orsat O_2 analyser (W. Feddeler, Germany) in each reactor. Determination of oxygen was performed daily. The exception was the first day when four values (0, 4.5, 10.5 and

24 h) were recorded in order to obtain as precise profile of oxygen as possible.

A sensor for carbon dioxide, connected to datalogging meter GM70 (Vaisala Oyj, Finland), was set above the composting material in the large reactor. During the process, the measurements of carbon dioxide concentrations were performed at intervals of 15 min.

For determination of carbon dioxide content, an aliquot volume of sodium hydroxide solution (used as a ‘‘trap’’), with the indicator of phenolphthalein, was titrated by standard solution of 1 M hydrochloric acid. The difference in titration between blank and sampled probes was used for calculation of the mass of the ‘‘trapped’’ carbon dioxide.

For determination of ammonia content, an aliquot volume of boric acid solution (used as a ‘‘trap’’), with the indicator of bromcresol green-methyl, was titrated by standard solution of 1 M hydrochloric acid. The difference in titration between sampled probe and blank probe was used for calculation of mass of the ‘‘trapped’’ ammonia.

Moisture content in the substrate was calculated from the difference between the masses before and after drying of samples in a dry oven at 105°C for 24 h, (APHA 1995). After cooling in a desiccator (30 min), the samples were incinerated at 550°C for 6 h, and then cooled again in a desiccator. The difference in the masses between dried and incinerated samples represents the mass of volatile solids (APHA 1995).

The loss of organic matter was calculated from the initial and final organic matter contents, according to the Eq. 1 (Haug 1993; Diaz et al. 2002):

$$k = \frac{[OM_m(\%) - OM_p(\%)] \cdot 100}{OM_m(\%) \cdot [100 - OM_p(\%)]} \quad (1)$$

where OM_m is the organic matter content at the beginning of the process; and OM_p is the organic matter content at the end of the process.

pH and electrical conductivity were measured by using a PC 510 Bench pH/Conductivity meter (Oakton, Singapore) in aqueous extract, which was obtained by shaking the samples mechanically for 30 min with distilled water at a compost to water ratio of 1:10. Suspension (10 g of sample and 100 ml of distilled water) was filtrated through the filter paper Whatman 42 Ashless Circles 125 mm Dia (Whatman, Great Britain) for 3 h.

The composting material was mixed only in the large reactor (R5), several times per day (for 10 min each time). After mixing, samples (about 50 g) were taken every day at the same time, from different places in the substrate (top, middle, bottom). The analysis of the fresh samples was performed immediately after taking them out of the reactor.

Each analysis was done in triplicate with calculation of the mean value.

The additional water wasn't added to composting material during the process because the composting mixture did not dry up. As it was already mentioned, the air passed through the gas washing bottle with distilled water in order to maintain the humidity at reactor inlet.

Microbial analysis

Colony-forming units (CFU) of mesophilic and thermophilic bacteria and fungi were determined by pour plate method (Prescot et al. 1996). One gram of each sample was suspended in 99 ml of physiological solution and then it was homogenized by a magnetic stirrer for 30 min. Dilution series (from 10^{-2} to 10^{-11}) were made from the prepared suspensions. One millilitre of each sample from the above mentioned dilution was put into sterile Petri dishes and was irrigated by 15–20 ml of sterile and cooled agar (at 45°C). Sabourand Maltose Agar was used for growth of fungi, and nutrient agar for growth of bacteria. The Petri dishes were incubated at 37°C/48 h for the growth of mesophilic bacteria, at 28°C/72 h for the growth of mesophilic fungi, at 55°C/48 h for the growth of thermophilic bacteria, and at 55°C/72 h for the growth of thermophilic fungi. CFU of mesophilic and thermophilic bacteria and fungi were counted over, and the results were expressed as a CFU of mesophilic and thermophilic bacteria and fungi per gram of the substrate/compost.

Statistical analysis

The k (loss of organic matter) characteristics of compost and its raw materials were subjected to ANOVA one-way analysis of variance to test differences. The Multiple Range Test was used to establish the significance of differences among treatments. The temperature, carbon dioxide, oxygen and ammonia patterns were also tested for significant difference over time. All analysis were performed using STATGRAPHICS statistical package (STATGRAPHICS 1996).

Results and discussion

Evolution of temperature

The temperature regimes of the composting reactors containing different mixtures are illustrated in Fig. 3. The lag period on temperature curve was not recorded because the original substrate was rich in microorganisms. Thus, after several hours the temperature in the composting mass started to rise due to intense biodegradation. The composting process reached the maximum temperature of 64.6°C after 2.1 days in reactor R5, 64.5°C after 1.3 days in reactor R2, whereas reactors R1, R3 and R4 reached lower maximum temperatures. The lowest maximum temperature (52.5°C) was achieved in reactor R3. After 8 days, there were statistically significant differences in temperature regime between reactors R2 and R4, as well as between these reactors and reactors R1, R3 and R5 ($P < 0.05$). During the whole composting period temperatures were the highest in reactors R2 and R5. The temperature in these reactors was maintained above 55°C for 2 days which should be sufficient to maximize sanitation (Stentiford 1996). According to Strauch and Ballarini (1994) only the thermophilic range of 55°C is sufficient to destroy pathogens. The temperatures in other reactors slowly decreased after reaching their maximum values. Reactors R3 and R4 reached temperatures bellow 50°C. Reactor R1 reached temperature of 55°C but just for a short period, on the first and on the fourth day. Consequently, reactors R1, R3 and R4 did not provide conditions for full sanitation and destroying of pathogens.

Evolution of carbon dioxide

The production of carbon dioxide is caused by mineralization of organic matter in the substrate (Bernal et al. 1998). Figure 4 shows the results of the carbon dioxide changes inside each of the reactors (measured by titration according to the above mentioned procedure). The mass of the produced carbon dioxide increased in all reactors proportionally to microorganisms' activity during the process and it was higher in reactors R2 and R5 than in the other reactors. The greatest mass of carbon dioxide was generated after the first 3 days. After the third day, easily degradable organic compounds were degraded and the microbial activity (especially bacteria activity) decreased. Therefore, the amount of produced carbon dioxide was reduced. It was observed that there were statistically significant differences in carbon dioxide evolution between reactor R3 and

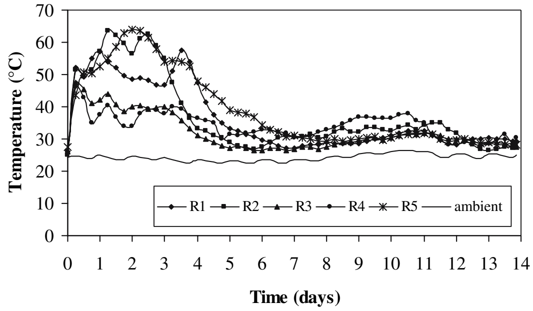

Fig. 3 Evolution of temperature during composting process (R1–R4 small reactors, R5 large reactor)

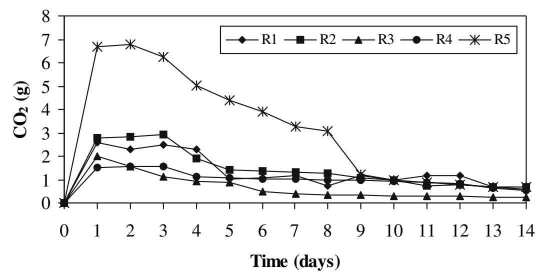

Fig. 4 Evolution of carbon dioxide during composting process (R1–R4 small reactors, R5 large reactor)

reactors R1 and R2, as well as between reactor R5 and other reactors ($P < 0.05$).

Figure 5 shows the concentration of carbon dioxide in the large reactor (R5) measured by sensor. The produced carbon dioxide directly followed the temperature profile of substrate, with fluctuations caused by mixing and sampling. The patterns of mass and volume concentration of produced carbon dioxide for reactor R5 (Figs. 4 and 5) were quite similar during the mesophilic and thermophilic phase, but slightly different from fifth to ninth day. The explanation for these discrepancies lies in the fact that volume concentration is a relative indicator of carbon dioxide content (which values depend on other components in the mixture: oxygen, nitrogen, water vapour, ammonia, nitrogen oxide, methane), while the mass of produced carbon dioxide is an absolute indicator of carbon dioxide content (which values give an exact information on its emission). The content of gas mixture above composting material was very variable especially during and after the thermophilic phase. It was observed during the experiment that water condensation occurred under the top of the reactor, leading to rewetting of the substrate. Therefore, a high partial pressure of water vapour could have been expected in the gas mixture above the composting material. An increase of the ammonia emission was observed from the fifth to ninth day (Fig. 6). The emission of nitrogen oxide could have been expected when the ammonia emission and temperature of the substrate began to decline. The relative high values for the mass of produced carbon dioxide from fifth to ninth day (Fig. 4) could be a sign that there was a degradation of hardly degradable organic compounds (cellulose, lignin).

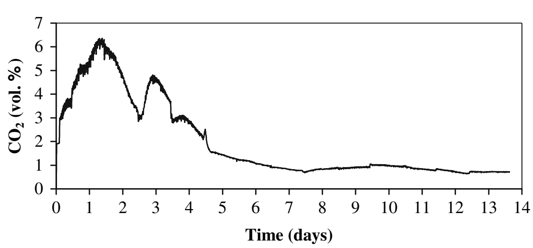

Fig. 5 Concentration of carbon dioxide in the gas mixture of the large reactor (measured by sensor)

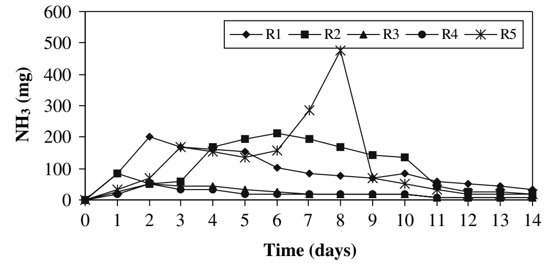

Fig. 6 Evolution of ammonia during composting process (R1–R4 small reactors, R5 large reactor)

Evolution of oxygen

The smallest concentration of oxygen, which is also the greatest consumption of oxygen, was noticed in the exit gas mixture from reactor R2 (16.0 vol. %) and from reactor R5 (11.7 vol. %) after the first day of the process (Fig. 7). Statistical analysis showed that there were statistically significant differences in carbon dioxide evolution between reactors R2 and R3, as well as between reactor R5 and other reactors ($P < 0.05$). During the whole process, the measured concentration of oxygen in the gas mixture of the reactor R3 was above 19 vol. %. Therefore, such a small consumption of oxygen indicated the minimum activity of microorganisms and the smallest degradation of organic matter when comparing to other reactors. Suler and Finstein (1977) reported that the oxygen concentration in the exit gas needs to be at least within 10–18% to prevent a decrease in metabolic activity based on carbon dioxide evolution.

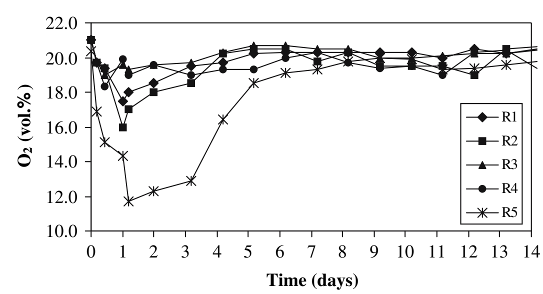

Fig. 7 Concentration of oxygen in the exit gas mixtures from reactors (R1–R4 small reactors, R5 large reactor)

Evolution of ammonia

The increased emission of ammonia was observed in reactors R2 and R5 (Fig. 6), which could be explained by a greater content of nitrogen in the initial mixture than in other reactors. On the other side, the greater contents of straw in reactors R3 and R4 did not provide the source of carbon for microorganisms, but they decreased the moisture content of the mixtures. Therefore, pores filled with air became greater, which made better conditions for degradation. As a consequence, modification of balance NH_4^+/NH_3 could have been expected. Temperature rose as the amount of straw in mixture increased, which helped production of ammonia because of increasing the ammonia vapour pressure (Dewes 1995). It was observed that there were no significant differences between reactors R1 and R2, R1 and R5, R2 and R5, and R3 and R4. Ammonia represents even 98% of emission of nitrogen from composting material (Beck-Friis et al. 2001). The losses of nitrogen often reach up to 33% during the composting of poultry manure (Hansen et al. 1989b). The other important factors for nitrogen loss, in the form of ammonia, are: temperature, mixing, and pH value of composting material (Martins and Dewes 1992), as well as particle size (Hansen et al. 1989a). The results for reactor R1 are surprising when comparing to reactors R2 and R5 as it seems to be obvious to expect an increase in ammonia release, because of the greater manure content. There appear to be complex interdependencies involved. The smaller straw addition in reactor R1 than in reactors R2 and R5 led to lower carbon to nitrogen ratio as well as to the decrease of temperatures. The temperature decrease diminished the ammonia vapour pressure, so the ammonia remained more dissolved in the water solution of the composting material. The pH value influenced the ammonia concentration in compost air space by controlling the distribution of ammonia and ammonium concentration in the aqueous phase. The combination of temperature-pH effects on ammonia release is not quite clear and should be the aim of future studies on composting organic wastes.

Evolution of organic matter

The degradation of organic matter was related to the loss of organic matter, which was, in turn, directly related to the microbial respiration (Paredes et al. 2002). The organic matter content of the materials decreased in all reactors during the process, but this reduction was greater in reactors R2 and R5 (Table 3). The greater loss of organic matter was achieved in reactor R5 than in reactor R2, which can be explained by daily mixing of material. As it could have been expected, the smallest loss of organic matter was achieved in reactor R3. The mixture in this reactor had the smallest addition of straw, so the carbon content was very low which did not provide a favourable condition for the growth and biological activity of microorganisms. There were statistically significant differences between k values for all reactors ($P < 0.05$).

Reactors R2 and R5

There were three reasons why the large (R5) and the small reactor (R2) with the same mixture were used. The first reason was to discuss their different performances. The second reason was in the fact that the large reactor (with external insulation and daily mixing) provided better simulation of a full-scale composting than the small reactor. The third reason was that the small reactor did not allow taking the samples for

Table 3 Degradation of organic matter (dw) in reactors

	R1	R2	R3	R4	R5
OM_m (%)	79.56	80.22	82.91	81.20	80.22
OM_p (%)	69.51	69.42	78.08	73.52	68.00
k (%)	41.40	44.50	26.60	35.70	47.60

k, loss of organic matter; OM_m, organic matter content at the beginning of the process; OM_p, organic matter content at the end of the process analysis because of small amount of compost mass inside the reactor. Compost temperature rose rapidly above ambient temperature in both reactors. Temperature remained elevated longer in the large than in the small reactor. The surface-to-volume ratio for the large and the small reactor were 0.15 and 0.55, respectively. The lower surface to volume ratio of the large reactor would reduce conductive heat loss through the walls (Hogan et al. 1989). The second temperature peak that occurred in reactor R2 was possibly a result of delayed microbial growth in the lower layers of composting mixtures, either due to water leached from the top, or due to lower heat removal rate caused by predominance of smaller, constant aeration rate, or both. The constant air flow in the small reactor may have enhanced cooling and drying of the composting mixture. Mixing facilitates constant and prolonged oxygen utilization by microbial populations. The differences in the rate of carbon dioxide evolution between the reactors R2 and R5 were large during the first 9 days of the process, and after that they were very small (Fig. 4). Periodic mixing of the composting mixture stimulated carbon dioxide production. Mixing would redistribute substrate and water, and provide additional aeration. Movement of the material aids aeration, introducing a fresh supply of air into the middle of composting mass where diffusion alone has been insufficient to maintain high oxygen and low carbon dioxide levels. Agitation assists homogeneity of the composting mass, the uniformity of temperature, preventing overheating in the centre of mass, and cooling at exposed surfaces.

Evolution of pH and electrical conductivity

Evolution of pH and electrical conductivity in the large reactor (R5) are presented in Fig. 8. The initial value of pH was 7.40, and final was 8.85. The maximum value was 8.86 (eighth day) and after that it had been maintained until the end of the process. The increase in pH was induced due to production of ammonia during ammonification and mineralization of organic nitrogen as a result of microbial activities (Bishop and Godfrey 1983; Mahimaraja et al. 1994). A decrease in pH on tenth day of composting was caused by the volatilization of ammoniacal nitrogen and the H^+-released as a result of microbial nitrification process by nitrifying bacteria (Eklind and Kirchmann 2000). The large quantities of carbon dioxide that are given off during the composting process with sufficient aeration might also be responsible for the decrease in pH value, because evaporation of water and release of carbon dioxide led to the acidification of the mixture once buffering effect of the bicarbonate had diminished (Cáceres et al. 2006).

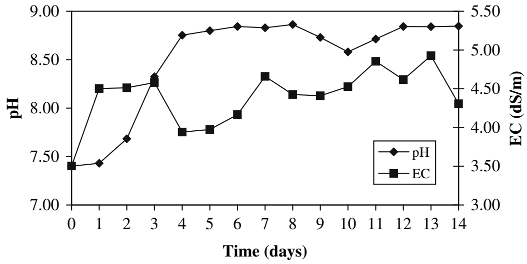

Fig. 8 Evolution of pH and electrical conductivity in the large reactor (R5) during composting process

The EC value reflected the degree of salinity in the compost, indicating its possible phytotoxic/phyto-inhibitory effects on the growth of plant if applied to soil. Electrical conductivity values increased from 3.50 to 4.31 dS m^{-1} during the composting process. These high values could be due to the effect of the concentration of salts as a consequence of the degradation of organic matter (Campbell et al. 1997).

Evolution of microbial population

The development of mesophilic and thermophilic microorganisms during composting is related to the mesophilic and thermophilic stages of the composting systems (Davis et al. 1991; Ishii et al. 2000; Riddech et al. 2002). The number of living mesophilic and thermophilic microorganisms was observed during the composting process. With the change of temperature in the reactors, number and kind of members in the mixed culture of microorganisms, participated in the substrate degradation (Figs. 9 and 10), also changed. Therefore, the number of mesophilic bacteria increased during the first day of experiment from 2.91×10^{10} to 2.74×10^{12} CFU g^{-1} substrate (dw)

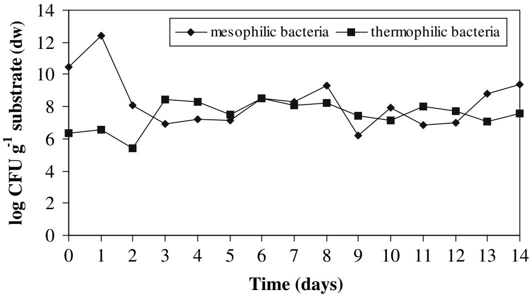

Fig. 9 Growth of mesophilic and thermophilic bacteria in the large reactor (R5) during composting process

(Fig. 9). On the second day, the number of mesophilic bacteria decreased to 1.16×10^8 CFU g^{-1} substrate (dw), because the substrate temperature shifted from mesophilic to thermophilic conditions. This reduction in the number was present until the fifth day. The increase in number of mesophilic bacteria was repeated after the fifth day, when the temperature became optimal for growth of this group of bacteria (38°C). There were some small variations in the number of mesophilic bacteria until the end of experiment because of slight changes in temperature within the optimal range. This number was 2.51×10^9 CFU g^{-1} substrate (dw) on the last day of the experiment.

Unlike mesophilic bacteria, thermophilic bacteria had the exponential growth in number from 2.41×10^6 to 2.70×10^8 CFU g^{-1} substrate (dw) because of rapid change of temperature in the reactor from 27.4 to 64.3°C during the first 3 days (Fig. 9). Their number was increasing until the eleventh day and than it started to decrease, which corresponds to literature data (Haug 1993). Bacteria are mainly responsible for beginning of the composting process because they consume the available dissolved matter and produce metabolic heat. By reviewing microscopic slides, it was noticed that dominant bacteria belonged to the class of *Bacillus*.

The similar curves of growth of mesophilic and thermophilic fungi were obtained (Fig. 10). The number of mesophilic fungi increased from 9.06×10^{10} to 1.47×10^{12} CFU g^{-1} substrate (dw) after the first day, and then it rapidly decreased because of the increase in temperature (64°C), which was suitable for the growth of thermophilic fungi from 9.56×10^3 to 1.16×10^5 CFU g^{-1} substrate (dw). It was noticed that the total number of mesophilic and thermophilic fungi hasn't changed significantly until the end of experiment. This group of microorganisms with celulolitic enzyme carries out degradation of the substrate. By reviewing microscopic slides, it was noticed that dominant mesophilic fungi were yeasts, while dominant thermophilic fungi were *Penicillium* sp., *Aspergillus* sp., and yeasts.

Microbial succession plays a key role in composting process and appearance of some microorganisms reflects the quality of maturing compost (Ishii et al. 2000; Ryckeboer et al. 2003). Additionally, the heat generated during composting helps in destruction of pathogens (Golueke 1977).

Conclusions

The advantages of a closed reactor are easily controlled emission of air polluting gases (carbon dioxide and ammonia) and rapid degradation of manure/straw mixture.

The change in the number and kind of microorganisms in the substrate was observed at different times during the composting process. Mesophilic bacteria and fungi predominated in the beginning, and started the degradation with generation of metabolic heat. By increasing the temperature in reactor, the number of thermophilic microorganisms also increased, which resulted in faster degradation of substrate. At the end of the composting, the number of microor-

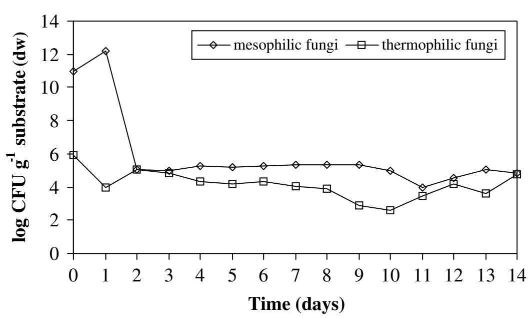

Fig. 10 Growth of mesophilic and thermophilic fungi in the large reactor (R5) during composting process

ganisms decreased because the amount of nutrients for their growth and propagation also decreased.

According to the experimental results, the highest values of organic matter degradation, temperature, carbon dioxide concentration and oxygen consumption were obtained in reactors R2 and R5, with higher values for reactor R5. These reactors had the same mixture content, but reactor R5 had greater volume and a daily mixing of material. Therefore, the mixture ratio of poultry manure to wheat straw 5.25:1 (dry weight) was better for composting process than the other mixture ratios.

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