R'95

Recovery Recycling Re-integration
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Volume IV
Chemical Processes
Biological Processes
Hospital Waste

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COMPOSTING IN STATIC BIOREACTORS IN LABORATORY
1. EFFECTS OF INSULATION ON TEMPERATURE AND PH

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A reproducible standard mixture of fresh, wet, relatively nitrogen-rich constituents, together with stored, dry, carbon-rich bulking agents, was decomposed in a closed batch system for two weeks. In five experiments the temperature in the well insulated static bioreactors reached peaks of up to 62 °C, and stayed above 40 °C for 4 to 7 days. In the less well insulated static bioreactors, the temperature peaked at 40 °C and lasted only a few hours then declined. The pH decreased in both types of bioreactors on days 1 and 2 and then increased faster in the less well insulated bioreactors.

Background

Cultivating experiments with different types of composts (Gajdos, 1986; Gajdos, 1987) were followed by composting experiments with backyard composters (Gajdos, 1992). Research on composting continued with a search for disintegrated, homogenized raw material suitable for biodegradation in a system with well insulated containers (Gajdos, 1991). There is still an elevated need for development of more efficient technologies to guarantee standard quality as mentioned by Bertoldi *et al.* (1987). My ambition is to achieve product-oriented use of composting - in contrast to (including Hogan *et al.*, 1989) process-oriented use of composting.

The main objective of this work was to develop a reference model of composting process suitable for manufacturing reproducible products.

Materials and Methods

Reproducible Standard Substrate (raw material) was composed of well disintegrated wet and dry organic materials (Table 1). The total amounts of elements (Table 2) were analyzed with the Carlo Erba instrument and with Inductive Coupled Plasma technique. The total composition of the standard substrate is presented in Figure 1. The hydrogen value was estimated following Petersson (1984).

Static Bioreactors for composting experiments were provided with forced aeration. Five thermo-bottles (ISOTHERM, Germany) were used as well insulated bioreactors and compared with two less well insulated bioreactors made of plexiglass cylinders. 800 g of standard substrate was treated in each bioreactor of 3 L volume.

Temperature was monitored by temperature sensors placed in different positions in the substrate and connected to a programmable datalogger INTAB AAC-2. Data were transmitted to an computer, analyzed, and temperature curves were printed.

pH was measured with a MESSKOFFER PH 10 LCD-pH meter.

Table 1. Constituents of standard substrate are presented in percent of fresh and dry weight.

ORGANIC MATERIAL	FRESH WEIGHT %	DRY WEIGHT %
Fresh, water-rich and relatively nitrogen-rich constituents:		
potato	35.7	22
carrot	21.4	7
cabbage	21.4	7
Dry, carbon-rich constituents:		
pine sawdust	14.3	42
barley straw	7.2	21

Table 2. Characteristics of the standard substrate and its constituents in ppm of dry matter.

ELEMENT	SUBSTRATE	POTATO	CARROT	CABBAGE	SAWDUST	STRAW
C	496000	448900	454500	468200	520800	475800
N	7900	19700	18900	22800	2100	6900
P	1166	2304	3220	3166	34	707
K	13113	22473	28223	31084	585	14890
Ca	2028	384	3980	5305	591	4345
Mg	718	1041	1913	1806	123	674
S	1514	1823	2198	8389	62	1300
Fe	65	87	284	25	6	62
B	6	.5	27	17	1	6
Mn	58	9	97	11	107	8
Na	1101	60	6927	717	13	2708
Si	403	104	234	22	15	1337
Zn	16	15	61	14	12	12
Al	38	67	213	3	8	11
Cu	5	11	13	6	1	4
Cr	1	1	1	1	1	2
Sr	10	4	35	22	2	20
Rb	10	19	41	13	2	6
Ba	9	3	61	4	4	13

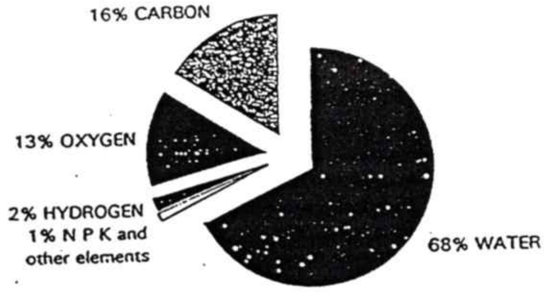

Figure 1. Composition of standard substrate. (Value of hydrogen according to Petersson 1984.)

Results and Discussion

Effects of insulation on temperature and pH are presented from five separate composting experiments (I - V) in laboratory in at least two parallel-worked bioreactors (Figures 2 - 4).

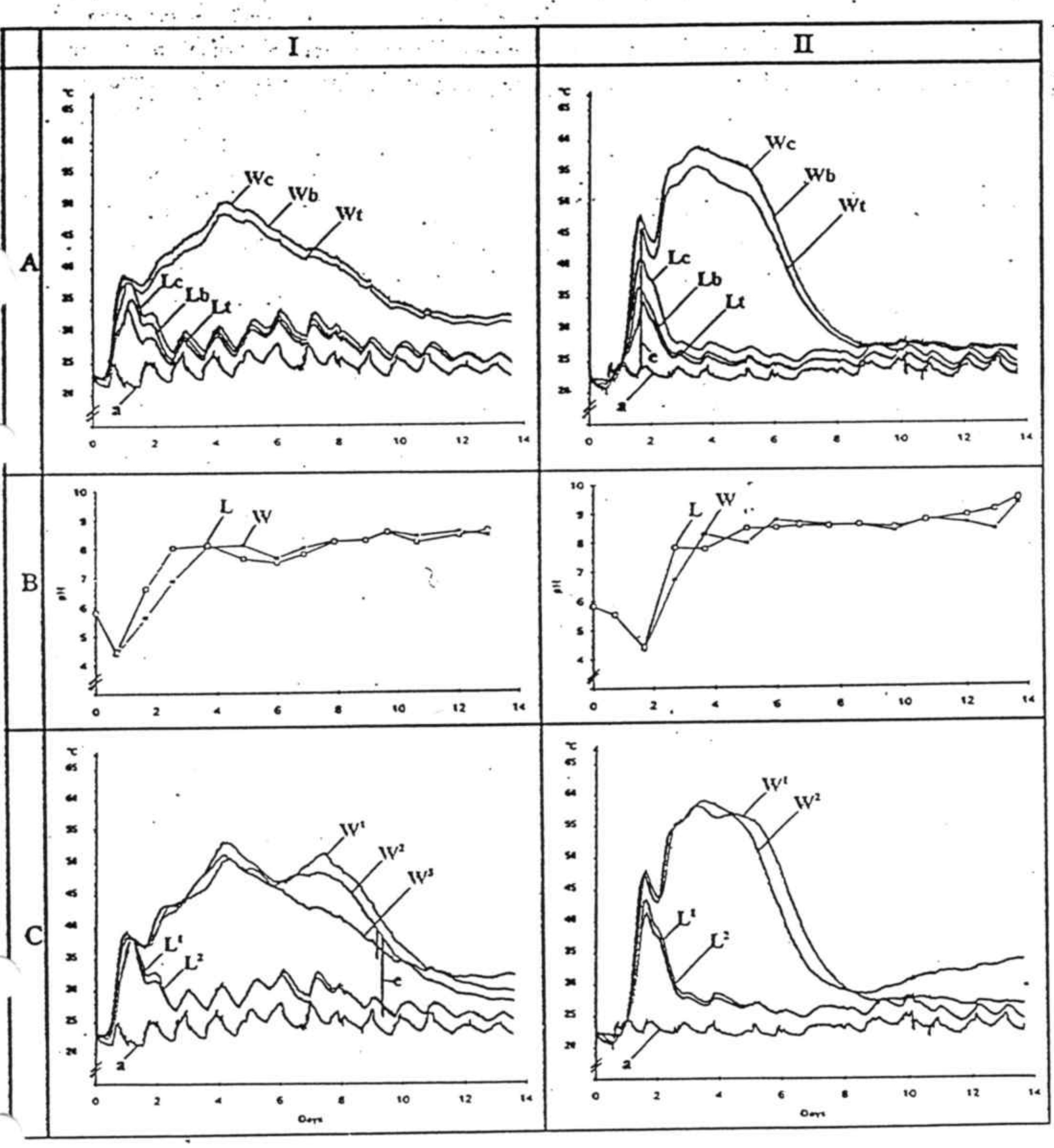

Figure 2. Temperature and pH from experiment I (left) and II (right) during two weeks of composting. W - well insulated bioreactors, L - less insulated bioreactors and a - incoming air.

A - Effect of insulation on the temperature during the decomposing process of the standard substrate in two simultaneously monitored static bioreactors with forced aeration. Three temperature sensors were placed in each bioreactor. c - in the center, b - by the wall at the bottom and t - by the wall at the top.

B - Effect of insulation on pH in the same bioreactors as in A.

C - Effect of insulation on temperature development during the decomposing process of the standard substrate in five (I - W^{1-3} and $L^{1,2}$) and four (II - $W^{1,2}$ and $L^{1,2}$) simultaneously worked static bioreactors with forced aeration (^{1,2,3} - replications). Temperature sensors were placed in the center of bioreactors.

e - Error caused by lack of contact between temperature sensors and the logger.

Temperature in the well insulated static bioreactors reached peaks of up to 62 °C, and stayed above 40 °C for 4 to 7 days. In the less well insulated static bioreactors, the temperature peaked at 40 °C and lasted only a few hours then declined. Comparable temperature curves were presented by Viel *et al.* (1987), Hogan *et al.* (1989) and Elwell *et al.* (1994).

Different shapes of temperature curves from different experiments in similarly working bioreactors can possibly be explained by small changes in raw material (caused by previous freezing or by biochemical processes during preparation of experiments), by disturbance in aeration system, by "human factor", etc.

The temperature variation inside the same static bioreactor from different positions in the substrate indicated that decomposition of the substrate, in spite of the small volume, is not really equal in whole mass. The temperature gradient from the center to the wall in less well insulated static bioreactors gave a picture of heterogenous and insufficiently decomposed composts when they are produced by static composting systems without good insulation.

pH. During decomposing processes pH curves had a similar shape in all presented experiments. pH decrease was slightly deeper, and following increase slightly slower, in the

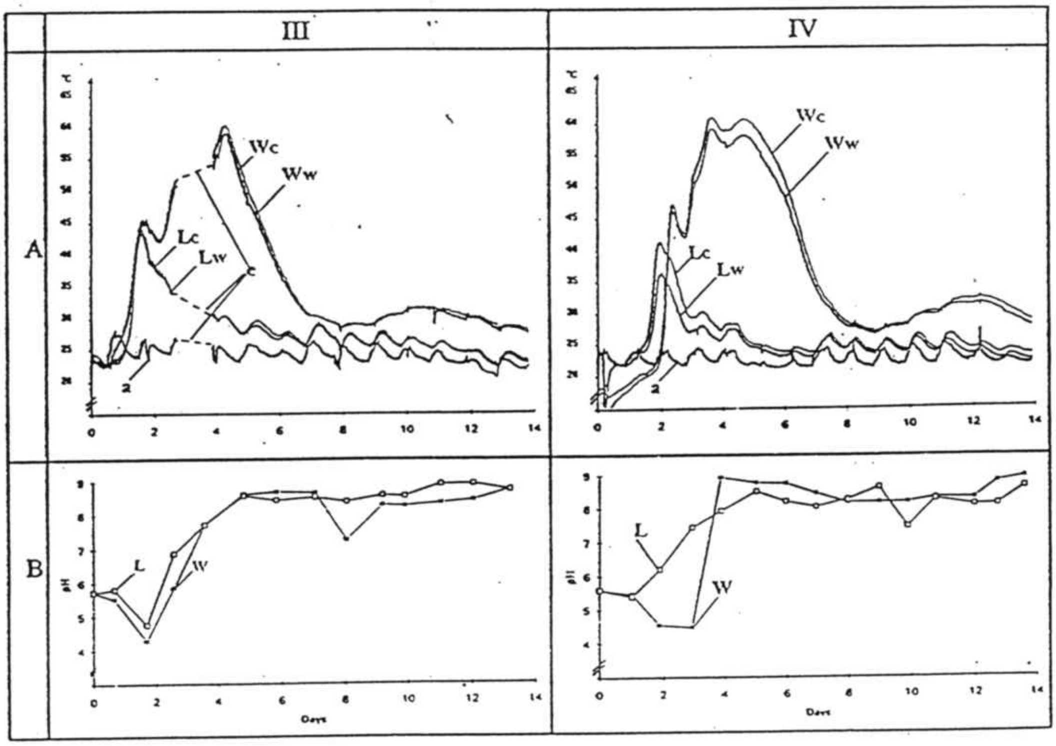

Figure 3. Temperature and pH from experiment III (left) and IV (right) during two weeks of composting. W - well insulated bioreactors, L - less insulated bioreactors and a - incoming air.

A - Effect of insulation on temperature development during the decomposing process of the standard substrate in two simultaneously monitored static bioreactors with forced aeration. Two temperature sensors were placed in each bioreactor. c - in the center and w - by the wall at the same level.

B - Effect of insulation on pH in the same bioreactors as in A.

e - Error caused by lack of contact between temperature sensors and the logger.

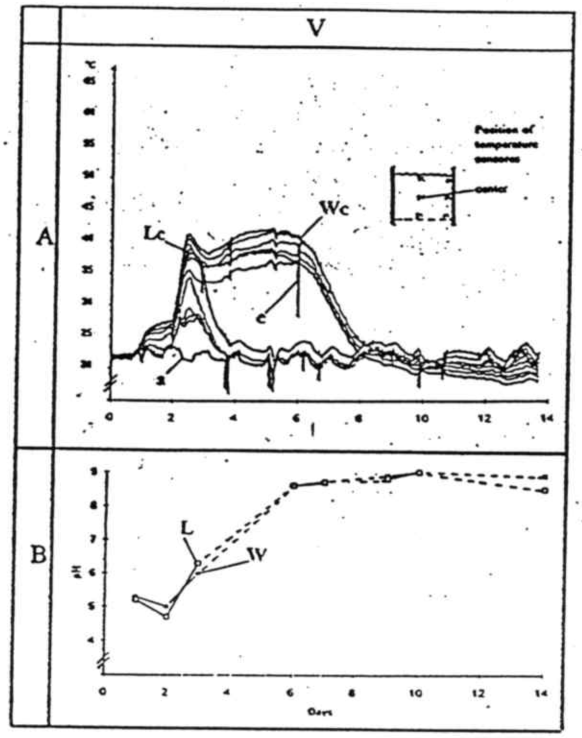

Figure 4. Temperature and pH from experiment V during two weeks of composting. W - well insulated bioreactor, L - less insulated bioreactor and a - air entering bioreactors.

A - Effect of insulation on temperature development during the decomposing process of the standard substrate in two simultaneously monitored static bioreactors with forced aeration. Six temperature sensors were placed in each bioreactor (as joted down in the picture).

B - Effect of insulation on pH in the same bioreactors as in A.

c - Error caused by lack of contact between temperature sensors and the logger.

well insulated bioreactors compared with the less well insulated ones. The lowest pH - between values 4 and 5 - was measured during the first two days. After the sharp increase, which ended in most experiments on day 4, the pH fluctuated between values 7 and 9. Two weeks of composting resulted in most cases in pH above 8. Similar pH curves were presented by Viel *et al.* (1987).

Material balance showed total mass loss of 8.8 % and dry matter loss of 4 % in the well insulated bioreactors and in less well insulated ones was losses 12.2 % and 21.1 % respectively.

Other observations.

The composted mass after two weeks became much darker than the substrate at the start of composting or when substrate was kept in anaerobic conditions.

Nitrogen escape was obvious when bioreactors were emptied, and ammonia smell appeared, in spite of the high amount of carbon in the substrate. This indicates that ratio of available carbon to available nitrogen was low.

At termination of experiment I we found heterogenous moisture conditions in the composted mass. "Small ball" of dry material was developed just above the inlet of air when net was used as an extra bottom in bioreactors. When corrugated rubber foam replaced the net 1-2 cm high dry front was observed just above the foam. There is an evident need of agitation to avoid variations in moisture content and temperature development in the composted mass on different places in bioreactors.

Conclusions

On the basis of the results presented in this study, it may be concluded that:

a) use of reproducible substrate opened new possibilities to build up the basic knowledge on biodegradation in bioreactors for improving factors affecting 1) equipments used for processes of biodegradation, 2) quality of final products, 3) plant nutrients recycling, 4) energy saving and 5) minimizing emissions (= pollutions = losses).
b) insulation of bioreactors plays an important role in temperature evolution in whole mass
c) pH curves indicated the importance of using batch systems in composting
e) effective short-time composting (mass stabilization) is possible when well disintegrated raw material is used
f) agitation will increase the possibilities to produce homogenous compost.

Used experimental system can serve all who wish to study and operate biological decomposing processes for different purposes, as for 1) nutrient recycling or 2) energy production (methane) and/or for 3) combination of these two processes, for 4) sanitization of organic wastes such as for example decreasing pathogens and weed seeds, for 5) degradation of chemicals etc.

Management of decomposing processes requires increased precision in all steps of the system.

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COMPOSTING IN STATIC BIOREACTORS IN LABORATORY
2. EFFECTS OF ADDITIVES ON TEMPERATURE AND PH

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Reproducible standard substrate, with and without additives of organic and inorganic compounds was composted in static bioreactors for two weeks. In five experiments the temperature development was similar during 2 or 3 days after start. Compared with standard substrate without additives, addition of a) "composting agent" caused higher temperature with three peaks, b) glucose prolonged the thermophile phase of composting, c) meat meal caused a higher peak but shortened the thermophile phase, d) ground paper accelerated the temperature increase after the start and e) addition of chicken residues caused two considerably higher temperature peaks. Differences in pH between the standard substrate, with and without additives, shows obvious tendencies.

Background

Inocula in composting has been described by Gotaas (1956). He mentioned different terms as "hormones", "biocatalysts" and "activated factors", and indicated that inocula in biodegradation are not advantageous since microorganisms are always present in very large numbers in organic materials. Golueke (1976) wrote likewise that the decomposing process was neither accelerated nor the final product improved when inocula were tested but he also suggested that inoculation would be of value only if microorganisms were unable to develop rapidly enough. He made distinction between a) microbiologist thinking of inoculation as minute additions and b) sanitary engineer thinking of "mass inoculation" which can significantly modify the physical and chemical properties of the material to be composted. Information about inocula was (and still is) obtained from open or closed systems of composting, while effect of additives on biodegradation in bioreactors is still poorly studied. Grey and Biddlestone (1974) suggested that in some circumstances the addition of other materials to organic waste may be necessary and that the subject of the worth of additives is still unproven.

The main objective of this work was to study changes in the decomposing process after the addition of organic and inorganic compounds to standard substrate, when biodegradation is performed in static bioreactors.

Materials and Methods

Reproducible Standard Substrate (raw material) was used as a base (Gajdos, 1994). Different materials of organic and inorganic origin were added just before the start of composting. Some of the standard substrate (all w/w) was replaced with the following additives: the composting agent "Weibulls BIO Kompostmedel" (0.25 %), glucose (2 % and 4 % respectively), meat meal (5 %), ground paper-pellets (5 %) and residues from one chicken (skin and bone) disintegrated and homogenized (10 %).

Static Bioreactors were used as described in previous report (Gajdoš, 1994).

Temperature was measured on different positions in the substrate with a programmable datalogger INTAB AAC-2 transferred to computer, analyzed, and temperature curves were printed.

pH was measured with a MESSKOFFER PH 10 LCD-pH meter.

Results and Discussion

Effects of additives on temperature and pH from five separate composting experiments (I - V), in well and less well nisulated static bioreactors, are presented in Figures 1 - 3.

Temperature in well insulated bioreactors monitored in the standard substrate with and without additives, was similar during 2 or 3 days after start of composting. a) 0,25 % composting agent caused higher temperature with three peaks, where all are followed by a deep fall of the temperature, probably caused by insufficient aeration (Figure 1, IA and IC). b) 2 % glucose prolonged the thermophile phase of composting with little more than one day (Figure 1, IIA and IIC), 4 % glucose by 4 to 5 days (Figure 2, IIIA and IIIC). c) 5 % meat meal caused a higher peak but shortened the thermophile phase (Figure 2, IVA and IVC). d) 5 % ground paper accelerated the temperature increase after the start but shortened the thermophile phase by some hours (Figure 2, IVA). e) When 10 % chicken residues were added a substantial fall of temperature appeared between the two sizeable temperature peaks (Figure 3).

pH in substrates treated in well insulated bioreactors. a) Composting agent affected a slower decrease the first day after the start, a little retarded rise day 8 when pH was higher than standard substrate - during temperature fall between two high peaks - and at termination pH was the same as in standard (Figure 1, IB). b) Addition of 2 % glucose caused a decrease from pH 5.8 at the start of composting to pH 3.8 by day 2, but the pH increased to 8.3 by day 4 and followed pH in standard, being just a little higher (Figure 1, IIB). 4 % glucose caused similar evolution in pH (Figure 2, IIIB). c) Addition of meat meal caused just a very slight fall of pH until day 2, then a fast rise above pH 8 and after day 4 the pH was highest in comparison with standard substrate with and without ground paper (Figure 2, IVB). d) Ground paper-pellets increased the initial pH to 6.8, followed by a decrease to 6.4 by day 1, then an increase to pH 8.4 by day 3 after which was mostly just below the standard substrates pH (Figure 2, IVB). e) Addition of chicken residue resulted in a slight decrease until day 2, then sharp increase, but on day 6 it started to lessen again when the temperature in mass decreased to between 27 and 30 °C. Unfortunately in this experiment pH was not measured daily (Figure 3, VB). Similar pH curves were presented by other investigators (Bågstam, 1977; Viel *et al.*1987; Michel *et al.*, 1993 and Elwell *et al.*, 1994). pH in substrates treated in less well insulated bioreactors first decreased slowly but after the lowest value increased faster, compared to pH in well insulated ones (Figure 2 D and 3 D).

Other observations.

The temperature variation inside the same static bioreactor from different positions in substrate with additives was more evident that in the substrate without additives. This certified that decomposition of the substrate, in spite of the small volume, is not really even in whole mass as already reported by Gajdos (1994). The temperature gradient from the center to the wall in less well insulated static bioreactors was broader than in well insulated ones. This again confirmed indications from previous experiments that composting systems without good insulation cannot produce homogenous, and from whole mass, sufficiently decomposed and well-balanced products.

After two weeks the composted mass became much darker than the substrate at the start of composting or substrate kept in anaerobic conditions.
Ammonia escape was obvious when bioreactors were emptied in spite of the high amount of carbon in the substrate. This indicates that the ratio of available carbon to available nitrogen was low.

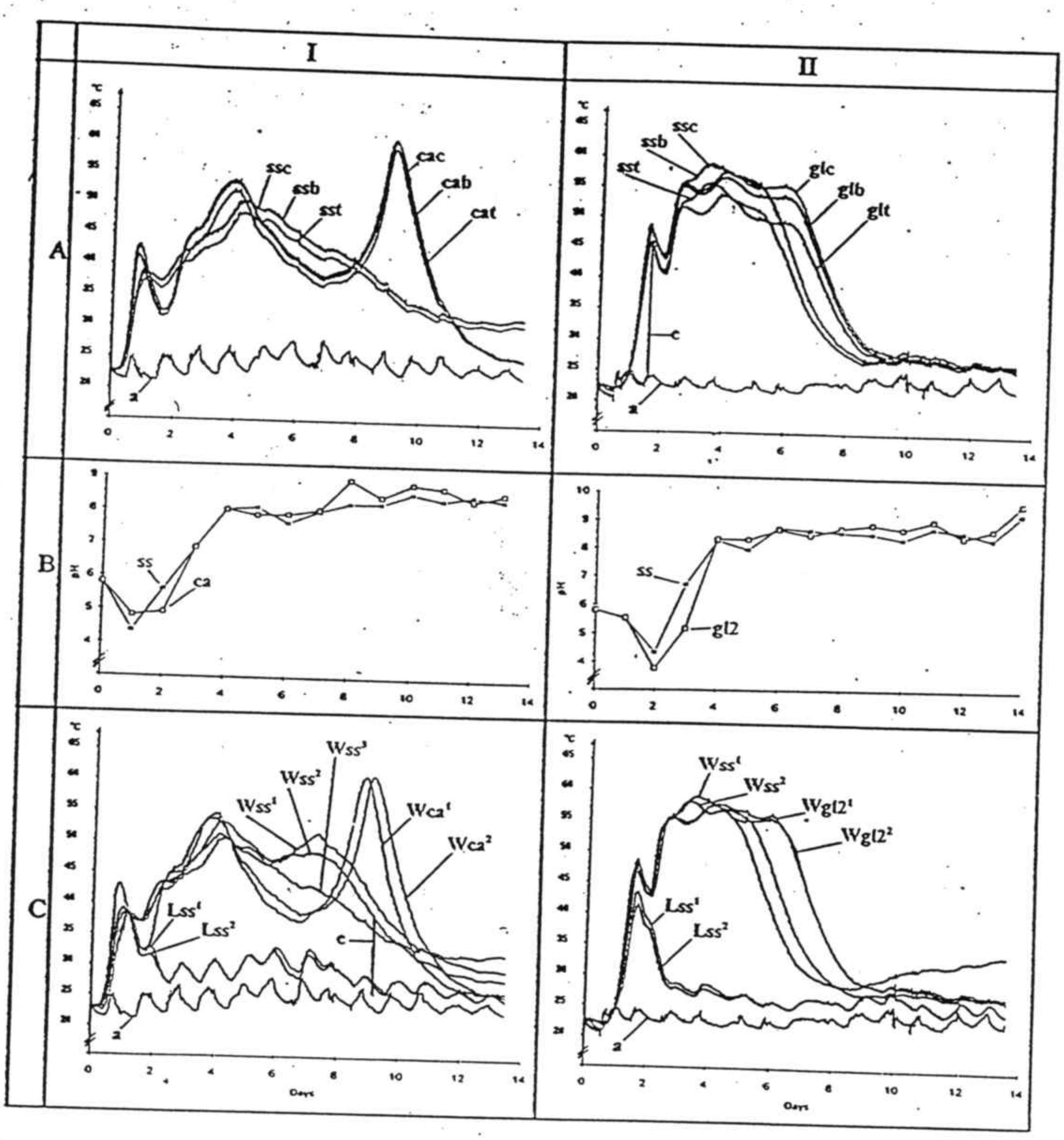

Figure 1. Temperature and pH from experiment I (left) and II (right) during two weeks of composting. Used additives (al w/w) to the standard substrate (**ss**) were 0,25 % composting agent (**ca**) and 2 % glucose (**gl2**). W - well insulated bioreactors, L - less insulated bioreactors and **a** - incoming air.

A - Effect of **ca** and **gl2** on temperature. **c** - in the center, **b** - by the wall at the bottom and **t** - by the wall at the top of the mass.

B - pH in the same bioreactors as in A.

C - Temperature in seven (IC) and six (IIC) simultaneously worked static bioreactors with forced aeration. Temperature sensors were placed in the center.

e - Error caused by lack of contact between temperature sensors and the logger.

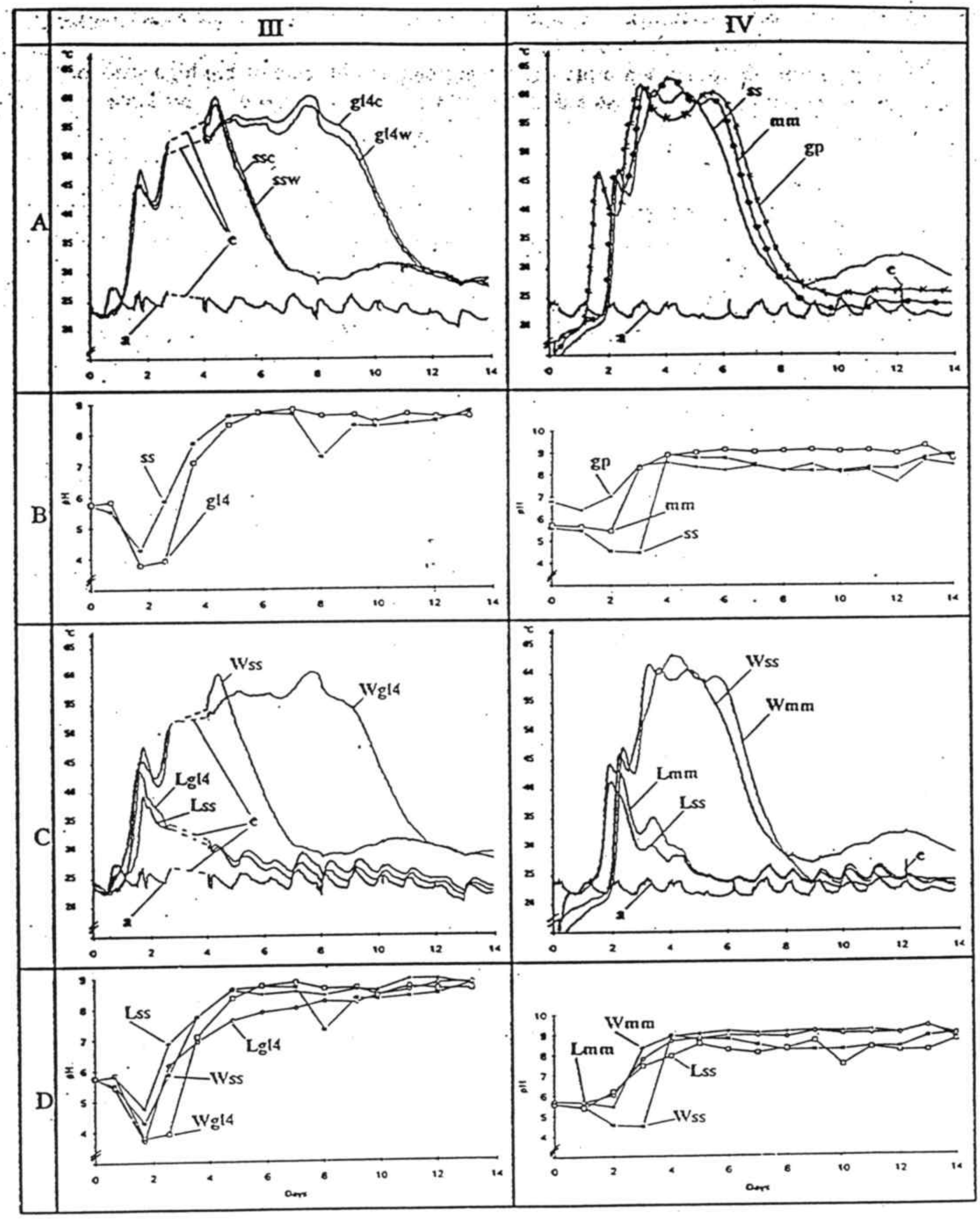

Figure 2. Temperature and pH from experiment III (left) and IV (right) during two weeks of composting. Used additives (al w/w) in standard substrate (**ss**) were 4 % glucose (**gl4**), 5 % meat meal (**mm**) and 5 % ground paper (**gp**). W - well insulated bioreactors, L - less insulated bioreactors and **a** - incoming air.

A - Effect of **gl4**, **mm** and gp on temperature. **c** - in the center and **w** - by the wall at the same level.

B - pH in the same bioreactors as in A.

C - Temperature developmment in four (III - W[1,2], L[1,2] and IV - W[1,2], L[1,2]) simultaneously worked static bioreactors ([1,2] - replications). Temperature sensors were placed in the center.

D - pH in the same bioreactors as in C.

e - Error caused by lack of contact between temperature sensors and the logger.

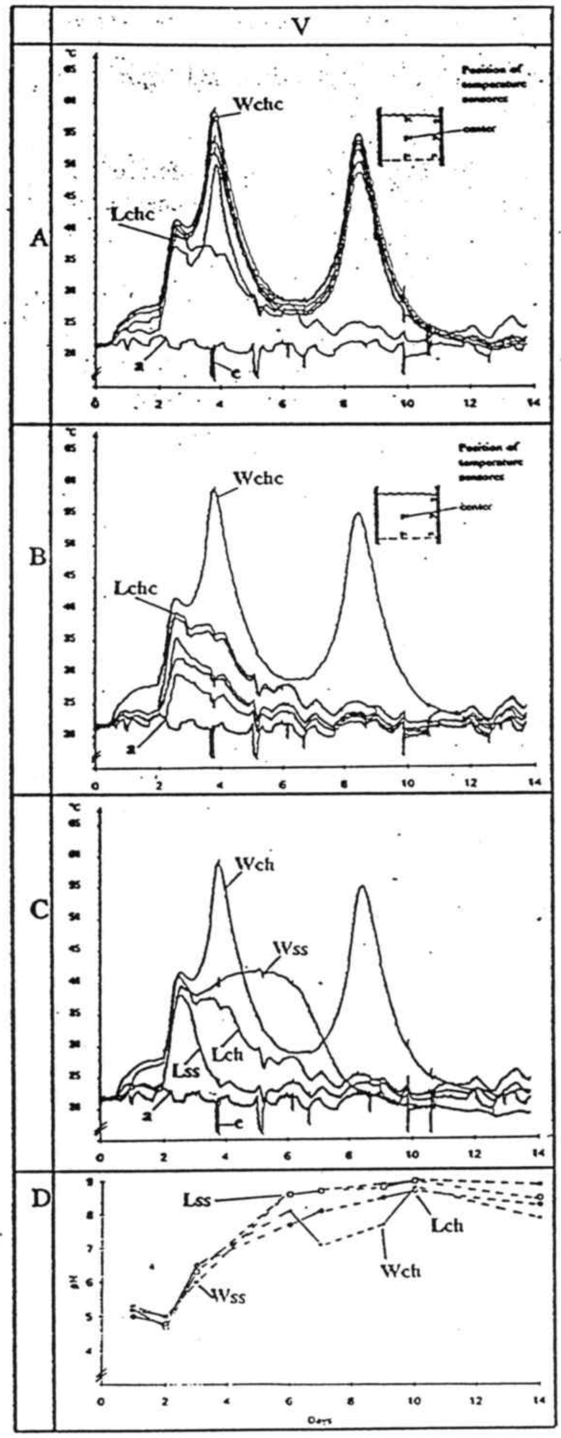

Figure 3. Temperature and pH from experiment V during two weeks of composting. Used additive in standard substrate (ss) was 10 % (w/w) of residues from one chicken (skin and bone) disintegrated and homogenized (ch). W - well insulated bioreactors, L - less insulated bioreactors, c - center and a - air entering bioreactors.

A - Effect of ch on temperature development in different positions. Six temperature sensors were placed in W (as joted down in the picture) and one in center of L.

B - Effect of ch on temperature development in different positions. Five temperature sensors were placed in L (as joted down in the picture) and one in center of W.

C - Temperature in center of four simultaneously worked static bioreactors (Wss, Wch, Lss and Lch).

D - pH in the same bioreactors as in C.

e - Error caused by lack of contact between temperature sensors and the logger.

Conclusions

On the basis of the results presented in this study, it may be concluded that:

a) additives can accelerate biodegradation and in that way be important in sanitization and stabilization of end-products

b) small amounts of additives can change rapidly biodergadative processes carried out in bioreactors
c) agitation during composting can accelerate processes of biodegradation and improve the quality of end-products.

To achieve homogenous reproducible composts (***biofertilizers***) with quality conformed to cultivation needs we have to study effects of additives more intensively. Experimental research in this field can result in "recipes" for product-oriented biodegradation of organic material.

A fully developed laboratory system for biological decomposition can be a very useful tool r obtaining necessary information about the needs of microorganisms when different mixtures of organic materials are used as raw material for the decomposing process. Understanding the processes involved in composting can lead to better defined and reproducible composts - biofertilizers - designed to the requirements of horticulture, agriculture and forestry.

Results from this investigation can be used for development of biological decomposing systems where organic wastes will be treated with respect to 1) microörganisms, 2) plant nutrients, 3) energy, 4) sanitary aspects and 4) the total impact on the environment.

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