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## **CHANGE OF PHYSICAL PROPERTIES OF BIODEGRADABLE WASTE DURING DECOMPOSITION**

### **Summary**

The article mentions results from changes of physical properties of composted material during the composting process. Composting conditions in compost pile were simulated in five vessels with volume of 90 m<sup>3</sup> under home conditions. Composted material was variously modified (mixing and turning, moistening, adding fresh material) during the composting process. Temperature and oxygen concentration inside vessels were measured, as well as reduction in volume of compost material during time, pH and electric conductivity of selected compost.

It appeared that the temperature of the compost material in small volume in the compost pile was lower than the requirement for hygienization of the composted material. The temperature higher than 50°C was measured only sporadically and already during the first week of the experiment temperatures inside the vessels corresponded with outside temperatures.

Oxygen concentration in all vessels was sufficient to ensure the aerobic process during the entire period of the experiment. The lowest measured oxygen concentration was higher than 10 %. These low values were measured only during the first week of the experiment, during the following weeks the oxygen concentrations exceeded 15% only with small exceptions.

Reduction in volume of the composted material highly depended on whether the compost material was mixed and turned during the course of the composting process. Mixed and turned composted material was reducing its volume significantly, quicker than the composted material not being mixed and turned. The effect of moistening on the composted material was not proved.

Measured pH values and electric conductivity (EC) values of the compost material from selected vessel K2 (composted material being mixed and turned, moistened, fresh compost material was not added) showed values fully corresponding with a quality well-matured compost. The average pH value was 7.76 with a standard deviation of 0.04 and the average EC value was 1.79 mS.cm<sup>-1</sup> with a standard deviation of 0.27.

**Key words:** biodegradable waste, decomposition, home composting

## INTRODUCTION

High share of biodegradable communal waste deposited in landfills is one of the most serious problems in the up-to-date waste economy in the Czech Republic. The main attempt at the waste treatment should be prevention to production of the biodegradable communal waste. Kotovicová and Vaverková [2008] dealt with the given problems including proposal of methodology for forecasting the development of ecological load with the biodegradable communal waste within the region. According to interpretation of applicable legislation in the Czech Republic home composting is interpreted as a method of prevention to production of waste.

During the period of the last 10–15 years hundreds of thousands of composters (by estimate) were sold in the Czech Republic for the purpose of home composting, but in most cases people are not satisfied with their functionalities, i.e. slow composting process in a composter, which is not being maintained. Most people are not willing to ensure regular composting process in the composter. Therefore they revert back to composting in the manner of a compost pile, again without maintaining it.

Therefore during the period of one vegetation season changes in volume and intensity of the composting process in composting piles of small volume with different manners of maintenance were monitored. For best quality compost visually selected out of the best maintained pile, two of the primary compost parameters were determined: pH and conductivity (specific electric conductivity, EC), and comparison was made of the mentioned parameters with data from other authors. Even if the mentioned compost parameters are only limitedly applicable to determine compost quality and its applicability on agricultural land [Lefebvre et al., 1994], after all they represent a certain guideline that can be followed up.

The objective of the experiment was to determine what manner of treatment of compost pile is the most effective way in order to ensure quick and proper home composting.

## MATERIAL AND METHODOLOGY

### Composition of the initial material

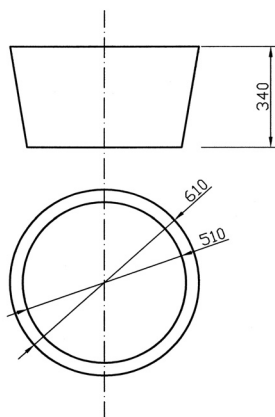
The initial material was a mixture of mown grass (with using rotary lawnmower) and dry woodchips in volumetric ratio 3:1. This mixture had the initial volume weight  $175 \text{ kg}\cdot\text{m}^{-3}$ . During the course of the experiment fresh material was added into three vessels, consisting of only pure mown grass (i.e. without adding woodchips).

### Shape and size of the experimental vessel

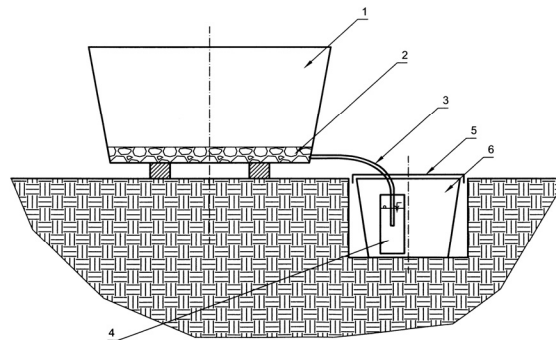
In order to prevent against environmental effects (including surrounding vegetation) the experimental composting piles were placed into vessels with the total volume of 90 dm<sup>3</sup>. In total, 5 vessels marked as K1 – K5 were operated.

Selection of vessels was proposed, so that it maximally simulates operation of the composting pile. At the same time at selection of vessels it was necessary to consider the requirement for relatively simple handling and options to perform measuring of selected characteristics, in particular changes in volume of initial material. Diagram of the vessel is displayed in Figure 1.

A systematic drainage was placed at bottom of the vessel with volume of 90 dm<sup>3</sup>, consisting of inert material with thickness of 25 mm. The systematic drain was covered with a mesh screen in order to ensure passability of the drain. Drain of water ingress was led from bottom of the vessel. Drain of water ingress was secured against possibility of air intake in the air-trap principle. Diagram of the experiment lay-out is displayed in Figure 2.



**Figure 1.** Diagram of the vessel



**Figure 2.** Scheme of experiment. 1 – experimental vessel, 2 – drain, 3 – drain of water ingress, 4 – air-trap, 5 – cover of the vessel for water ingress, 6 – vessel for water ingress

### Experiment procedure

The experiment was commenced in a non-sheltered place within the premises of the Mendel University in Brno on 9th May 2011 after grass had been firstly mown within the premises. Each experimental vessel (K1 – K5) contained 60 dm<sup>3</sup> of mixture of grass and woodchips.

During the first week of the experiment selected measuring was regularly repeated. For the following months the measuring was performed on weekly base.

The process of biomass degradation was modified in selected vessels during the course of time. Survey of treatment of degraded material is mentioned in the Table 1. During the course of degradation, biomass in the experimental vessels K1 and K2 was manually mixed and turned every week. The experimental vessels K3, K4 and K5 were left without mixing and turning.

If required, water was added into vessels K1, K2 and K5 during the course of the experiment. Water was not manually added to vessels K3 and K4 (i.e. only rainwater came into these vessels).

During the degradation process freshly mown grass phytomass was added into the experimental vessels K1, K4 and K5. Nothing was added into the vessels K2 and K3.

By operational reasons the last measuring of oxygen concentration was performed on 1st August 2011. Owing to sufficient biological stabilization the last measuring in vessel K2 was performed on 5th September 2011.

The entire experiment was ended on 31st October 2011.

**Table 1.** Survey of treatment of degraded material

	<b>K1</b>	<b>K2</b>	<b>K3</b>	<b>K4</b>	<b>K5</b>
<b>Feedstock volume</b>	60 dm <sup>3</sup>	60 dm <sup>3</sup>	60 dm <sup>3</sup>	60 dm <sup>3</sup>	60 dm <sup>3</sup>
<b>Biomass mixing</b>	once a week	once a week	-	-	-
<b>Water refilling</b>	11.5.: 10 dm <sup>3</sup> 27.6.: 6 dm <sup>3</sup> 12.9.: 4 dm <sup>3</sup>	11.5.: 10 dm <sup>3</sup> 27.6.: 2 dm <sup>3</sup> 12.9.: 0 dm <sup>3</sup>	-	-	11.5.: 6 dm <sup>3</sup> 27.6.: 0 dm <sup>3</sup> 12.9.: 6 dm <sup>3</sup>
<b>Grass refilling</b>	20.6.: 38.4 dm <sup>3</sup> 1.8.: 37.2 dm <sup>3</sup>	-	-	20.6.: 23.4 dm <sup>3</sup> 1.8.: 23.0 dm <sup>3</sup>	20.6.: 34.0 dm <sup>3</sup> 1.8.: 25.2 dm <sup>3</sup>

### Temperature measuring

Temperature measuring inside the vessels with waste and temperatures of outdoor air (at height of the vessels) was performed by an inserted digital thermometer with range (-50; +150) °C with accuracy 0.1 °C. Temperature inside the experimental vessels was measured always at depth of 5 – 10 cm from the top biomass layer at 01:00 p.m., approximately in the same place of compost, until the temperature was steady. The measuring was performed in second, fourth and eighth day after the commencement of the experiment and afterwards on weekly base.

### Oxygen concentration measuring

Oxygen concentration measuring was performed by gas analyser Greisinger GOX 100 by means of an induction tube and an air induction device. When measuring, the induction tube was inserted at depth of 5 – 15 cm from the middle of the experimental vessel. The air induction device induced air from biomass to the digital meter 3 times in sequence. It displayed the given concentration and consequently the lowest measured value of oxygen concentration was recorded. The measuring was performed until degradable material was much too compacted, so that actual oxygen concentration inside the vessel could not be measured. Last measuring of oxygen concentration inside the vessel was performed on 1<sup>st</sup> August 2011.

### Measuring of residual volume of degraded material

As already mentioned the experiment was performed in vessels of blunted cone shape with known height and known diameters and semi-diameters of end parts. Since the processed material was not deposited directly at bottom of the vessel, but on the drain layer, it was necessary to measure the actual diameter/semi-diameter of the vessel in place of biomass placing. This semi-diameter was 259 mm ( $r_1 = 259$  mm).

For calculation of residual volume of degraded material initially depth of “level” of degraded material under top lip of the experimental vessel was measured ( $h$  [cm]). Depth was measured by tape measure with accuracy of 10 mm. From this value height of degraded material in the vessel was simply calculated.

$$v = 340 - 25 - h \quad [\text{mm}] \quad (1)$$

For calculation of residual volume it was necessary to calculate semi-diameter of the vessel in place of “level” of degraded material, which was changing together with change of height of the material. Formula for calculation of semi-diameter of the vessel  $r_2$  in place of level of degraded material was established from known data on shape and dimensions of the vessel.

$$r_2 = r_1 + v \frac{(610 - 510)/2}{340} \quad [\text{mm}] \quad (2)$$

Value of volume of residual biomass was calculated from formula for calculation of volume of blunted cone:

$$V = \frac{\pi \cdot v}{3} (r_1^2 + r_1 r_2 + r_2^2) \quad [\text{mm}^3] \quad (3)$$

where:

- $V$  – volume of residual biomass
- $v$  – height of residual biomass in the vessel
- $r_1$  – semi-diameter of bottom part of the experimental vessel (in place of biomass placing)
- $r_2$  – semi-diameter of the experimental vessel at height

### pH and conductivity measuring of selected compost (K2)

Owing to determination of pH and conductivity, a sample of compost was taken from K2 vessel on 5<sup>th</sup> September 2011, i.e. around 17 weeks after start of degradation. Measuring of pH and conductivity was performed by the Sension<sup>TM</sup>+MM 150 apparatus, equipped with the Sensor 50 59 sensor for current measuring of pH, conductivity (EC) and temperature of a sample. Calibration was performed before first use of the apparatus in compliance with the instructions for use of the apparatus. At determining physical-chemical parameters of individual samples of compost the method of saturated medium was applied, as described by Johnsson et al. [2005] and Muldowney [2011].

Samples from other vessels unlike K2 vessel were not taken by reason of unfinished composting process.

## RESULTS AND DISCUSSION

### Temperature of degradable material

Measured values of composted material temperatures are displayed in Figure 3.

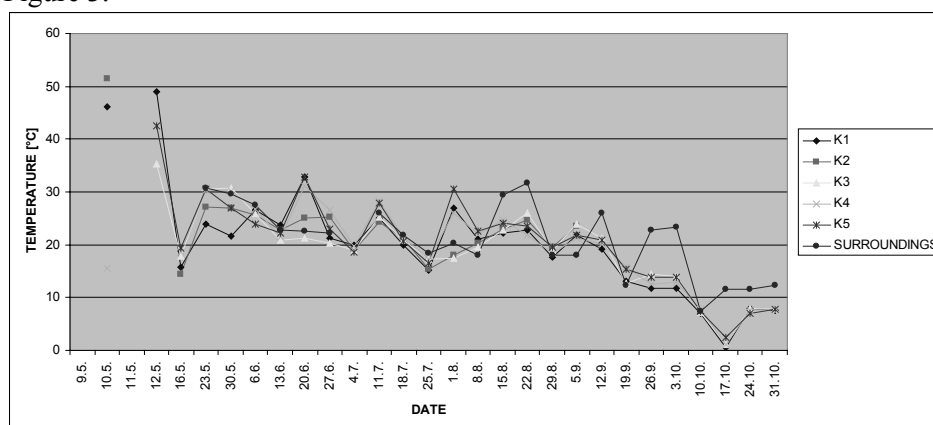


Figure 3. Composted material temperatures

As it is evident from Fig. 3, temperatures during the composting process were low. Maximum temperature measured in K2 vessel on second day after the start of the experiment was 51.5 °C. From this time the temperature of composted material did never exceed 50 °C and during the first week composting temperatures in all vessels recorded drop to the outdoor temperature. These temperature characteristics (the temperature of composted material corresponds with the outdoor temperature or is lower in consequence of thermal lag) remained the same until the end of the experiment. Measured temperature values do not correspond with any of relevant experiments, as it was described by Kuchařiková [2007], Odstrčilová [2007], Váňa [2009] and Mazalová [2010].

Measured temperature values do not reach at all the temperatures required for hygienization of the composted material (small equipment, waste from gardens and greenery  $T > 45$  °C during 5 days). Low temperatures are probably associated with small volume of composted material. So it can be assumed that microbial decomposition is not such intensive as is in the case of use of a composter (having approximately four times larger volume) or even in the case of composting at the public composting facility.

#### Oxygen concentration inside the vessel during the degradation process

Measured values of oxygen concentration inside the vessels at the course of the degradation process are displayed in Figure 4.

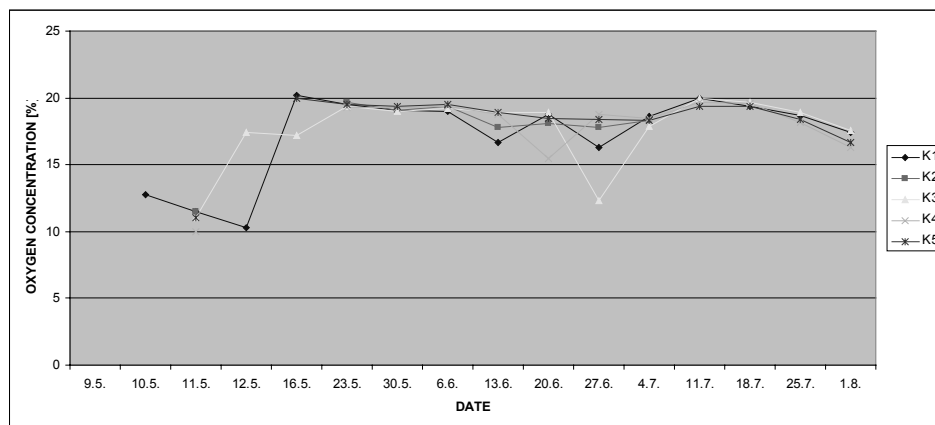


Figure 4. Oxygen concentration

The measured values show that during the first week of the experiment the oxygen concentration inside the vessel with composted material was significantly lower than during the following weeks. This indicates intensive com-

posting process during the first week of the experiment. Measured values (including drop in oxygen concentration during the initial period of the experiment) correspond with the values measured by Mazalová [2010].

It was proved that in case of composting in a composting pile (or in a vessel with airtight bottom and side wall, with large open ground plan area), sufficient volume of aerial oxygen is provided for regular composting process.

### Drop in volume of composted material

Values of drop in volume of composted material, calculated on the basis of measured values of lowering of height of composted material from the lip of the vessel, are displayed in Figure 5.

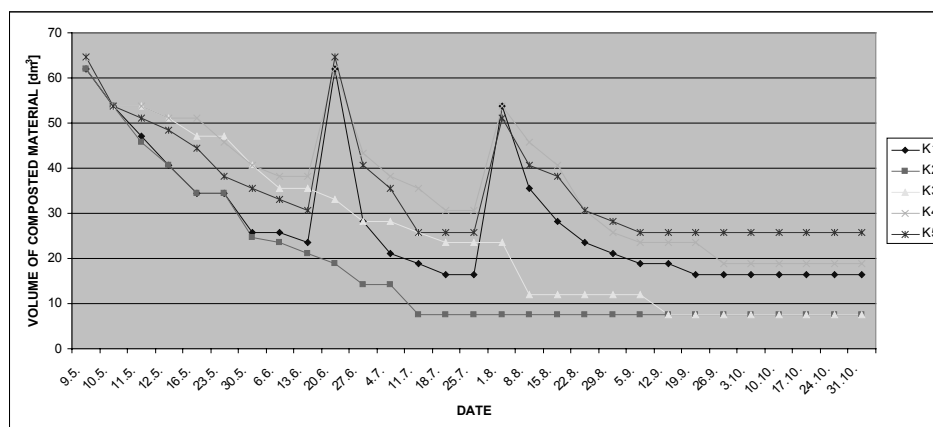


Figure 5. Volume of composted material

As it is evident from Fig. 5, the quickest drop in volume of composted material was recorded in the K1 and K2 vessels, which were regularly mixed and turned. Measure of volumetric reduction was so great that after adding material into K1 vessel (20th June), volume of composted material reduced to the level of K3 vessel during one week, the vessel K3 not mixed or filled up. During the following weeks the volume of material in mixed and turned K1 vessel continued to a drop of value compared to the non-mixed K3 – K5 vessels. After second filling-up (1st August) of selected vessels (K1, K4 and K5), the volume of composted material again continued to drop being the quickest for mixed and turned vessel K1. The recorded volumetric quantity of composted material in the vessels after second filling-up (1st August) did not drop to the level of volumetric quantity of composted material in the vessels without filling-up. The level of volumetric reduction of composted material during the course of time corre-



sponds with data discovered by Kotulová and Váňa [2001], Altmann et al. [2007], Váňa [2009] and Mahelová [2010].

Effect of moistening in the experimental vessels on reduction in volume cannot be determined. Comparing the volume of composted material in the K4 vessel (filled-up, not moistened) and in the K5 vessel (filled-up, moistened) we find out that until 22nd August the volume of composted material in the K5 vessel was lower than in the K4 vessel. After 22nd August the situation changed and the volume of composted material in the K4 vessel was lower than in K5 vessel.

### Measured values of pH and electric conductivity of selected compost (K2)

Values of pH and electric conductivity measured at samples from the K2 vessel are shown in Table 2.

**Table 2.** Values of pH and electric conductivity

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
pH	7.79	7.79	7.80	7.81	7.80	7.74	7.77	7.75	7.67	7.71	7.72	7.73
EC [ $\text{mS}\cdot\text{cm}^{-1}$ ]	1.88	2.06	2.20	1.79	1.69	1.60	1.94	1.23	2.05	1.41	1.88	1.70

The measured pH values achieve the average value of 7.76 with the standard deviation of 0.04. Received data are very balanced and correspond with values measured by Himanen [2011] and Kalamdhad and Kazmi [2009]. Such relatively high pH value is usually measured for freshly matured compost and consecutively slowly drops during the time of several weeks. Even though the measured values were the interval determined in CSN 46 5765 standard “Industrial composts”, (i.e., pH = 6.0 – 8.5), this criterion cannot be considered as sufficiently evidential in assessing the compost quality.

The measured values of conductivity reach the average value of  $1.79 \text{ mS}\cdot\text{cm}^{-1}$  with the standard deviation of 0.27. The received data are relatively balanced and steady, compared to other authors (in particular Komilis at al. [2011]). When comparing the absolute value of conductivity of samples of compost with data from other authors, the measured values are rather low; the lowest values:  $1.5 \text{ mS}\cdot\text{cm}^{-1}$  – mentioned by Himanen [2011], furthermore  $2.23 \text{ mS}\cdot\text{cm}^{-1}$  Komilis at al. [2011],  $2.5 \text{ mS}\cdot\text{cm}^{-1}$  Kalamdhad and Kazmi [2009] and  $2.3 - 3.4 \text{ mS}\cdot\text{cm}^{-1}$  Huber-Humer at al. [2011].

The CSN standard “Industrial composts” does not mention electric conductivity as one of parameters of the compost quality, but according to the Austrian standard ÖNORM S 2200 “Gütekriterien für Komposte aus biogenen Abfällen“ (Quality criteria for composts from biogenous waste) value of conductivity should for raw compost not exceed  $4 \text{ mS}\cdot\text{cm}^{-1}$ , for matured compost –

$2 \text{ mS}\cdot\text{cm}^{-1}$ . Three quarters of evaluated samples of compost from the K2 vessel satisfy the limit values for matured compost; the remaining one quarter of samples is near to these limit values.

## CONCLUSION

The described experiment showed advantages and disadvantages of home composting in a compost pile.

The composting process of small volume of biodegradable waste in the compost pile is not sufficiently intensive in order to maintain adequate temperature necessary for hygienization of the entire volume of the composted material. Therefore it is possible to safely compost under home conditions only waste from maintenance of gardens and further kitchen vegetable waste.

If a citizen is willing to regularly mix and turn the composted material, then for grass composting it is possible to produce compost already after 3 months. Reduction in volume during the composting process is so large, so that the compost backfill does not take too much space in a garden. It is possible to compost waste from garden during the vegetation season in the backfill and produced compost can be applied on land before commencement of the next vegetation season.

If a citizen is not willing to mix or turn the composted material, the composting process time is much extended and use of compost already during the next vegetation season cannot be assumed. As well reduction in volume is lower than in case of turned and mixed composting pile and higher demands on space for non-maintained composting pile can be expected.

Owing to natural effect of rainfall, water moistening of dry composted material has significantly smaller importance for optimization of the composting process.

On the basis of measured characteristics it was proved that turning and mixing the composted material is the most important operation in order to ensure proper composting process, be specific also under home conditions. Without mixing and turning the composting pile it is not possible to quickly compost the waste from maintenance of house gardens together with achieving a good quality of compost.

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