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Higher pH and faster decomposition in biowaste composting by increased aeration

C. Sundberg *, H. Jönsson

Department of Biometry and Engineering, Swedish University of Agricultural Sciences, P.O. Box 7032, SE-750 07 Uppsala, Sweden

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Abstract

Composting of source separated municipal biowaste has at several plants in Scandinavia been hampered by low pH. In this study the hypothesis that increased aeration would improve the process was tested in full-scale experiments at two large composting plants. The O_2 concentrations were high (>15%) even at the low aeration rates, so the prevailing low pH was not due to an anaerobic process environment. In spite of this, increased aeration rates at the start of the process resulted in higher microbial activity, increased pH and a more stable compost product. At one plant the decomposition rate varied in proportion to the aeration rate, to the extent that the temperatures and O_2 concentrations were similar during the early processes even though aeration rates varied between 10 and 50 $m^3/(h, m^3$ compost). However, increased aeration caused severe drying of the compost, but at one plant the addition of water was adequate to prevent drying. In conclusion, by increasing the aeration rates and adding water to compensate for drying, it was possible to shorten the time needed to produce a stable compost product and thus to increase the efficiency of the composting plants.

1. Introduction

Composting of biowaste (source-separated biodegradable municipal waste) is an important part of the European Union waste management strategy for reducing waste going to landfill, and many composting plants have been built in recent years. However, biowaste composting in Scandinavia has been troubled by low pH during the process, partly due to the low pH of the incoming waste, which often has a pH in the range 4.5–5.1 (Eklind et al., 1997; Norgaard and Sorheim, 2004). The low pH during the process results in corrosion, odour, slow decomposition and thus inefficient use of the facilities, low compost quality and difficulties in attaining temperatures high enough for proper sanitization.

Composting is an oxygen-consuming heat-generating microbial process, and a highly active dynamic microbial system that changes its own environmental conditions. Most notable is the increasing temperature. Mesophilic microorganisms are active up to 40–45 °C, while thermophilic organisms have optimum temperatures above that. Moisture is essential for the function of the composting process, but excessive moisture reduces the airspace in the compost matrix and thus causes oxygen limitation. In active composts, the oxygen present in the pore space is consumed within minutes, so a continuous supply of fresh air is crucial for the process to remain aerobic.

The low pH in biowaste is caused by short-chain organic acids, mainly lactic acid and acetic acid (Eklind et al., 1997). The microbial formation and decomposition of organic acids depends on the oxygen level and temperature. Higher oxygen concentration gives lower maximum concentrations of organic acids in the compost and a faster decomposition of the acids, and thus a faster rise in pH (Beck-Friis et al., 2003). In composting reactor experiments, it has been shown that the time until the pH increases and high-rate decomposition starts can be shortened if the composting temperature is kept in the mesophilic range (below 40 °C) until the pH in condensate

* Corresponding author. Tel.: +46 18 67 18 11; fax: +46 18 67 18 88.
E-mail address: cecilia.sundberg@bt.slu.se (C. Sundberg).

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formed from exhaust gas is above 5 (Smårs et al., 2002). Increased aeration increases cooling and may thus give both higher oxygen concentration and decreased temperature, two process conditions that have been shown to result in a faster increase in pH during composting. The main objective of this work was to test at full scale the hypothesis that increased aeration would make pH rise faster, reach a higher level during the composting process, and result in an increased decomposition rate. A further objective was to investigate the extent of drying caused by the increased aeration, and thus the water addition requirement.

2. Materials and methods

2.1. The composting plants

The Hogstad composting facility, managed by the municipal company IVAR in the Stavanger region of Norway, treats 25,000 ton of biowaste (source-separated household food and garden waste) per year. The waste mixture is composted in a hall, in an agitated bed system, where the substrate is entered at one end and removed at the other end (Fig. 1). The process is performed in reinforced concrete bays 5 m wide, 42 m long and 2.5 m deep, although only filled to a 2 m depth. The material is turned every 2–4 days by mechanised agitators, which move it 4.7 m forward each time. After nine turns, 20–30 days of composting, the compost has come to the other end and is removed from the hall. The aeration of each bay is divided into four zones with separate fans, each 7–15 m long. The bays are aerated by negative aeration (drawing the gases out through perforated floors underneath the bays) except for the first zone (first 5 m) in one bay, which is aerated by positive aeration.

The Støleheia composting facility, managed by the municipal company Renovasjonsselskapet for the Kristiansand Region (RKR) in Kristiansand, Norway, also treats source separated household biowaste (11,000 ton in 2004) in an agitated bed system in a hall with reinforced concrete bays, 2.8 m wide, 2.2 m deep and 64 m long, into which air is blown from below. The bays are aerated in five separate zones and turned by mechanised agitators at intervals of 2–3 days, each time moving the material 4.2 m towards the end of the hall. The residence time in each zone is 5–7 days. After 30–40 days the compost has reached the far end and is removed from the hall.

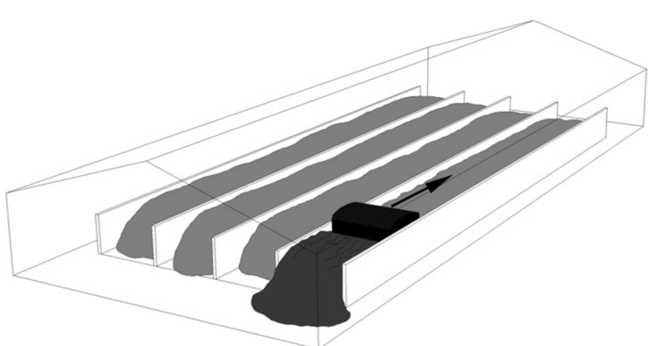

Fig. 1. Schematic drawing of the composting plants. Substrate is entered at the rear end of the building and compost is removed at the front end. The turning machine moves along the bay (arrow) and the compost is moved in the opposite direction. The bays are aerated from below by positive (RKR) or negative (IVAR) aeration. Aeration is supplied in 4 (RKR) or 5 (IVAR) zones separated along the length of the bays.

2.2. Experimental set-up

At IVAR, two composting bays (I1 and I2) were monitored in September–November 2004. Three consecutive batches, of which the first two (A and B) are reported here, were monitored in I1, and two consecutive batches in I2. At RKR, two consecutive batches (A and B) in three composting bays (R1, R2 and R3) were monitored in June–July 2004. At IVAR, the whole process was monitored, whereas the investigation at RKR focused on the first 8 days. Each bay had a different aeration schedule, with the lowest rate in I1 and R1. Other factors, such as turning frequency, were kept as similar as possible between the batches and bays at each plant.

The input air was taken from the hall (20–30 °C) at both plants. At IVAR, the aeration was continuous in all bays, while fan sizes and valve settings differed between bays, resulting in varying aeration rates (Fig. 2). At RKR, the varying aeration between the bays was due to differences in fan sizes and on/off intervals.

At both plants, the aeration rates were much higher in the first zone than in the later zones. The difference in aeration rate between the bays was large in the beginning and smaller later on (Fig. 2). At IVAR the aeration rate in the first zone was about three times higher in I2 than in I1. Also in the second zone, bay I2 received more air than I1. There were no distinct differences in aeration rates between the two bays in the other zones, i.e., from day 10 onwards.

At RKR, the aeration in the first zone in R2 and R3 was continuous, but in R1 the aeration was intermittent (2 min on, 10 min off), and the average aeration rate is presented in Fig. 2. In the second zone the aeration in R1 and R2 was set at 1 min on, 10 min off, and in R3 5 min on, 10 min off. At IVAR water was added and mixed in during turning of the compost, and at RKR water was added by spraying on top of the bays for 5–20 min/h at night (Table 1). At RKR, the sprinkler system for water addition did not cover the first 12 m of the bays, so no water was added during the first week of the process. The water addition was set to give more water to the bay that received more aeration, so 4.1, 8.2 and 11.5 m^3 of water was added to each batch in R1, R2 and R3, respectively.

At both plants, the main substrate was biodegradable waste from households, mainly kitchen waste. This waste was collected in bags made of paper or biodegradable plastics and was shredded on arrival to open the bags. At IVAR, a mixture of waste (73% on wet weight basis), crushed wood (variable size, <80 mm, 13%) and structural