EFFECT OF AIR FLOW RATES AND MIXING PERIODS ON THE COMPOSTION OF FOOD RESIDUES

HESHAM A. FARAG
Agricultural Engineering Research Institute ARC, Dokki, Giza

(Manuscript received 9 March 2008)

Abstract

Food waste and sawdust were used to produce compost using a composting bioreactor system. The moisture content and C:N ratio of the initial mixture were adjusted at 60% and 30:1, respectively. Three aeration rates and two mixing periods were used in this experiment. Moisture content, dry matter, pH, total Kjeldahl nitrogen, total carbon, bulk density, total phosphate and total potassium were measured on the initial mixture and at the end of composting process. The temperature changes and CO$_2$ rates were monitored and recorded in all the bioreactors. The results indicated that the maximum temperature ranged from 48 to 52 °C depending on the aeration rate and mixing period. The maximum temperature that was higher than 50 °C was found only in bioreactors C1 and C2 and was maintained for three days. In all reactors the CO$_2$ emission increased and was proportional to the temperature and aeration rates. The relation between temperatures, emissions of carbon dioxide, aeration rates and the mixing period in this study was found to be ($T = 20 + 6.5$ $\text{CO}_2 + 24.4 - 0.02$), $T$: the compost temperature (°C), $A$: the aeration rate (m$^3$/hr), $M$: mixing period (hr), CO$_2$: emission of carbon dioxide (%). An aeration rate of 0.15 m$^3$/hr and mixing period of 12 h produced good quality compost in 18 days and saved 50% of the power consumed in the mixing operation.

Key words: aeration rates, bioreactor, compost, food residues, mixing, waste recycle, CO$_2$, Temperature.

INTRODUCTION

Composting is seen as a mean of turning waste materials into a valuable product that can be recycled back to the soil. It promotes soil fertility, reduces environmental pollution and eliminates weed seed and pathogen viability. The quality of compost is affected by several factors including; pH, temperature, moisture content, availability of micronutrients, C:N ratio, bulk density, mixing and oxygen supply.

Polprasert et al. (1994) reported that the composted water hyacinth plants mixed with leaves and pig manure contained N, P, and K of about 2.2, 1.5 and 0.8 % respectively. The pile with a C: N ratio of 30:1 had a higher temperature build – up than that of 25:1 during the first few days of composting.

Liang et al. (2003) conducted composting experiments using a 2-factors factorial design with six temperatures (22, 29, 36, 43, 50, and 57 °C) and five
moisture contents (30, 40, 50, 60, and 70%). The microbial activity was measured as O₂ uptake rate (mg g⁻¹ h⁻¹) using a computer controlled respirometer. In this study, moisture content proved to be a dominant factor impacting aerobic microbial activity of the composting blend. Fifty percent moisture content appeared to be the minimum requirement for obtaining activities greater than 1.0 mg g⁻¹ h⁻¹ while the range of 60 – 70% provided maximum activities. Temperature was also documented to be an important factor for biosolids composting. For the main effect of temperature, the magnitude of cumulative O₂ uptake was found to be highest at 43 °C.

Alkaeik and Ghaly (2006) performed heat and mass balance on a laboratory composting bioreactor operating on tomato plants residues. Wood shavings and municipal solid compost were used as a bulking agent and inoculums, respectively. The moisture content and C:N ratio were adjusted at 60% and 30:1, respectively. The temperature peaked after 31 h of operation reaching 63.3 °C and lasted for 9 h. The result of the thermal analysis indicated that the average heat production value was 14.6 kJ/g DM degraded. The conductive heat losses through the cylindrical body and the sidewalls of the bioreactor accounted for 62.6 kJ. The moisture content stayed relatively constant 59.7 ± 0.61 %. The reduction in volatile solids, total carbohydrate, fat and grease, protein, and TKN-N (total Kjeldahl nitrogen) were 29.1, 31.7, 88.8, 17.8 and 11.0%, respectively. The NH₄⁺-N remained unchanged (0.33 – 0.35 %).

Ghaly et al. (2006) reported on the bioreactor operated on an infected mixture of tomato plant residues, wood shavings, and municipal solid compost (1: 1.5: 0.28). Tap water and urea were added to adjust the moisture content and C:N ratio to 60% and 30:1, respectively. Used cooking oil was added as a bioavailable carbon source to compensate for heat losses from the system and extend the thermophilic composting stage. The controlled thermophilic composting process was successful in destroying R. cinereus.

Hatem and Ghaly (1994) produced compost from municipal solid waste. The composting materials used in the study consisted of food wastes (30%) grass clippings (30%) leaves (30%) and sawdust (10%). Two aeration rates 0.35 and 1.70 L/min. (0.0425 and 0.0850 kg/ min) were investigated. In all the experiments, the surface temperature of the compost material reached its maximum (43 – 53 °C) within 2 days from the start of the experiment, remained relatively constant for 4 days and then began to fall off back to the ambient temperature. Similar trends were observed for the temperature at the center of the compost mass. The process was considered complete when the surface temperature decreased to the room temperature. The moisture content was reduced from 83 – 89 % to 72 – 76 %. The pH of the raw materials remained in the range of 8-9. However, increased the percentage of
ammonium nitrogen, from 7 - 13% to 25 - 40 % indicating that the organic nitrogen was converted to ammonium nitrogen. The final material had a dark brownish – black color with an earthy smell.

OBJECTIVE

The aim of this study was to investigate the effectiveness of aeration rate and mixing period on the compost quality and maturity; and to study the relation of temperature, aeration rate, mixing period and carbon dioxide (CO₂) emission during the composting process.

EXPERIMENTAL APPARATUS

The composting system shown in Figure 1 consisted of a frame, three bioreactors, aeration system and a data acquisition system. The frame was made of two parts. The main part was made of three aluminum sheets (3.2mm thick), the central one measured 330 X 1100 mm and the two side sheets measured 140 X 1100 mm each. They were soldered together making a vertical channel (U shape) with a length of 1100 mm, a width of 330 mm and a depth of 140 mm. This U shape stand hold the mixing motors, flow meters, air and exhaust gas manifolds and tubing, and the thermocouple wires. The second part of the frame was a horizontal supporter made of three 50 X50 mm aluminum angles 3.2 mm thick, two of which measured 700 mm, whereas the third one measured 328 mm and kept the other two angles 330 mm apart. The aluminum angles were permanently soldered together. Each bioreactor was constructed of 203 mm (ID) polyvinyl chloride (PVC) pipe. The length and the wall thickness of the tube were 520 and 5 mm, respectively. They were horizontally fixed to the main frame. One end of the tube was covered with removable circular Plexiglas plate (for the cleaning purposes) of 203 mm diameter and 6 mm thickness. This plate was recessed and secured into the cylinder by means of six stainless steel screws (6 mm).
The fixed circular plate fitted into an aluminum ring, which was fastened into the frame by means of four bolts (6 mm) and nuts. There were three holes at the bottom and one at the top of the bioreactor, which were drilled and threaded to take a 12 mm nylon hose barb. The three holes at the bottom were connected to a manifold by 6.4 mm diameter Tygon tubing and used for aeration, whereas the fourth one at the top was used for the exhaust gas.

In order to maintain isothermal conditions, the bioreactors were insulated and continuously mixed. Both the removable and fixed circular plates were insulated with a 38.0 mm thick Styrofoam layer, while the tube was insulated with 38.0 mm thick fiberglass. The three bioreactors were fixed into the frame. A removable 10.0 mm diameter solid stainless steel shaft, having five stainless steel collars on the shaft in which five bolts of 69 mm in length and 6 mm diameter each, was mounted on two bearings. The shaft was rotated by a thermally protected electric motor (Model No. 127P1466/B, D.C., Sigma Instruments Inc., Braintree, MA, USA).

The air was supplied continuously to the bottom of the bioreactor from the laboratory air supply. It passed through a pressure regulator and a pressure gauge (to maintain a pressure of about 5 kPa), then through a water bath (to humidify the inlet air to nearly 100% saturation) and finally through a flow meter (Model 12461—14, Cole-Parmer Instrument Company, Vernon Hills, IL, USA). The data acquisition unit consisted of a master unit, a thermocouple scanning card, software, temperature sensors, a personal computer and a printer. The master unit (Multiscan 1200, Omega,
Stamford, CT, USA) was connected to a computer via RS 232 interface. The Thermocouple/Volt Scanning Card (MTC/24, Omega, Stamford, CT, USA) contained 24 isolated differential input channels. A window-based (Temp-view) software that featured a graphical spreadsheet-style user interface, allowed easy configurations of hardware and acquisition and display parameters. Four type T (copper-constantan) thermocouples (Cole Parmer, Chicago, IL, USA) were used for each bioreactor for temperature measurements. Three thermocouples were located at the bottom of the bioreactor and were used to measure the temperature of the compost mass. Whereas the fourth was located at the top of the bioreactor, near the outlet air exit (21 mm away) and was used to measure the temperature of the exhaust gas. Thermocouple locations, on the bottom of all bioreactors, were chosen to be far enough from the inlet air (65 mm away). An IBM personal computer (Pentium IV) and an HP (Hewlett-Packard) Laserjet 4 printer was used. A simple computer program written by basic language was used to control the mixing period. The program was running by an IBM computer (under DOS, operating system) to turn on/off the mixer.

**MATERIALS**

The raw materials used in this study included food waste and saw dust. The food waste was obtained from the O' Brain Hall Residence of Dalhousie University, Halifax, Nova Scotia, Canada. The food waste was shredded and packaged then stored in the freezer at -20 °C. The saw dust obtained from a local lumber mill (Barrett lumber, Lower Sackville, Nova Scotia). Characteristics of these materials are shown in Table 1.

**Table 1. Characteristics of raw materials food waste and saw dust.**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Food waste</th>
<th>Saw dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content %</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Dry matter (kg/kg)</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>pH</td>
<td>4.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Weight of N (kg/kg)</td>
<td>0.006</td>
<td>0.001</td>
</tr>
<tr>
<td>Weight of C (kg/kg)</td>
<td>0.09</td>
<td>0.4</td>
</tr>
<tr>
<td>Bulk Density (kg/m³)</td>
<td>620</td>
<td>190</td>
</tr>
<tr>
<td>Total P (g/kg)</td>
<td>2.3</td>
<td>0.00</td>
</tr>
<tr>
<td>Total K (g/kg)</td>
<td>3.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**EXPERIMENTAL PROCEDURE**

The temperature sensors (Thermocouples type T) were calibrated using ice and boiling water baths. The thermocouples including the fittings were immersed into the
ice bath and hooked up to the data acquisition system individually. The thermocouple reading as temperature in degree centigrade was corrected to read zero °C (offset) and then into the boiling water to correct the upper limit. The calibration equation is a linear relationship as follows:

\[ T_{\text{Corrected}} = a \times T_{\text{Actual}} + b \]  

(1)

where:
- \( T_{\text{Corrected}} \) is the corrected temperature reading,
- \( T_{\text{Actual}} \) actual temperature reading,
- \( a \) slope of the linear line, constant
- \( b \) intercept (offset), constant.

The amount of sawdust (S) added to each kg of food waste to adjust the C:N ratio at 30:1 and the moisture content at 60% was determined using the following formula (Esther and Julie, 2001):

\[ \text{C:N} = \frac{\text{C in waste} + \text{C in sawdust}}{\text{N in waste} + \text{N in sawdust}} \]

\[ = \frac{0.09 + S(0.4)}{0.006 + S(0.001)} ; \quad S = 0.25 \text{ Kg} \]

A mixture of food waste and sawdust at a ratio of 4:1 a moisture content of 60% was prepared. 25 kg of the final mixture was mixed well and divided into 3.5 kg packages. One package was placed in each bioreactor which occupied 75% of the total volume of the bioreactor. Air flow rates of 0.075, 0.1 and 0.15 m³/h were used during the experiment. A mixing speed of 5.0 rpm was used in two different mixing periods 12 and 24 h as shown in Table 2. The temperature was continuously monitored during the study.

Table 2. The experiment design.

<table>
<thead>
<tr>
<th>Composting mixture</th>
<th>Aeration time (h)</th>
<th>Mixing speed rpm</th>
<th>Mixing time (h)</th>
<th>Aeration rate (m³/h)</th>
<th>Bioreactors and replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food wastes and sawdust</td>
<td>24</td>
<td>5</td>
<td>12</td>
<td>0.075</td>
<td>( A_1 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>( B_1 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td>( C_1 )</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td></td>
<td>0.075</td>
<td>( A_2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>( B_2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td>( C_2 )</td>
<td></td>
</tr>
</tbody>
</table>

The CO₂ was performed every day using a portable CO₂ digital meter (Columbus Instruments Portable gas meter (PGM)). Total nitrogen (TKN), total carbon (TC), dry matter (DM), bulk density, pH, total P and total K were performed on the initial and
The moisture content (MC) and the dry matter were determined according to the On Farm Composting Handbook (Rynk 1992 – NRAES- 54) by drying the samples at 105 °C for 24 h until the constant weight then the moisture was calculated using the following formula

\[ MC\% = \frac{(W_w - W_d)}{W_w} \]

Where:
- \( MC\% \) : Moisture content %
- \( W_w \) : Wet weight (g)
- \( W_d \) : Dry weight (g)

The dry matter was determined as the difference between total weight and weight of water in each sample.

The compost pH was measured using Fisher Accumet pH meter, 50cm² sample of compost material was diluted 1:10 (v:v) distilled – deionized water and placed in the mechanical shaker at 230 rpm for 30 minutes. For Total Kjeldahl Nitrogen (TKN) 1 gm of the composted material was digested with 4 ml concentrated sulphuric acid (H₂SO₄) and 20 ml distilled water, then placed in digester at 420 °C for 1 h under vacuumed ventilator and then titrated. The bulk density was determined by filling container of known volume and weight with the materials and the filled container was weighed. The bulk density equals the filled container weight minus the empty container weight divided by the container volume. Total carbon, dry matter and nutrients elements of the composted sample were determined at the Materials Engineering Center (MEC) of Dalhousie University. Elements were determined by flame atomic absorption spectrometer (Spectra AA 55B, Varian Australia Pty Ltd. Mulgrave, Victoria, Australia) with detection limit of 1 ppm except Carbon dioxide and non-carbonate carbon were determined with Leco carbon analyzer (Model 516-000).

RESULTS AND DISCUSSION

General properties

Some chemical and physical properties of the initial mixture and the produced compost are presented in Table 3. The initial moisture content of the mixed materials was adjusted at 60% and the final moisture contents were in the range of 43% - 54%.
Table 3. The general properties of the initial mixture and the final products from each bioreactor.

<table>
<thead>
<tr>
<th>Mixture or Bioreactor</th>
<th>NC (%)</th>
<th>DM (kg/kg)</th>
<th>pH</th>
<th>TN (kg/kg)</th>
<th>T.C (kg/kg)</th>
<th>Bulk density (kg/m³)</th>
<th>Total P (kg/kg)</th>
<th>Total K (kg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial mixture</td>
<td>59</td>
<td>0.35</td>
<td>5.5</td>
<td>0.0004</td>
<td>0.12</td>
<td>522</td>
<td>1.2</td>
<td>3.2</td>
</tr>
<tr>
<td>A</td>
<td>59a</td>
<td>0.3a</td>
<td>8.0a</td>
<td>0.0350</td>
<td>0.14</td>
<td>479a</td>
<td>1.9a</td>
<td>2.3a</td>
</tr>
<tr>
<td>B</td>
<td>59b</td>
<td>0.2b</td>
<td>8.0b</td>
<td>0.075b</td>
<td>0.05a</td>
<td>461b</td>
<td>2.0a</td>
<td>3.3a</td>
</tr>
<tr>
<td>C</td>
<td>45c</td>
<td>0.27c</td>
<td>8.7c</td>
<td>0.069c</td>
<td>0.08c</td>
<td>424c</td>
<td>2.1c</td>
<td>3.1c</td>
</tr>
<tr>
<td>A</td>
<td>57a</td>
<td>0.3a</td>
<td>8.0a</td>
<td>0.060a</td>
<td>0.1a</td>
<td>465a</td>
<td>2.0a</td>
<td>3.0a</td>
</tr>
<tr>
<td>B</td>
<td>46b</td>
<td>0.28b</td>
<td>8.0b</td>
<td>0.070b</td>
<td>0.09a</td>
<td>445b</td>
<td>2.0a</td>
<td>3.2a</td>
</tr>
<tr>
<td>C</td>
<td>43c</td>
<td>0.27b</td>
<td>8.0a</td>
<td>0.061b</td>
<td>0.08b</td>
<td>420c</td>
<td>2.0a</td>
<td>3.0b</td>
</tr>
</tbody>
</table>

A, B, C: The compost produced from 12h mixing period and aeration rates 0.75, 0.1, and 0.15 m³/h respectively.

A, B, C: The compost produced from 24h mixing period and aeration rates 0.75, 0.1, and 0.15 m³/h respectively.

Means within a group followed by the same letters were not significantly different at probability 0.05 using Duncan test (SAS ver.5, 1985).

The moisture of the compost materials provides an environment rich in dissolved nutrients essential for microbial degradation activities. Changes were observed in the moisture content of the materials due to the water lost with exhaust gas. Richard et al (2002) reported that the optimum moisture content of the initial composting mixtures varies from 59 to 70%. Laing et al (2003) found 50% moisture content seems to be the minimum requirement for rapid increase in microbial activity, while 60 to 70% provided maximum activities during the composting process. The authors also stated that decreasing the initial moisture content found at the end of the composting process. The results also showed that the amounts of moisture lost after the composting process depends on the aeration rate and mixing period. A positive relationship was found between loss of moisture and increase of aeration rate and/or mixing period. Franke (1997) stated that decreasing moisture content during the composting depended on the aeration rate and the microbial activity. Kuıcu and Yıldız (2004) stated that with different aeration rates the moisture contents of all samples were decreased continuously during composting. By the end of the compost process the moisture contents were declined from 71% to 65, 64, and 57% at aeration rates 0.1, 0.21, and 0.41 l/min/kg, respectively.

The dry matter decreased at the end of the composting process related to the microbial activity. The total dry matter loss was in the range of 14 – 22 % depending on the aeration rate and the mixing period. The results showed that with increasing of
the aeration rate and/or mixing period the dry matter loss increased. The maximum
dry matter loss was found with aeration rate 0.15 m³/h and at all the mixing period.
Rajbanshi and Inubushi (1998) reported that the total dry matter loss was 157 mg/g
and 120 mg/g after the composting operation depending on the microbial activities.
Kulcu and Yıldız (2004) stated that the higher dry and organic matter lost were
observed in the reactor had the higher aeration rate and the decrease was more
pronounced during the first stages of the process.

The pH levels of the compost materials varied during the composting process.
The final pH increased from 5.5 to approximately 8.5 - 8.7. The results showed no
significant effect of the aeration rate or the mixing period on the pH values. Bañitas
(1992) found alkaline pH values in composts made from wastes and olive tree leaves.
Rajbanshi and Inubushi (1998) reported that during the microbial decomposition of
plant materials, decarboxylation of organic anions results in a pH rise. Kulcu and Yıldız
(2004) stated that with different aeration rates there were no significant differences
between the pH values during and at the end of the composting process, the final pH
values were in the range of 8.5 - 8.8.

Increasing in total nitrogen was observed with all treatments. The higher value
of TN was noticed in the compost produced from aeration rate 0.1 m³/h and 12 h
mixing period. NH₃ smell was noticed during the experiment that is due to loss of NH₃-
N with exhaust gas, this explain why the TN did not have a proportional increase
with the aeration rate in this study. Franke (1997) proposed that the NH₃ emission
increased with the composting time. The higher release of NH₃ gas noticed during
peak temperature and with the higher aeration rate. Rajbanshi and Inubushi (1998)
reported that unproportional loss of different elements of the organic matter seems to
be the reason for the increase in the nitrogen concentration during the composting
process. Kulcu and Yıldız (2004) found that increasing the aeration rate from 0.1 L/min
to 0.4 L/min increased the concentration of total nitrogen from 3.4 to 3.9 mg/g but
with increasing the aeration rate to 0.8 L/min, the TN reduced to 3.4 mg/g.

The percent reduction of the total carbon ranged from 16 to 33 % depending
on the aeration rate. The high reduction percents were found with the high aeration
rate 0.15 m³/h while the mixing period effectiveness was regardless. Kulcu and Yıldız
(2004) found the same results at different aeration rates. However the reduction
amounts in the total carbon generally was low in this experiment (reduced from 0.12
to 0.08) maybe due to the fact that most of the carbon in sawdust was not
reduction of 65% after 31 days and 68% after 22 days of composting crop and food
days of composting of sewage sludge and vegetable wastes.

The bulk density of the mixture compost materials were declined in all the final
compost samples. The results indicated that the bulk density decreased by a percent
range from 10% to 20% depending on the aeration rate and mixing period. The
results indicated that by increasing the aeration rate and mixing period the reduction
in bulk density increased due to the reduction of the moisture content during the
composting process. Esther and Julie (2001) found that the bulk density of the
compost materials decreased from 452 to 412 kg/m³ with the composting time. Suzelle
et al. (2002) reported that there was a decrease in the bulk density of the mixture
compost materials ranging from 40 to 55% at the end of the compost processes
depending on the air flow rates.

The quantity of the nutrients (total phosphorus and total potassium) is
important in the mixture wastes for microorganism's growth as well as in the final
product as an indicator for the quality of compost. The initial amount of the total
phosphate and the total potassium were studied during this experiment and it was
found to be sufficient for the microbial growth according to Manios (2004) who
suggested nutrients concentration in the mixture waste not less than 0.4 mg/g. At the
end of the experiment the concentration of the total phosphate was increased from
1.2 to 1.9 and 2.0 g/kg as well the total potassium increased from 3.0 to 3.3 and 3.5
g/kg. Manios (2004) stated that nutrients concentrations in the compost mixture
especially agriculture based, is concerned with the suitability of utilization of the final
product as a plant nutrients.

**Temperature and carbon dioxide**

The average temperature profiles during the composting process are presented
in figure 2. The maximum temperature ranged from 48 to 52 °C depending on the
aeration rate and mixing speed. The temperature started to increase inside the
bioreactors by the third or fourth day. Temperatures higher than 40 °C were observed
in all bioreactors after one week and remained for 5 – 6 days. The maximum
temperature that was higher than 50 °C was found only in bioreactors C₁ and C₂ and
was maintained for three days. Liang et al. (2003) stated that temperature has been
shown to be a critical determinant of composting efficiency. The temperature range
for optimal composting is between 52 and 60 °C.
Kulcu and Yalildiz (2004) reported that the composting process reached the temperature of 50°C after the first week. However in this experiment there was a proportional relation between the temperature and the aeration rate. On the other hand there was no effect for the mixing period when the aeration rate was at 0.15 m³/h. Hatem and Ghaly (1994) reported that the highest surface temperatures in the composting process were observed with increased aeration rates that due to higher aeration rates promoted maximum microbial growth. Kulcu and Yalildiz (2004) stated that using a different aeration rate a significant difference in temperature regime was found among all composting reactors after the second week. After 11 days from starting the composting process the temperatures gradually decreased. The possible reason for this decrease is because of the decrease in bioavailable carbon and nitrogen sources for the microorganisms activities. Esther and Julia (2001) reported that temperature remain high for one week or more before decreasing. The maximum temperatures should not exceed 66 °C otherwise microbial activity will diminish due to spore formation.

**Carbon dioxide (CO₂)**

The CO₂ production in the composting process was due to the mineralization of the organic matter. Figure 3. shows the relation between the composting times and the CO₂ emissions at different aeration rates and mixing period. In all reactors the CO₂ emission increased and proportional with temperatures and aeration rates due to the following equation (Alkoaik, 2004):

\[
C_6H_{12}O_6 + O_2 \xrightarrow{\text{Microbes}} CO_2 + H_2O + \text{heat}
\]
Fig. 3. CO₂ emissions during the composting process

Verdonck et al. (1994) reported that in the composting process when the temperature is high, a large amount of CO₂ is produced due to the intense microbiological activity. The maximum CO₂ output was found at the temperatures ranging from 55 to 60 °C. Manios et al. (2006) stated that carbon availability and temperature profile of the composting process have a significant effect on the production of CO₂. The results indicated that CO₂ emission was increased after three days and decreased after thirteen days with all aeration rates and mixing periods. Kulcu and Yaldız (2004) stated that CO₂ rate increased in all bioreactors depending on microorganism activity and aeration rate. The authors also stated that the CO₂ rate was increased after four days and decreased after ten days in all the aerated bioreactors.

The relation between the temperatures, the accumulation emissions of carbon dioxide, the aeration rates and the mixing period in this study could be simulated by an equation which was investigated using the regressions analysis by (Minitab, 14.20 LEAD technologies 2004).

\[ T = 20 + 6.5 \times \text{CO}_2 + 24 \times \text{A} - 0.01 \times \text{M} \]

Where:
- \( T \): is the compost temperature (°C)
- \( A \): the aeration rate (m³/h)
- \( M \): mixing period (h)
- \( \text{CO}_2 \): emission of carbon dioxide (%)
CONCLUSIONS

A composting system consisting of three bioreactors was used to produce compost from food waste. According to the results the general properties which included, moisture content, dry matter, pH, total Kjeldahl nitrogen, total carbon, bulk density, total phosphate and total potassium were changed at the end of the composting process and the changes depended on both the aeration rates and mixing period. The temperatures and CO2 were in a proportional relation in all the bioreactors. A treatment combination of an aeration rate 0.15 m3/h and a12 h mixing period produced a good quality compost in 18 days and as well as saving 50% of the power consumed in the mixing operation compared with the continuous mixing. The general properties of the compost produced from this treatment were: 45%, 0.27 kg/kg, 8.7, 0.006 kg/kg, 0.08 kg/kg, 424 kg/m3, 2.1g/kg and 3.5g/kg for moisture content, dry matter, pH, TKN, TC, Bulk density, P and K respectively.

ACKNOWLEDGMENTS

The Biological Engineering Department, Dalhousie University, Halifax Nova Scotia, Funded this study; I thank all the staff of the Biological Engineering Department for their efforts.

REFERENCES


تأثير معدلات النمو وزمن التقليل على كيميوست مختلطة الأطعمة

هشام عبد المنعم فرج

معهد بحوث النباتات الزراعية - مركز بحوث الزراعة - الدقهلية - جيزة

تم استخدام خليط من مخلطات الطعام مع نشارة القش، لإنتاج كيميوست باستخدام مخمر حيوى حيث تم تصنيع ثلاث مخللات حيوية سعة كل منها التجريبية 23 كجم وزودت بنظام نمو وملعب تناهي في إضافة إلى سلة محبطة حبوب من نوع (T, thermocouples) لكل مخمر متصلة بنظام توقف لتسجيل وتخطيط البيانات على المنبه الآلي على مدار اليوم، وذلك بعنصر التكنولوجيا الحيوية بجامعة داينيس لين، كندا. وتمت التجربة عند رطوبة 50% ودرجة حرارة 28 درجة مئوية في الدور المغلق في الفترة من 10 لـ 15 يومًا معبأة في ساعة مع فترات زمنية من 26 و 24 ساعة. تم تقدير كلا من المحتوى النموي والمواد النباتية والألبان، والخميرة الحيوية والنشارة النباتية والكرياتن والكرياتين، السوائل والشاشه في البلاستيك ورغم التعبير النباتي، وتسمى النشارة النباتية في الحركة، وتباع الآن كمكملات مختلطة فائدة صلة في تطبيق التربة. وتم تسجيل النوري النباتي في الحركة، ودورة نباتات مختلطة في الجرعة، وقد أظهرت النتائج أن درجات الحرارة التي تتجاوز بين 20 درجة مئوية تتأثر بمعدلات النمو وفترة التقليل، وقد توقفت درجة الحرارة المرتفعة (أعلى 50 درجة مئوية) مع معدلات نموية 0.6 معبأة وضع كلا من زمن التقليل 26 و24 ساعة خلال اليوم وقد استمرت تلك الحرارة أعلى من 40 مئوية لمدة ثلاث أيام. وقدmouseout أن فيه تأثير كبسيل الكرويين يتسبب طريقة مع درجات الحرارة ومواد النباتية. وقد أمكن التوصل إلى علاقة ترتبط بين كفاءة المعاملات باستخدام برنامج Minitab الرياضي كالتالي:

\[ T = 20 + 6.5 \% \text{CO}_2 + 24 A - 0.01 M \]

حيث 3 درجة حرارة للكرويون أثناء التقليل (ساعة)، 24 A كأسيد الكرويون المبدئ (%)، A معدل النمو (ساعة)، م زمن التقليل (ساعة).

وقد أظهرت النتائج النباتية أن مع استعمال معدل نمو 15، م زمن التقليل 12 ساعة يومياً يت亻 kيميوست عالي الجودة خلال 18 يوم فقط مع توفير 50% من الطاقة المستفيدة في عمليّة التقليل.