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

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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 C_1 and C_2 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 ($T = 20 + 6.5\ CO_2 + 24\ A - 0.01M$); T: the compost temperature (°C), A: the aeration rate (m^3/h), M: mixing period (h), CO_2: emission of carbon dioxide (%). An aeration rate of 0.15 m^3/h 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, bulking 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 O_2 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 O_2 uptake was found to be highest at 43 °C.

Alkoaik 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 NH_4^+-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 *B. cinerea.*

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 0.85 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 (CO_2) 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 held 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 203mm diameter and 6 mm thickness. This plate was recessed and secured into the cylinder by means of six stainless steel screws (6 mm).

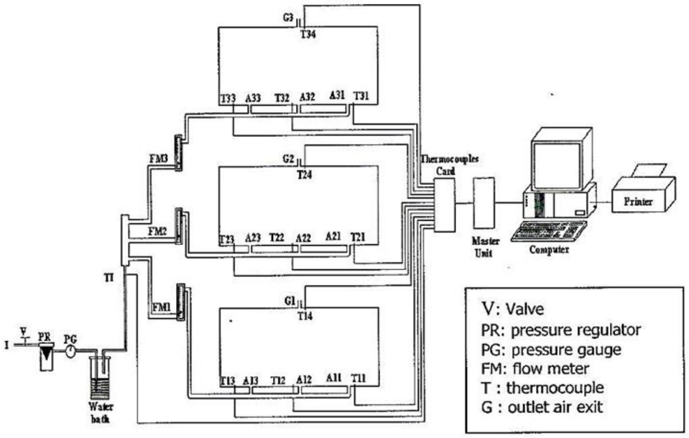

Fig.1. Bioreactors and the experimental setup

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. 127P1486/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 gage (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 32461—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) Laser Jet 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 /of 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 packged 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 sawdust.

Characteristics	Food waste	Saw dust
Moisture content %	70	30
Dry matter (kg/kg)	0.2	0.7
pH	4.5	7.6
Weight of N (kg/kg)	0.006	0.001
Weight of C (kg/kg)	0.09	0.4
Bulk Density (kg/m^3)	620	198
Total P (g/kg)	2.3	0.00
Total K (g/kg)	3.5	0.4

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:

$$T_{Corrected} = a \times T_{Actual} \pm b \qquad (1)$$

where:

$T_{Corrected}$	is the corrected temperature reading,
T_{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 at30:1 and the moisture content at 60% was determined using the following formula (Esther and Julie, 2001):-

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

$$30 = \frac{0.09 + S(0.4)}{0.006 + S(0.001)} \quad ; \quad S = 0.25 \text{ Kg}$$

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 m^3/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.

Composting mixture	Aeration time (h)	Mixing speed rpm	Mixing time (h)	Aeration rate (m3/h)	Bioreactors and replicates
Food wastes and sawdust	24	5	12	0.075	A_1
				0.1	B_1
				0.15	C_1
			24	0.075	A_2
				0.1	B_2
				0.15	C_2

The CO_2 was performed every day using a portable co_2 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 final samples. The moisture content (MC) and the dry matter were determined according to the On Farm Composting Hand Book (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

$$MC\% = (W_w - W_d) / W_w$$

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, $50cm^3$ sample of compost material was diluted 1:10 (v:v) distilled – deionzed 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 (H_2SO_4) and 20 ml distilled water, then placed in digester at 420 °C for 1h 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 Ply 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

Mixture and bioreactors	MC (%)	DM (kg/kg)	pH	TKN (kg/kg)	T.C (kg/kg)	Bulk density (kg/m^3)	Total P (g/kg)	Total K (g/kg)
Initial mixture	*60*	*0.35*	*5.5*	*0.004*	*0.12*	*522*	*1.2*	*3.0*
A_1	54a	0.3a	8.6a	0.005b	0.1a	470a	1.9a	3.3a
B_1	50b	0.3a	8.7a	0.0075b	0.09a	461b	2.0a	3.3a
C_1	45c	0.27b	8.7a	0.006b	0.08b	424c	2.1a	3.5a
A_2	53a	0.3a	8.6a	0.006b	0.1a	468b	2.0a	3.0a
B_2	46c	0.28b	8.6a	0.007b	0.09a	445b	2.0a	3.5a
C_2	43c	0.27b	8.6a	0.005a	0.08b	420c	2.0a	3.5a

A_1, B_1, C_1: The compost produced from 12h mixing period and aeration rates 0.75, 0.1, and 0.15 m^3/h respectively.

A_2, B_2, C_2: The compost produced from 24h mixing period and aeration rates 0.75, 0.1, and 0.15 m^3/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 50 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. Kulcu and Yaldiz (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 m^3/h and at all the mixing period. Rajbanshi and Inubushi (1998) reported that the total dry matter loss was 157 mg/g and 120mg/g after the composting operation depending on the microbial activities. Kulcu and Yaldiz (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 composition 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. Balitas (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 Yaldiz (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 TKN was noticed in the compost produced from aeration rate $0.1m^3/h$ and 12h mixing period. NH_3 smell was noticed during the experiment that is due to loss of NH_3-N with exhaust gas, this explain why the TKN did not have a proportional increase with the aeration rate in this study. Franke (1997) proposed that the NH_3 emission increased with the composting time. The higher release of NH_3 gas noticed during peck 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 Yaldiz (2004) found that increasing the aeration rate from 0.1L/min to 0.4L/min increased the concentration of total nitrogen from 3.4 to 3.9 mg/g but with increasing the aeration rate to 0.8L/min. the TKN reduced to 3.4mg/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 $0.15m^3/h$ while the mixing period effectiveness was regardless. Kulcu and Yaldiz (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 bioavailable source for microbes. Back – Friis et al (2001) achieved total carbon reduction of 65% after 31 days and 68% after 22 days of composting crop and food waste. Wang, *et al.* (2003) observed reduction of organic carbon of 14% during 12 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 ranged from 10 % to 20% depending of the aeration rate and mixing period. The results indicated that by increasing the aeration arte 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/m^3 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 C_1 and C_2 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.

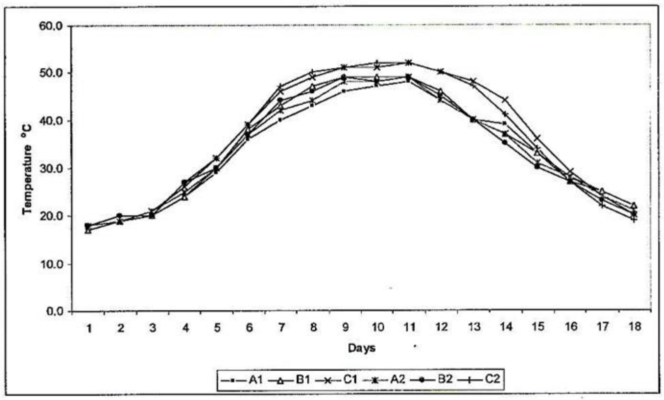

Fig. 2. Temperatures during the composting process

Kulcu and Yalidiz (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 m^3/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 Yaldiz (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 Julie (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 CO_2 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 CO_2 emissions at different aeration rates and mixing period. In all reactors the CO_2 emission increased and proportional with temperatures and aeration rates due to the following equation(Alkoaik, 2004):-

$$C_x H_y O_z + O_2 \xrightarrow{Microbes} CO_2 + H_2O + heat$$

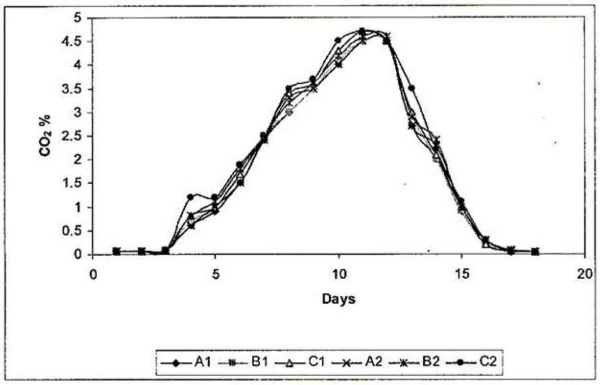

Fig. 3. CO_2 emissions during the composting process

Verdonck *et al.* (1984) reported that in the composting process when the temperature is high; a large amount of CO_2 is produced due to the intense microbiological activity. The maximum CO_2 output were 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 has a significant effect on the production of CO_2. The results indicated that CO_2 emission was increased after three days and decreased after thirteen days with all aeration rates and mixing periods. Kulcu and Yaldiz (2004) stated that CO_2 rate increased in all bioreactors depending on microorganism activity and aeration rate. The authers also stated that the CO_2 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).

$$T = 20 + 6.5\,CO_2 + 24\,A - 0.01M$$

Where: -

T: is the compost temperature (°C)
A: the aeration rate (m^3/h)
M: mixing period (h)
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 CO_2 were in a proportional relation in all the bioreactors. A treatment combination of an aeration rate 0.15 m^3/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 continueous 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/m^3, 2.1g/kg and 3.5g/kg for moisture content, dry matter, pH, TKN, TC, Bulk density, P and K respectively.

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تأثير معدلات التهوية وزمن التقليب على كمبوست مخلفات الأطعمة

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تم استخدام خليط من مخلفات الطعام مع نشارة الخشب لإنتاج كمبوست باستخدام مخمر حيوي حيث تم تصنيع ثلاث مخمرات حيوية سعة كلا منها التجريبية ٣,٥ كجم وزودت بنظام تهوية ومقلب داخلي إضافة إلي أربعة مجسات حرارية من النوع (T, thermocouples) لكل مخمر متصلة بنظام رقمي لتسجيل وتخزين البيانات على الحاسب الآلي على مدار اليوم وذلك بمعل الهندسة الحيوية بجامعة دالهوسي، كندا. وتمت التجارب عند رطوبة ٦٠% ونسبة كربون إلي نيتروجين ١:٣٠ للخليط المستخدم و استخدام في تلك التجربة ٣ معدلات تهوية هي ٠,٠٧٥ ، أو ٠,١ ، ٠,١٥ م^{٣} / ساعة مع فترتين لزمن التقليب ١٢ و ٢٤ ساعة. تم تقدير كلا من المحتوى الرطوبي و المادة الجافة ودرجة الحموضة والنيتروجين الكلي و الكربون الكلي و الفوسفات و البوتاسيوم في بداية التجربة و في المنتج النهائي . وتم تسجيل التغير الدوري في الحرارة وانبعاث ثاني أكسيد الكربون خلال مراحل التخمير داخل المخمرات المستخدمة في التجربة وقد أظهرت النتائج أن درجات الحرارة التي تراوحت بين ٤٨ إلي ٥٢ درجة مئوية تتأثر بمعدلات التهوية وفترة التقليب ، وقد لوحظت درجة الحرارة القصوى (أكثر من ٥٠ درجة مئوية) مع معدلات تهوية ٠,١٥ م^{٣}/ساعة ومع كلا من زمني التقليب ١٢ و٢٤ ساعة خلال اليوم وقد استمرت تلك الحرارة أعلى من ٥٠ مئوي لمدة ثلاث أيام . وقد تلاحظ أن انبعاث ثاني أكسيد الكربون يتناسب طرديا" مع درجات الحرارة ومعدلات التهوية. وقد أمكن التوصل إلي علاقة تربط بين كافة المعاملات باستخدام برنامج Minitab الرياضي كتالي:-

$$(T = 20 + 6.5\,CO_2 + 24\,A - 0.01M)$$

حيث T درجة حرارة الكمبوست أثناء التخمر(مئوي) ، CO2 ثاني أكسيد الكربون المنبعث(%) ، A معدل التهوية (م^{٣}/ساعة) ، M زمن التقليب (ساعة).

وقد أظهرت النتائج النهائية أن مع استخدام معدل تهوية ٠,١٥ م^{٣}/ساعة مع فترة تقليب ١٢ ساعة يوميا ينتج كمبوست عالي الجودة خلال ١٨ يوم فقط مع توفير ٥٠% من الطاقة المستهلكة في عملية التقليب.