The Application of a Fed Batch Reactor for Composting of Vegetable and Fruit Wastes

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Abstract

The performance of fed batch composting on vegetable and fruit wastes were studied in comparison with the batch reactor. Four waste feeding rates were studied in the fed batch reactor and three ratios of waste and sawdust were studied in the batch reactor. Both studies were carried out with an aeration rate of 10.62 l m^{-3} min^{-1}. The optimum rate of waste for a fed batch reactor was 21.23 kg m^{-3} day^{-1} where the highest percentage of dry mass loss and the shortest composting time were achieved. The maximum constant rate (k=0.0028 day^{-1}) of batch composting was obtained under an initial ratio of waste to sawdust of 1:1.50 (w w^{-1}), whereas an initial ratio of waste to sawdust of 1:0.15 resulted in the development of anaerobic conditions within the reactor; consequently, the rate of waste degradation was the lowest (k = 0.0007 day^{-1}). Within 36 days the fed batch reactor could decompose 4 times more wastes than the batch reactor within the same operating conditions. It was found that the constant rate of batch and fed batch composting of vegetable and fruit wastes can be described by a first-order model.

Keywords: Fed batch reactor, composting, composting kinetics, vegetable and fruit waste

1. Introduction

Pollution from market waste, especially the acid leachate from vegetable and fruit wastes (green wastes) accounts for 13-25% of the municipal solid waste in Thailand. Hence, an effective solution is urgently required for the treatment of the remarkable increase in green wastes from fresh markets [1,2]. Vegetable and fruit wastes, containing high organic composition (70-80%) and moisture content (80-90%), are easily decomposed in tropical countries like Thailand. Thus, these wastes are suitable for biological recycling by a composting process as the process helps reduce the volume of waste and also stabilizes the waste [3,4,5].

Recently, the technique of feeding substrate into a batch culture, termed as fed batch culture, has been applied in composting machines and is widely used to compost meal residues in Japanese households, restaurants, and hospitals. Fed batch culture was initially proposed for improving process control and increasing yields of fermenting processes, its operation has been employed for composting, since its culture can be applied for generating waste intermittently [6,7]. Nakasaki *et al.* (2002) described that fed batch composting was a suitable technique for daily introducing waste into the reactor at a constant amount (constant feeding rate). The accumulated waste mixed with sawdust, was agitated and composted under excessive aeration in the reactor for several months. Several reports have studied the performance of fed batch composting of food waste by testing a Japanese composting machine. These studies mostly discussed the microbial and biochemical changes and the degradation of organic matter under constant feeding rate [7,8,9]. Terazawa *et al.* (1993) reported that the type A-I GADE composting machine, containing 4 kg of sawdust as starting material, could stabilize 59.5 kg of fed garbage over three months (feeding rate of 0.69 kg day^{-1}) before the system began to fail. Tripetchkul *et al.* (1999) did not successfully apply the GADE reactor for composting food waste, which was generated in Thailand using Shorea obtusa sawdust under an initial moisture content between 51.5 and 63.7%. The study noted that a putrid odor and structural instability were noticeable in all experiments within 3 weeks. Apparently, no reports have focused on using the fed batch reactor for vegetable and fruit wastes composting. Thus, the objective of this study was to investigate the performance of a fed batch reactor for the composting of vegetable and fruit wastes in comparison with a batch reactor. The effects of feeding rate and waste to sawdust ratio on the composting efficiencies of fed batch and batch reactors were also examined.

2. Materials and methods

2.1. Materials and composting reactor

Vegetable and fruit wastes were collected from Bangkok Islam-Mai market, Thailand. They were minced manually to 2.5-5.0 cm in size before using as raw material. Physical and chemical characteristics of the materials are reported in Table 1. The wastes mixed with urea and sawdust, were screened with a sieve with mesh no. 40 (0.425 mm) and no. 60 (0.250 mm), and composted under preset conditions according to the experimental design (Table 2). An acrylic reactor with 4.71 working volume (20 cm diameter, and 20 cm height) was used for fed batch and batch composting. To support the loaded materials and to distribute the air, a perforated acrylic plate was placed on a stand at 5 cm from the base of the reactor. Forced aeration was supplied by using an air compressor and operated under continuous positive pressure mode. The air was controlled at a constant rate by using an air flow meter and ventilated to the surrounding via an air vent (1 cm diameter) from the top of the reactor.

2.2. Fed batch composting

With reference to a point made by Vallini *et al.* (1990) and Vallini *et al.* (1993), the composting of green wastes at high moisture content (>80%) can release large amounts of leachate. As a result, it blocks the oxygen supply to the mixture, causing the biomass to compact and eventually causes system failure under the acidic environment. In an attempt to avoid the inhibitory effect of leachate, the operation of the fed batch reactor was divided into feeding and curing stages. In the feeding stage, a constant rate of waste was fed to the reactor every day. This stage was terminated after the moisture content of the mixture reached 70-80% and then the process entered the curing stage. Under the curing stage, with no waste adding, the waste was composted until it was compost. The mixture in both fed batch and batch reactors was turned manually once a day to ensure a uniform decomposition.

2.3. Physical and chemical analysis

Physical and chemical properties of the mixture were monitored throughout the composting process. Composting samples taken from the top, middle, and bottom of the reactor were analyzed for moisture content, ash content, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), and pH according to standard methods [11]. The loss of dry mass and composting kinetics (k) were also determined. Basically, weight loss is the reduction of weight of materials before and after composting, however the calculation of weight loss in the fed batch reactor (feeding stage) from this study was based on two assumptions. First, when microorganisms are incubated in the presence of two or more substrates, the substrates will be degraded in the order of their ease of degradation. Second, the major part of sawdust is made from resistant materials (lignocelluloses), which require more time for biological degradation. Therefore, the weight loss during the feeding stage was calculated by subtracting the residual wet weight of the composting materials, excluding the sawdust, from the cumulative wet weight of waste introduced into the reactor. The percentage of dry mass loss was the ratio of the decrease of their dry weight in the reactor to the cumulative dry weight introduced into the reactor [7,12].

The constant rate of waste degradation (k) from the fed batch (curing stage) and batch reactors were determined in terms of the degraded TOC as a function of time, which was obtained by plotting the logarithm of the ratio of the TOC at any time to the initial TOC versus time. The k value is the slope of the fitted straight line obtained in each condition [13]. The difference between treatments used analysis of variance (ANOVA) at the 95% confidence level.

3. Results and discussion

3.1 Change of temperature and moisture content

Fed batch composting reactor

The temperature profiles under four different conditions of fed batch reactor were shown in Figure 1. During the composting period, the ambient temperature fluctuated between 25 and 30°C. After the addition of wastes the temperature of all treatments rapidly increased (34.5-38.5°C) before dropping on Day 2. The second increase was observed from Day 3 to Day 6, before declining to the ambient temperature (29-31°C) from Day 7 to Day 32 of composting. The feeding stage was terminated at Day 6 (FB1), Day 3 (FB2), and Day 2 (FB3 and FB4), the moisture content of all treatments increased from 41.07-43.50% to 70.39-79.28% (Table 3). Then, the materials were composted continuously during the curing stage, without the further addition of waste, under mesophilic temperatures (27-31°C) until the end of the composting process. Decreasing moisture content was found at the curing stage and the final values observed ranged between 32.60% and 45.08% on Day 36 (FB1), Day 57 (FB2), and Day 66 (FB3 and FB4), as shown in Table 3.

Batch composting reactor

The development of temperature patterns of Run B1 and Run B2 were the same (Figure 2). The temperatures rose to peaks (43.5-47 °C) by Day 3 before further dropping to the ambient temperature about Day 4 (B1) and Day 10 (B2), respectively. In Run B3, although the temperature pattern followed in the same trend, the temperatures were maintained above 35°C for several days before declining to the ambient temperature from day 8 to day 17 (Figure 2). As the batch composting progressed, the initial moisture contents decreased from 61.03% (B2)-42.32% (B3) to 47.86% (B2)-32.52% (B3) at Day 36 (Table 3). On the other hand, the moisture content of Run B1 leveled off at 74.61-78.19% until the end of observation (Day 21).

In the feeding stage of the fed batch reactor, the temperature rose as a result of the produced heat attributed to degradable organic components being utilized [14,15,16]. After frequent addition of wastes, declining temperature occurred due to the rapid increase of moisture content, cooling the temperature development. The produced heat was mainly used to evaporate excess moisture, leaching from green wastes rather than being accumulated in the biomass [4,17]. Under the high feeding rate of 84.92 kg m^{-3} day^{-1}, the rapid increase of temperature may be from the microorganisms which used substrates, which enhanced the activity, leading to a rapid temperature increase [18]. However, it was found that the moisture content increased rapidly under high feeding rates (42.46-84.92 kg m^{-3} day^{-1}), which not only affected an early termination of the feeding stage, but also lengthened the entire composting time. On the other hand, the feeding stage of the fed batch reactor could be extended (6 days) and the composting process was shorter (36 days) under operating conditions of 21.23 kg m^{-3} day^{-1}. This suggests that the feeding rate had a strong effect on the change of moisture content and composting performance as indicated by the increasing rate of moisture content of compost among treatments differing significantly ($P<0.05$). High moisture content inhibits air diffusion in the compost matrix and finally limits the oxygen availability to microorganisms [3,15,16,19]. Therefore, in order to obtain a satisfactory process, the feeding rate should be carefully controlled as one of the important parameters for fed batch composting of vegetable and fruit wastes leading to the release of high leacheate. After increasing the ratio of waste to sawdust to 1:1.50 (B3), a temperature of above 35°C could be kept in the batch system longer than under other conditions. It should be noted that composting under the conditions of run B3 helped absorb the leachate and effectively created porosity in the mixture. In aerobic composting, the activities need enough oxygen in order to ensure aerobic conditions and prevent the occurrence of anaerobic conditions [20,21]. Therefore, batch composting under the condition of 1:1.50 seemed better than under the conditions of 1:0.62 and 1:0.15 and as a result the activities were enhanced and temperatures, then, were maintained at a higher level. Batch composting under too low amounts of sawdust (B1) caused the mixture to compact and reductive activities took place due to the release of a lot of green waste leachate. However, when the ratio of sawdust to vegetable and fruit wastes was increased from 1:0.15 to 1:0.62, these problems did not arise. The results demonstrated that an air flow rate of 10.62 l m^{-3} min^{-1} was suitable for Run B2 and Run B3 in which the produced heat and ventilation could balance the moisture evaporation and production effectively without moisture control. This was confirmed by the gradual decrease in moisture content observed (Table 3). It is well known that the rate of aeration can affect the changes of temperature and moisture content during the composting, thus it should be provided to balance the evaporation and production of water [14,16,17].

3.2 pH and carbon to nitrogen ratio (C/N) of compost

Fed batch composting reactor

During the feeding stage, the initial pH values (5.92-6.13) of all treatments were increased rapidly above 8 by Day 2 and then the values leveled off at pH 7-9 from Day 2 to Day 21 (FB1) and Day 36 (FB2, FB3, and FB4), respectively (Table 3). Results from Table 3 indicated that the changes in pH followed that of the moisture changes: as the moisture increased, the pH increased. The final compost had a pH value between 7 and 8 (Table 3) and was therefore slightly alkaline. In the experiments FB1 and FB2, the C/N ratios fluctuated during the first 20 days. Thereafter, they leveled off at a ratio of 65 (Day 20-40) before dropping to between 46 and 49 from Day 36 to Day 66, respectively (Figure 3). The C/N ratios of Run FB3 and Run FB4 fluctuated slightly between 41 and 50 (Day 0-10) before increasing to 54-58 from Day 13 to Day 45. The final C/N ratios decreased and ranged between 46 and 49 (Figure 3).

Batch composting reactor

Initial pH values slightly dropped within the first 3 days before rising to 7 or more from Day 3 to Day 6. The pH in all treatments, except Run B1, leveled off above pH 8 from Day 6 to Day 20 before declining to 7-7.8 (day 36). The reactor of Run B1 had a pH value above 8 from Day 6 until Day 21 (Table 3). The initial C/N ratio of Run B1 dropped continuously throughout the composting time and the final value was around 22. From Day 0 to Day 36 of composting, a fluctuation of C/N ratios between 27 and 35 was found under the conditions of Run B2. In run B3 the initial C/N ratio increased rapidly from 33 to 42 within 8 days before dropping to around 31 on Day 36 (Figure 4).

At the beginning stage of composting, a rapid increase in pH was a result from urea mineralization, which liberated a large amount of NH_4-N ions into the composting system and led to the pH rising. The increases in temperature and pH in the early stage of the fed batch composting suggested that the rate of decomposition might be accelerated by urea supplementation [22,23]. However, the adding of urea could enhance the nitrogen (N) loss through mineralization and volatilization in gaseous stage under high pH conditions (>8) as indicated by the increasing C/N ratios of all treatments [4,21]. Lower C/N ratios under the conditions of Run FB3 and Run FB4 might be because most of the gas was kept within the system by dissolving into the mixture under higher moisture content conditions. In addition to moisture content, anaerobic metabolism is also an important condition for the N conservation. Barrington *et al.* (1997) reported that the degradation of urea was slow under anaerobic conditions, which were likely to be promoted under high moisture composting. Consequently, most of the N content was conserved under high feeding rate conditions (FB3 and FB4). Decreasing final C/N ratios might result in the NH_3-N being further immobilized or nitrified by the microorganisms under the slight alkaline composting conditions [24].

A drop of pH in the early stage of the batch experiments resulted in the formation of organic acids. Increasing the pH value indicated that urea supplementation enhanced the rate of decomposition and mineralization [22,23]. In addition to the effect of urea supplementation, the quantity of sawdust was also an important factor affecting microbial activities as well as the mineralization and volatilization as indicated by the presence of a strong smell of ammonia gas under the conditions of Run B2 and Run B3. Increasing the porous structure of compost could enhance the N loss as volatilized ammonia, especially under high pH and forced aeration [4,21]. Consequently, the N loss as the C/N ratios increased was obvious in the active stage of run B3 of the batch reactor. However, a reduction of final C/N ratios and pH values suggested that the chemical properties of the compost had been more stabilized [21,25]. Run B1 demonstrated the effect of higher moisture contents (77-83%) which helped dissolve ammonia and kept most of the NH^{+}_{4}-N ions within the system, resulting in the conservation of the N contents as indicated by a drop of C/N ratios [4].

It has been suggested that the reduction of the initial C/N ratio to 20 or below would reflect a degree of maturity, however, a change of the C/N ratio only, might not be a good indicator for the evaluation of the maturity of compost in this study because of the effects of environmental factors on the utilization of carbon and nitrogen sources during the composting, such as the supplemented urea, type of bulking agent, and method of aeration etc. [4,15,21,25,26].

3.3. Degradation of organic material

Fed batch composting reactor

The dry mass loss in the feeding and curing stages of the fed batch reactor was 19.40-65.19% and 28.38-58.15%, respectively (Table 4). The loss was highest at a feeding rate of 21.23 (FB1), followed by 42.46 (FB2), 63.69 (FB3), and 84.92 (FB4) kg m^{-3} day^{-1} (Table 4). The study found that the observed effect of different feeding rates on the percentage of dry mass loss differed significantly ($P<0.05$). The kinetic plot of the fed batch reactor in the curing stage followed a first-order model as indicated by high linear regression coefficients ranging between 0.67 and 0.93 (Figure 5). The constant rate was highest under the conditions of Run FB1 (0.0016 day^{-1}), followed by Run FB2 (0.0009 day^{-1}), Run FB3 and Run FB4 (0.0006 day^{-1}).

Batch Composting Reactor

As shown in Table 4, the percentage of dry mass loss under batch operation was 11.66-41.49%. It was found that the effect of the waste to sawdust ratio on the loss of dry mass among different treatments differed significantly ($P<0.05$). The kinetic plot of the batch reactor followed a first-order model (r^2=0.25-0.86) and the highest constant rate was achieved under the conditions of Run B3 (0.0028 day^{-1}), followed by Run B2 (0.0023 day^{-1}), and Run B1 (0.0007 day^{-1}).

The highest dry mass loss and rate constant obtained under Run FB1, where the increase in moisture content was slow, indicated that the fed batch operation of green waste at the lowest feeding rate of 21.23 kg m^{-3} day^{-1} resulted in better oxygen distribution and microbial activities in the system than at higher feeding rates (42.46-84.92 kg m^{-3} day^{-1}). On the other hand, higher feeding rates (42.46-84.92 kg m^{-3} day^{-1}) caused a rapid increase in moisture contents, which adversely affected temperature development, and biodegradation as indicated by lower degradation rates and percentages of dry mass loss [3,15,16,17,19]. It should be noted that the feeding rate is one of the important factors that have a strong effect on the degradation in the fed batch reactor. The radar diagram demonstrated that a feeding rate of 21.23 kg m^{-3} day^{-1} was the optimum condition for the fed batch reactor in which both the highest percentage of dry mass loss and the shortest composting time were achieved within 36 days (Figure 6).

As the quantity of sawdust increased from a ratio of 1:0.15 to 1:0.62, the rate of degradation increased about 2 times. It should be noted that starting an initial ratio of waste to sawdust of 1:0.62 of green waste composting indeed enhanced the rate of degradation due to the porosity of the mixture as well as causing the oxygen utilization to increase [13]. After Day 36, the compost runs of B2 and B3 resembled humus. On the other hand, unpleasant conditions, such as foul odor, damp and compact mixture, were found under the conditions of Run B1 within 7 days of the composting. This suggested that starting the batch reactor under high moisture content (81.23%) could render the failure of green waste composting under anaerobic conditions as reported by Vallini *et al.* (1993). As indicated by the constant rate determined, it was found that a waste to sawdust ratio of 1:1.50 (B3) appeared to be optimum for the batch reactor. Although no significant difference in the constant rate was noticed for both runs of B2 and B3, Run B3 was recommended due to a better development of temperatures.

Table 5 compares the composting performance between fed batch and batch reactors, based on the same preset conditions such as a waste to sawdust ratio of 1:1.5, an initial moisture content of around 40%, a C/N ratio ranging 30-40, and an aeration rate of 10.62 l m^{-3} min^{-1}. The study found that the batch reactor offered a simple and reliable technique for composting green waste, which tended to release a lot of leachate. However, the fed batch reactor could decompose about a 4 times higher amount of waste as the batch reactor within 36 days and it required a lower quantity of amendments. The total amount of waste introduced daily into the fed batch reactor was 600g (FB1), 800g (FB2), 900g (FB3), and 800g (FB4). The lower rate constants for the curing stage of the fed batch reactor, than those reported for the batch reactor, might be because most of the resistant materials of the green waste and sawdust (cellulose, hemicellulose, and lignin) were mainly consumed in the later stage which required more extensive and comprehensive degradation [12,26].

4. Conclusion

This study shows that the fed batch reactor is practicable for the composting of vegetable and fruit wastes under a feeding rate of 21.23 kg m^{-3} day^{-1} and an aeration rate of 10.62 l m^{-3} min^{-1}. However, under fed batch composting, care must be taken not to increase the moisture content during the feeding stage, which is critical for the performance of the composting. Higher feeding rates of 42.46-84.92 kg m^{-3} day^{-1} not only adversely affected the rate of degradation, but also required a longer composting time. As judged by the composting performance and kinetics, green waste composting with the ratio of waste to sawdust of 1:1.50 was the optimum conditions for the batch reactor. The batch reactor with the ratio of waste to sawdust of 1:0.15 failed within 7 days as the system demonstrated anaerobic conditions and the lowest rate constant obtained. It was found that within 36 days the fed batch reactor could decompose 4 times more than the batch reactor under the same operating conditions. The feeding rate and waste to sawdust ratio were important factors for the fed batch and batch reactors which affect the moisture content of the system as well as the rate of degradation. It was found that most degradable organic matter was mainly consumed in the feeding stage of the fed batch reactor and the constant rate of the fed batch and batch composting of vegetable and fruit wastes followed a first-order model.

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6. References

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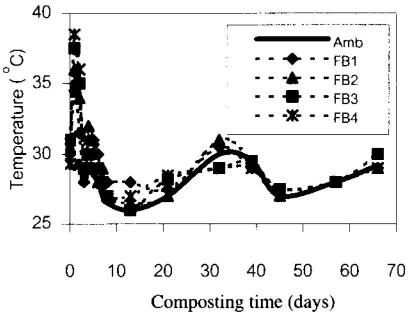

Figure 1. Temperature changes (Fed batch)

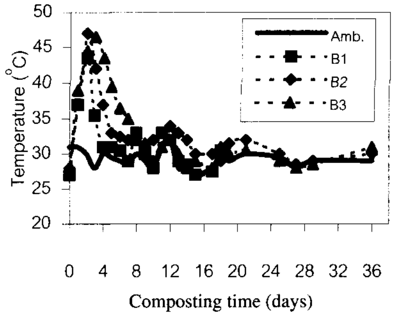

Figure 2. Temperature changes (Batch)

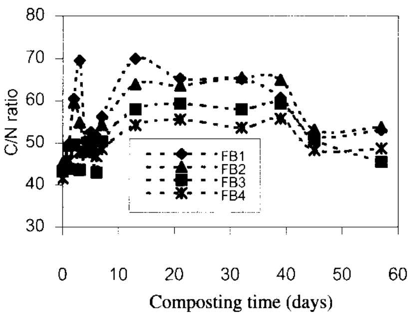

Figure 3. The C/N ratio changes (Fed batch)

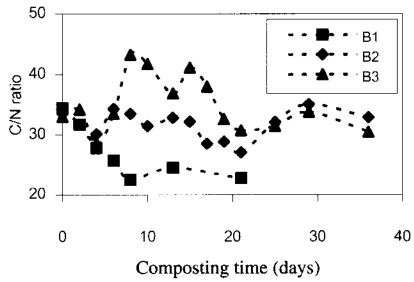

Figure 4. The C/N ratio changes (Batch)

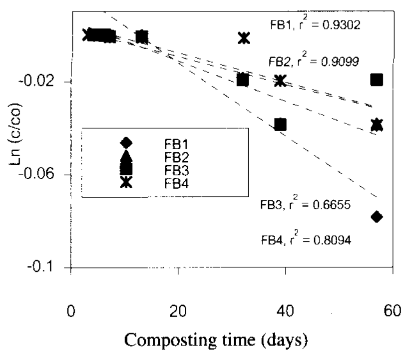

Figure 5. Determination of the constant rate of fed batch reactor (Curing stage)

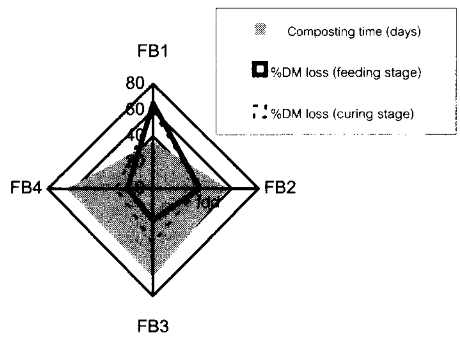

Figure 6. Optimization of fed batch reactor under waste feeding rate of 21.23 kg m^{-3} day^{-1}

Table 1. Properties of materials

Properties	Materials: Vegetable and fruit waste	Sawdust
Bulk density (g cc^{-1})*	0.452-0.600(0.547±0.059)	0.336-0.345(0.341±0.004)
Moisture content (%)*	89-93(90.32±1.52)	9-10(9.71±0.41)
Dry matter (%)	7-11(9.68±1.52)	89-92(90.91±1.44)
pH	4.0-5.2(4.63±0.49)	3.9-5.1(4.43±0.56)
Ash (%)**	5.1-9.3(7.74±1.61)	0.1-0.2(0.15±0.06)
TOC (%)**	50-52(50.41±0.88)	54-55(54.57±0.04)
TKN (%)**	2.0-2.4(2.11±0.32)	0.08-0.19(0.13±0.05)
C/N ratio	21-25(22.58±2.52)	284-657(424.63±149.17)

*, Wet basis; **, Dry basis; The values in parentheses are means and standard deviations.

Table 2. The experimental design

Fed batch composting reactor		
Run	Feeding rate (kg m^{-3} day^{-1}, wet wt.)	Experimental condition
FB1	21.23	Initial waste to sawdust ratio (1:1.50)
FB2	42.46	Initial C/N ratio (30-40)
FB3	63.69	Aeration rate (10.62 l m^{-3} min^{-1})
FB4	84.92	
Batch composting reactor		
Run	Waste to sawdust ratio (w w^{-1}, wet wt.)	Experimental condition
B1	1:0.15	Initial C/N ratio (30-40)
B2	1:0.62	Aeration rate (10.62 l m^{-3} min^{-1})
B3	1:1.50	

Table 3. Changes in moisture content and pH during the fed batch and batch composting

Day	Moisture content (%)				pH			
	FB1	FB2	FB3	FB4	FB1	FB2	FB3	FB4
0	43.50	41.07	41.50	43.39	5.93	5.92	6.07	6.13
1	53.66	59.69	67.36	67.83	7.83	6.87	7.20	6.28
2	60.38	65.34	72.76	79.28	8.74	8.87	8.70	7.91
3	60.86	70.98	76.82	76.92	9.30	9.19	9.03	9.13
4	61.66	74.80	74.40	73.33	8.94	8.82	8.45	8.99
5	68.24	74.65	75.02	74.65	8.33	8.30	8.38	8.41
6	70.39	73.22	74.08	74.22	8.56	8.75	8.83	8.90
13	70.62	72.11	72.43	73.90	9.22	9.26	9.20	9.24
21	64.45	69.11	70.27	69.38	7.78	9.33	9.31	9.28
36	32.60	44.98	52.53	52.69	7.60	7.82	7.91	8.49
57	ND	40.01	46.31	48.16	7.25	7.90	7.66	7.67
66	ND	ND	43.47	45.08	7.35	7.23	7.31	7.51
Day	Moisture content (%)				pH			
	B1	B2	B3		B1	B2	B3	
0	81.23	61.03	42.32		4.74	4.89	4.86	
2	82.67	63.79	45.30		3.87	4.56	5.37	
4	83.42	63.83	46.17		6.91	6.94	6.62	
6	81.94	61.37	44.40		7.22	8.44	7.50	
13	77.69	60.27	38.80		9.06	8.56	8.56	
21	77.43	54.09	32.99		8.67	7.65	8.11	
36	ND	47.86	32.52		ND	7.44	7.42	

ND, Not detected; Values are average of duplicates of composite sample.

Table 4. Losses of dry mass during the fed batch and batch composting

Dry mass loss of compost of fed batch reactor							
	Feeding stage[1]			Curing stage[2]			
Run	Feeding time	Total waste	Total loss	Initial mass	Final mass	Loss	k(day^{-1})
FB1	6 days	58.08g	37.86g 65.19%	251.90g	105.41g	146.49g 58.15%	0.0016 (0.93)
FB2	4 days	77.44g	27.15g 35.52%	276.46g	178.66g	97.80g 35.38%	0.0009 (0.91)
FB3	3 days	87.12g	20.68g 23.73%	310.76g	188.51g	122.25g 39.34%	0.0006 (0.67)
FB4	2 days	77.44g	15.02g 19.40%	265.77g	190.35g	75.41g 28.38%	0.0006 (0.81)

Dry mass loss of compost of batch reactor								
	Before composting			After composting				
Run	%MC	Wet wt.	Dry wt.	%MC	Wet wt.	Dry wt.	Loss	k(day^{-1})
B1	81.23	1.506g	0.283g	77.43	1.108g	0.250g	11.53%	0.0007 (0.25)
B2	61.03	1.503g	0.586g	47.86	0.714g	0.372g	36.44%	0.0023 (0.80)
B3	42.32	1.509g	0.870g	32.52	0.754g	0.509g	41.54%	0.0028 (0.86)

[1], The calculation was based on total dry weight of waste introduced into the reactor;
[2], The calculation was based on total dry weight of waste and sawdust;
Values in parentheses are the regression coefficients.

Table 5. Composting performance of fed batch and batch reactor

	Composting technique	
Operating conditions	Fed batch reactor	Batch reactor
Size of raw material, cm	2.5-5.0	2.5-5.0
Initial moisture content, %	43.50	42.32
Initial C/N ratio[1]	44.47	33.04
Aeration rate, l m^{-3} min^{-1}	10.62	10.62
Initial waste to sawdust ratio[2], w w^{-1}	200g:300g	200g:300g
Feeding rate, kg m^{-3} day^{-1}	21.23	None

	Composting technique	
Composting performance	Fed batch reactor	Batch reactor
Total amount of the input waste[2], g	600	None
Total amount of the treated waste[2], g	800	200
Total dry mass loss, %	65.19^{F}, 58.15^{C}	41.49
Composting kinetic (k), day^{-1}	0.0016^{C}	0.0028
Composting time, day	36	36

[1], The C/N ratio varied between 30 and 40; [2], Based on a wet weight basis; [F], Feeding stage; [C], Curing stage.