Using the thermophilic aerobic process to decompose industrial food wastes

Utilisation du procédé aérobie thermophile pour la décomposition de déchets agroalimentaires industriels.

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Abstract

A full-scale study of the thermophilic aerobic decomposition of industrial food wastes was performed for two months in Hokkaido, Japan, using a reactor that was already in operation. The process reactor contained cedar chips, which acted as a bulking agent and water absorbent. Air was supplied through the bottom of the reactor, so that the added organic matter was decomposed aerobically. Water was evaporated by the heat generated in the reactor and the organic matter was decomposed almost completely, as it was converted into carbon dioxide, water, and minerals (ash).The process reactor is 52 m long, 6 m wide and 2.5 m deep. Cedar chips in the reactor ranged in size from 5 mm to 30 mm. A total of 924 t of organic wastes were added to the reactor from the time it was first put into operation, including 470 t of vegetable waste, 370 t of scallop waste and 80 t of squid wastes, at an average feeding rate of 7 t/day. During this study, the temperature of the reactor reached a maximum of 73 C and was generally maintained between 45 and 70 C. The moisture content of the reactor contents, including the combination of cedar chips and decomposed waste, was about 55%, and the pH of the contents was more than 8. The ash content of the reactor contents increased over time, as the waste was converted into water, carbon dioxide and ash. However, the total volume of the contents did not increase at all over time, because only the residual ash and a small amount of organic wastes remained in the reactor.

Résumé

Une étude grandeur réelle sur la décomposition aérobie thermophile de déchets agroalimentaires industriels a été effectuée sur une période de 2 mois à Hokkaido, Japon, sur un réacteur fonctionnant en routine. Le réacteur contient des copeaux de cèdre qui jouent le rôle d'agent de texture et d'absorbant de l'humidité. L'air est insufflé par la base du réacteur ; ainsi la matière organique ajoutée à celui-ci est décomposée par voie aérobie. L'eau est évaporée par la chaleur produite dans le réacteur et la matière organique est entièrement décomposée, en CO_2, H_2O et matières minérales (cendres). Les dimensions du réacteur sont 52 m (longueur),

6 m (largeur) et 2,5 m en profondeur. Les copeaux de cèdre dans le réacteur sont de taille variable allant de 5 mm à 30 mm. Un total de 924 t de déchets organiques ont été apportés au réacteur depuis le démarrage parmi lesquels 470 t de déchets végétaux, 370 t de déchets de coquillages marins et 80 de déchets de calamars. Le taux d'apport journalier s'établit à 7 t/jour. Au cours de cette étude, la température du réacteur augmente jusqu'à 70°C. L'humidité à l'intérieur du réacteur s'établit à 55% et le pH est supérieur à 8. Le taux de cendres du contenu du réacteur augmente au cours du temps. Cependant, le volume total contenu n'augmente pas, car au cours du procédé les déchets organiques sont décomposés et seules les cendres et une part de MO résiduelle demeurent dans le réacteur.

1. Introduction

Couillard et al (1989) used the thermophilic aerobic process to treat organic wastewater that initially had a high COD. In their study, they maintained their reactor in the thermophilic range by using heaters. Paulsrud and Langel (1985) studied aerobic thermophilic digestion of pre-thickened sludge. They studied the decomposition of the pre-thickened sludge according to the principals of composting, without any additives to act as a bulking agent or water absorbent. Liu et al. (1992, 1993) investigated the treatment of organic wastewater that initially had a high BOD and high-suspended solids. Their process reactor contained cedar chips as bulking agents and a water absorbent and air was supplied through the bottom of their reactor, so the organic matter was decomposed aerobically within the thermophilic range. This thermophilic aerobic process basically operates according to the same principles as composting, but the high temperatures and long retention time result in a low volume of ash instead of a large quantity of finished compost product. In Liu's reactor, wastewater was evaporated by the heat generated in the reactor and the organic matter was decomposed almost completely.

Composting of livestock wastes and kitchen wastes is becoming popular in Japan. However, it is becoming harder to distribute the compost product to farmers, because many poultry and swine farmers and municipalities are producing compost from animal wastes, kitchen wastes and sludge. Essentially, more compost is being produced than distributors can sell. It is also becoming harder to incinerate or landfill the organic wastes from food industries and households because those treatments are not economical and legislation is strict. As a result, food industries, distributors and suppliers of agricultural products have been eager to reduce the volume of their wastes as much as possible.

The thermophilic aerobic process was developed to decompose organic wastes into carbon dioxide, water and a small volume of ash. The first full-scale plant was constructed in Hokkaido in 1997. There are many agricultural product distributors and seafood industries in Hokkaido. The treatment facility was built for decomposing industrial food wastes, including waste vegetables, scallop and squid wastes, etc. This study was carried out to determine the decomposition rate of organic wastes using the thermophilic aerobic process at this full-scale plant.

2. Materials and methods

Full scale plant

The treatment facility consists of a reactor, a feeding cart, four augers and a bio-filter as shown in figure 1. The process reactor is 52 m long, 6 m wide and 2.5 m deep, with a total volume of 630 m^3. The reactor contains cedar chips ranging in size from 5 mm to 30 mm, to a depth of 1.65 m, for a total volume of cedar chips of 415 m^3. Air is supplied continuously through the bottom of the reactor at a rate of 45 m^3/min by a blower. The wastes are added once per day by a feeding cart that travels over the reactor. Four vertical augers agitate the reactor contents, including the combination of cedar chips and decomposed waste, every four hours. The official decomposing capacity of the reactor is 20 t/day. A bio-filter (15 m long, 5.4 m wide and 2.5 m deep) is used to deodorize the exhaust gas. The filter contains the same cedar chips as the reactor. The chips were smeared with activated sludge. Exhaust air is blown out at an air rate of 160 m^3/min.

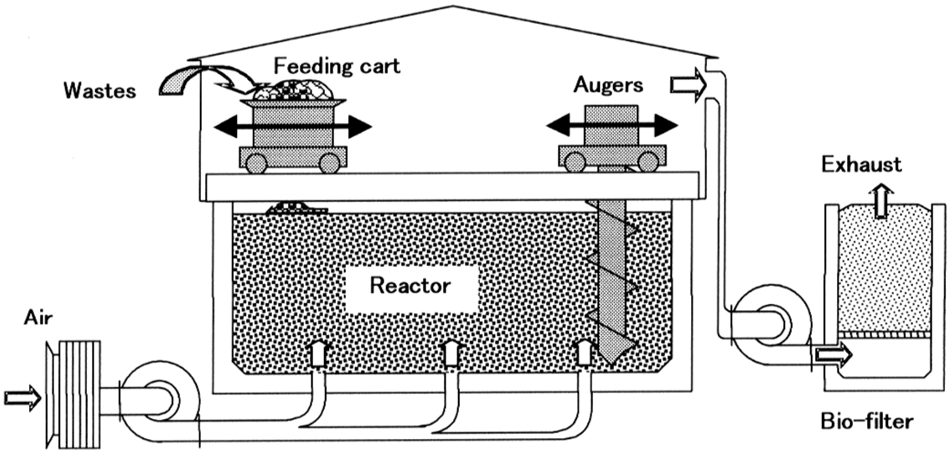

Figure 1
Schématic of full scale reactor

Sampling and analyses

Samples were taken manually from 9 fixed locations within the reactor every Thursday. The sampling locations were about 50 cm beneath the surface of the reactor contents. We determined that the composition of the reactor contents at the surface and the bottom of the reactor was similar, because the reactor contents were well agitated by the augers. All samples were analyzed for bulk density, moisture content, pH and ash content. The first and last samples were analyzed for N, P, K, C and cadmium contents.

3. Results and discussion

Wastes materials

The facility was originally put into operation on May 10, 1997. We studied this facility for approximately 2 months, from August 29 to October 25, 1997. Prior to our study, a record of the feeding rate and the temperature of the reactor contents was maintained.

A total of 924 t of organic wastes were added to the reactor at an average rate of about 7 t/day over the 160-day period from May 10 to October 25, with the exception of 30 days when the facility was temporarily shut down, as shown in figure 2. This waste consisted of 470 t of vegetables waste, 373 t of scallop waste and 80 t of squid waste as shown table 1. Over the course of this two-month study, a total of 344 t of organic wastes were added to the reactor, including 234 t of vegetable waste and 110 t of scallop waste, at an average feeding rate of 8.6 t/day. The maximum amount that added on any one day was 22 t.

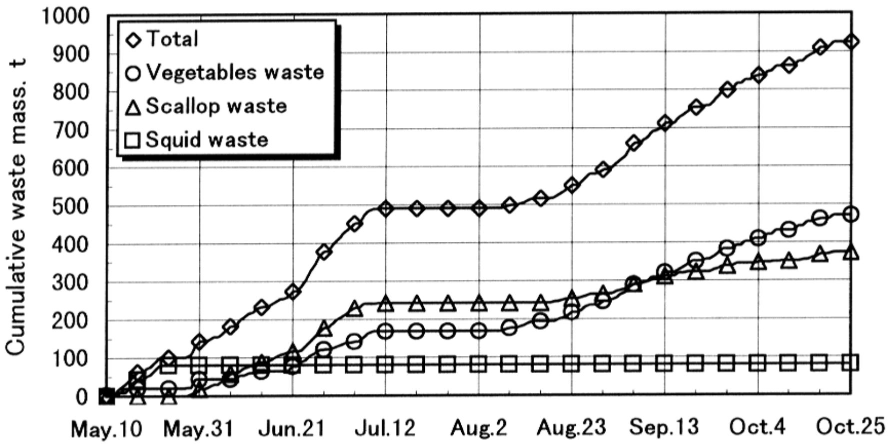

Figure 2
Cumulative added waste mass.

	Mass (t)	Moisture content (%)	Ash content (% DM)	Cd (mg/kg DM)
Vegetable waste	470.5	90.1	6.5	-
Raw scallop waste	186.5	86.0	18.9	60.0
Boiled scallop waste	186.5	76.4	6.7	21.2.
Squid waste	80.0	64.8	4.7	79.5
Mixture	923.5	84.3	8.4	32.7

Table 1
Added waste (May 10~Oct.23)

The initial moisture content of the incoming waste mixture was approximately 85%. The initial ash content of the vegetable waste was about 6%, that of raw scallop waste was about 19 % and that of squid wastes was 5% as shown in table 1.

Temperature

The reactor temperature was measured at 3 places, each about 50 cm below the surface of the reactor contents. The average temperature of the reactor reached a maximum of 73°C and was generally maintained between 45° and 70°C as shown in figure 3.

When the reactor was first put into operation in May, aerobic digestion became active shortly after the first waste was added and the reactor temperature increased. The temperature reached around 70°C at the beginning of July, about three months after the reactor started. When no new waste was added during the period from July 11 to August 7, the temperature decreased gradually and was about 25°C at the beginning of August. Once feeding resumed on August 8, the temperature rose quickly to 70°C and was maintained between 45°C and 70°C, just like the initial period of operation before feeding was temporarily suspended. Because new waste was not added on Sundays, the temperature on Mondays tended to be slightly lower than on other days. However, the temperature rose again on the following day, after fresh waste was added.

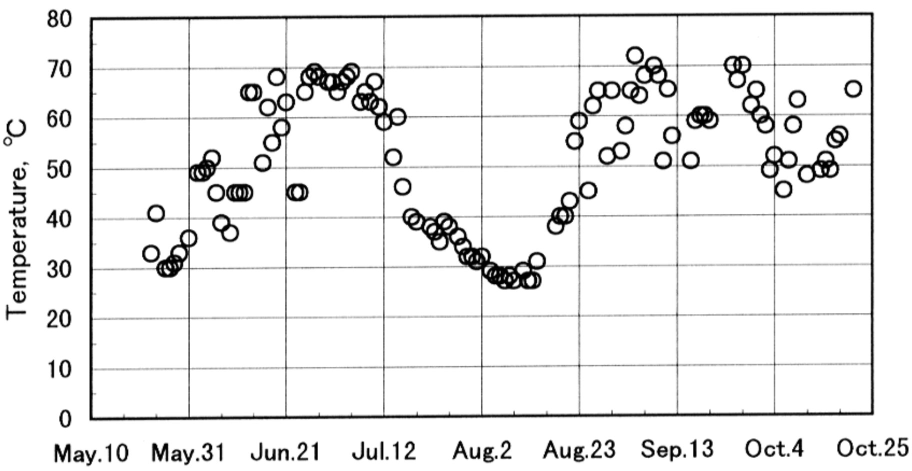

Figure 3
Temperature of reactor

Moisture content

The moisture content of the reactor contents, including the combination of cedar chips and decomposed waste, was maintained between 53% and 57% during this study. The moisture content at the auger side of the reactor tended to be higher than the moisture content at the feeder side, as shown in figure 4. This may be due to the fact that when the fresh waste, which has a high moisture content, was dumped from the feeding cart, it tended to fall more towards the auger side than the feeder side. Also, the exhaust air is blown from the feeder side to the auger side, which could tend to dry the reactor contents at the feeder side.

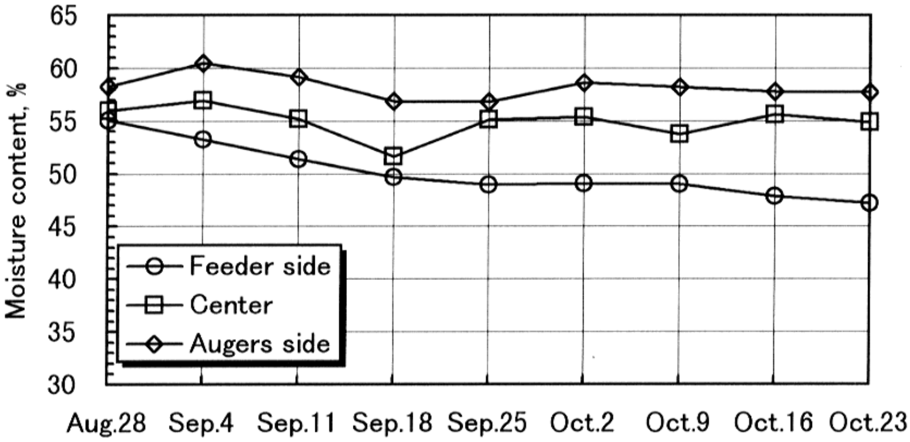

Figure 4
Moisture content of reactor

pH

The average pH values of the reactor contents were maintained between 7.8 and 8.3 during this study. These alkaline pH values meant that added organic wastes were well digested aerobically. The pH values recorded at the auger side and the central part were more than 8, but the pH values at the feeder side were about 7, as shown in figure 5. Because less fresh waste was added to the feeder side, and because the moisture content at the feeder side was less than 50%, it was thought that the aerobic digestion process might actually be more active near the augers and central part, resulting in elevated ammonium nitrogen concentrations at these locations.

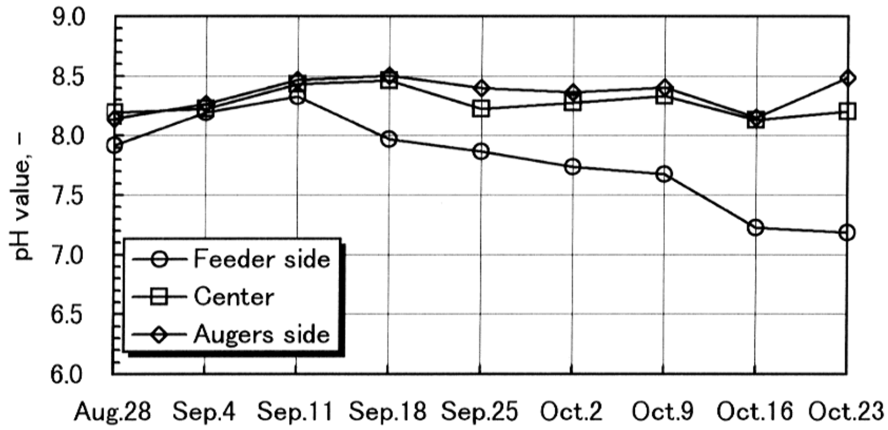

Figure 5
pH of reactor

Ash

Figure 6 shows the measured and estimated ash content of the reactor contents. The measured ash content is calculated from the ash content of samples taken from the reactor, as well as the volume and mass of the reactor contents. The estimated ash content is calculated based upon the average ash content of the added wastes, and the volume and mass of the reactor contents. The ash content increased over time, as fresh wastes were added and the wastes were converted into water, carbon dioxide and ash.

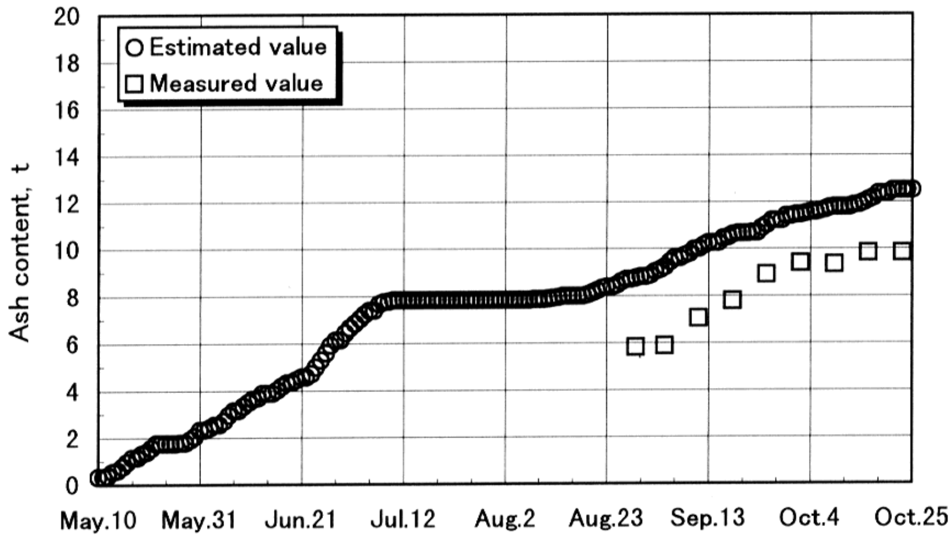

Figure 6
Ash content of reactor

The relationship between the measured ash content (y) and the estimated ash content (x) is linear and can be expressed as $y = 1.23x - 5.21$. The coefficient of determination of the regression equation between them is more than 0.96. The reason why the relationship is not precisely $y = x$ is that the ash content of the added wastes and the mass of the reactor contents could not be measured precisely.

Over the two-month course of this study, a total of 344 t of organic wastes were added to the reactor. However, the total volume of the reactor contents did not increase at all over time, because only the residual ash and a small amount of organic wastes remained in the reactor along with the cedar chips, which are slow to decompose. Figure 7 shows the masses of organic matter and ash on August 28, the masses of ash and organic matter added during this study, and the masses of organic matter and ash on October 23. As shown in the figure, at the beginning of the study the reactor contained a total of 63.9 (= 58.1+ 5.8) t of organic matter plus ash. During the study, the total organic matter and ash added to the reactor amounted to 43.7 (=3.8+39.9) t. By the time the study finished on October 23, the reactor contents had increased by only 9.4 (=4.0+5.4) t, even though the reactor received 344 t of fresh organic waste over the two month period. The decomposition rate of the added organic matter can be calculated as (39.9-5.4) 100/39.9 = 86.5 %. The reduction rate of the added wastes including water can be calculated as (299.8+39.9+3.8-4.0-5.4)100/(299.8+39.9+3.8) = 97.2 %, where 299.8 t is the water content of added wastes.

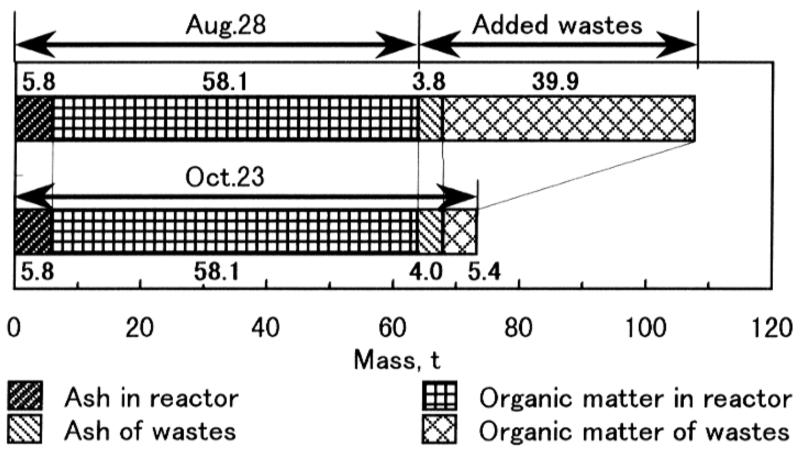

Figure 7
Components of reactor contents

In conclusion, the added organic matter decomposed at a rate of 86.5% and the reduction rate of the added wastes was 97.2 %. Because a large portion of the waste was decomposed or reduced using the thermophilic aerobic process, the total volume of the reactor contents did not increase at all over time. The facility can be expected to operate for a long period of time, perhaps even two or three years, without removing the finished product (ash) from the reactor.

	MC %	pH -	Ash %DM	T-C %DM	T-N %DM	C/N -	P2O5 %DM	K2O %DM	Cd mg/kgDM
Aug.28	56.4	8.1	9.1	42.8	1.86	23.1	1.38	1.40	48.6
Oct.23	53.3	8.0	13.4	41.3	2.48	16.7	1.68	2.31	57.1

Table 2
Average results of reactor contents

Table 2 shows the average results of the reactor contents. When organic wastes are added to a typical composting process, the nitrogen, phosphorus, potassium and carbon contents can be expected to increase. In the thermophilic aerobic process, however, the carbon is converted to carbon dioxide and the nitrogen is emitted as ammonia, so the carbon and nitrogen contents were not expected to increase much during decomposition. In fact, the carbon decreased but the nitrogen did not decrease in this study, so the C/N ratio decreased. Phosphorus, potassium and cadmium accumulated during this study. Since the final products from this facility include cadmium, the products cannot be used as fertilizer and must be properly disposed of at an enclosed landfill site.

Conclusions

Industrial food wastes were decomposed using the thermophilic aerobic process in a full-scale plant, consisting of a reactor containing cedar chips as a bulking agent and water absorbent. The reactor volume was 780 m^3 and a total of 344 t of industrial food wastes were added over the two-month period of this study. The temperature of the reactor contents was maintained between 45 C and 70 C and the pH of the reactor contents ranged between 7.8 and 8.3. As the wastes were added every day, the ash content of the reactor increased. However, the total volume of the reactor contents did not increase at all over time, because only the residual ash and a small amount of organic wastes remained in the reactor. The added organic matter decomposed by 86.5 % over the course of this study, and the waste was reduced by 97.2 %.

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