

NOTE

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Biodegradation of nonlignocellulosic substances I: system for complete decomposition of garbage using sawdust and aerobic soil bacteria

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Abstract A system for effective garbage decomposition using sawdust and aerobic soil bacteria was examined. The machinery used in this process, the garbage automatic decomposer-extinguisher (GADE), is composed of a container with an automatic mechanical mixer and a drain for liquid formed by the decomposition of garbage. The aerobic soil bacteria, cultivated in sawdust, degrades garbage within the container. The GADE machine, containing 4 kg of sawdust, totally decomposed 59.75 kg of garbage within 3 months (0.66 kg/day). Constant temperature, pH level, and moisture content of the matrix throughout the experimental period suggested stable degrading action. The residual sawdust and drainage water from the GADE machine were converted to fertilizers or soil conditioners (GADE compost) by the garbage decomposition process. Neither inhibited germination or growth of three test crops: komatsuna, Chinese cabbage (*Brassica campestris*), hatsukadaikon, radish (*Raphanus sativus* L. var. *radicula*), and bisai (*Raphanus* sp.).

Key words GADE · Garbage · Sawdust · Aerobic soil bacteria · Fertilizer

Introduction

Environmental problems affect people's daily lives throughout the world, especially those living in big cities.

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The treatment of waste is one of the most serious challenges. In Japan, incinerated waste and landfill use are beginning to exceed the amount almost all local governments can handle. In particular, the treatment of food-related organic waste is a difficult problem because it can easily rot and produce a bad odor. The frequency of collecting city waste set aside for recycling must be greatly increased due to sanitary considerations concerning their rapid spoilage, even if this spoilage is insignificant otherwise.

In addition, rain forest resources in danger of being depleted must be used and reused more effectively. Abolishing incineration is the best way to achieve this end, as is a policy of becoming less dependent on foreign lumber and instead utilizing Japanese forests, which are generally in need of thinning anyway. In either case, wood must not be incinerated or reclaimed but may instead be grained and used to degrade food waste as an artificial soil matrix.¹⁻⁴

An alternative solution in cities is the biodegradation system of microorganisms.⁵ The garbage automatic decomposer-extinguisher (GADE), which uses sawdust as a matrix in its container,⁶⁻⁸ degrades wastes quickly without odor and therefore without insects.^{5,9} Sawdust functions as a matrix in which food waste is degraded, and the matrix can be used for several months until it is filled with residuals, namely minerals and low-molecular-weight organic matter (Fig. 1). In this study, we tested the amount and content of the garbage that the GADE machine could handle effectively. Conditions in the container were measured, as the same quantity of garbage was placed in it daily. The effects of residual sawdust and drainage water as fertilizer were also examined.

Materials and methods

GADE machine

The machine used in this system, the GADE, comes in several types. The automatic mechanical mixer in the GADE machine (Mitsui Home Co.) contains indepen-

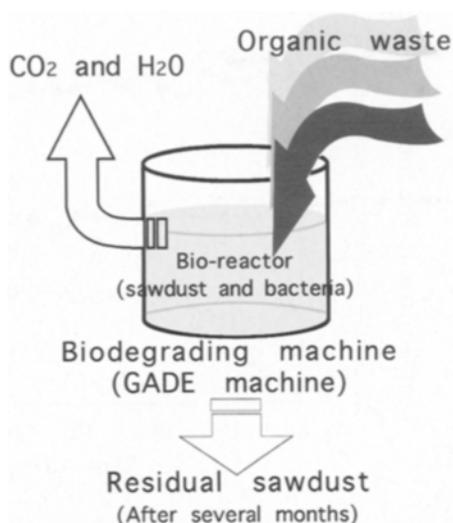


Fig. 1. Biodegrading system

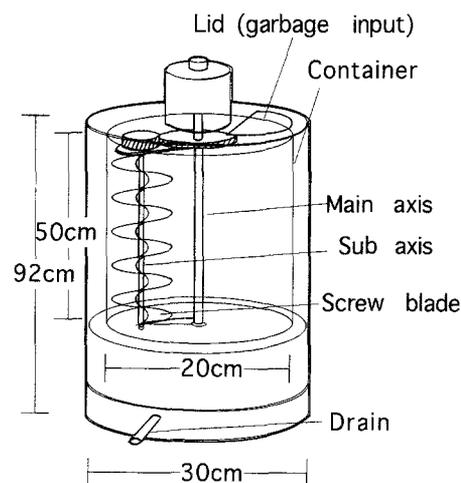


Fig. 2. Design of the GADE machine for a household (Mitsui Home Co.)

Table 1. Amount of garbage degraded by a GADE machine in 3 months

Material	Garbage degraded (kg)		
	1-45 Days	46-90 Days	1-90 Days (total)
Wastes during cooking			
Fruits	9.60 (28.4)	6.59 (25.4)	16.19 (27.1)
Vegetables	11.87 (35.1)	12.84 (49.4)	24.71 (41.3)
Meat and fish	4.10 (12.1)	2.64 (10.2)	6.74 (11.3)
Subtotal	25.57 (75.7)	22.07 (84.9)	47.64 (79.7)
Leftovers			
Cereals	2.88 (8.5)	1.08 (4.2)	3.96 (6.6)
Vegetables	1.74 (5.1)	0.95 (3.7)	2.69 (4.5)
Meat and fish	1.64 (4.9)	1.19 (4.6)	2.83 (4.7)
Others	1.97 (5.8)	0.70 (2.7)	2.67 (4.5)
Subtotal	8.23 (24.3)	3.92 (15.1)	12.15 (20.3)
Total	33.80 (100)	25.99 (100)	59.79 (100)

Numbers in parentheses are percents

The experimental period was 90 days beginning October 5, 1991. The amount of garbage per day was 0.66kg

dently rotating geared dual axes (Fig. 2) with a rotating central vertical axis. This axis is attached by arms on the top and bottom to an independently rotating subaxis, which is carried by the rotation of the main axis around the inner perimeter of the container. The subaxis is equipped with an upwardly rotating screw blade. The two movements mix sawdust and garbage effectively and supply enough air for aerobic bacterial activity. The screws function automatically for 5 minutes every 6h and also operate for 5 min after garbage is placed in it.

Experiment to test the ability of GADE machines

The sawdust, a mixture of western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) was prepared by a lumber mill. Sawdust of 10-80mesh was collected and used as the matrix for the GADE machines. Moisture content of the sawdust was adjusted to 60% on a wet weight basis.

The garbage was prepared experimentally by six students in a dormitory of Hokkaido University, three in each group (I and II). The garbage was separated according to the classification described in Table 1. Each item was weighed every day and added to the GADE machine (Table 1). The experiment was performed over a period of 90 days starting from October 5, 1991. The garbage was put in the GADE machine with 5g of seed including *Bacillus* sp. (Mitsui Home Co.) every day.

Experiment to measure decomposition in the container

Preparation of sawdust and garbage

The sawdust of larch [*Larix kaempferi* (Lamb.) Carrière] was passed through a 10-mesh sieve and was adjusted to a moisture content to 60% on a wet weight basis. The garbage, as mentioned earlier, was prepared at a student dormitory in Hokkaido University.

Measurement of conditions in the container

The GADE machine was set up in a room with a temperature of 25°C and relative humidity (RH) 60%. The garbage was put in the GADE machine at a rate of 0.7 kg/day. Temperature, pH level, and moisture content of the matrix were measured every 3 days. The experiment lasted 60 days.

Cultivation of vegetables with GADE compost

Three vegetables – komatsuna, Chinese cabbage (*Brassica campestris*), hatsukadaikon, radish (*Raphanus sativus* var. *radicula* DC.), and bisai (*Raphanus* sp.) – were cultivated using residual sawdust and drainage water as fertilizer. The total nitrogen, phosphate, and potassium contents in the residual sawdust were analyzed by the Japan Fertilizer and Feed Inspection Association (JFFIA). The levels were 1.07%, 0.54%, and 0.44%, respectively. The corresponding levels in the drainage water were 0.06%, 0.02%, and 0.7%, respectively.

A test of suppression against the germination and growth of komatsuna in a greenhouse was conducted by the JFFIA. Mixtures of diluvium soil and residual sawdust in ratios of 0:100, 17:83, 20:80, 25:75, and 33:67 by volume were added at 500 ml per pot. Drainage water – solutions at concentrations of 0%, 50%, and 100% – were supplied at 60% of maximum water-holding capacity per pot before the test. The experimental period lasted 16 days.

Hatsukadaikon and bisai were cultivated in pots [370 mm (L), 150 mm (W), 120 mm (H)] in open air for 53 days starting from July 22, 1991. Forest soil obtained from the Hokkaido University Forests in Tomakomai, Hokkaido was used as a reference; and various concentrations of residual sawdust or drainage water were used as fertilizers. Mixtures of soil and residual sawdust, in ratios of 5:1, 1:1, and 0:1 by volume, were prepared in advance in a 6-l pot. Drainage water solutions at concentrations of 20%, 50%, and 100% were supplied at 200 ml per pot every 7 days.

Results and discussion

Performance of the GADE machines

Table 1 shows that the total amount of garbage collected from six persons during 90 days was 59.79 kg (0.66 kg/day). The garbage processed in the GADE machine, which used 4 kg of sawdust (251), was considered to be degraded with little solid output. The results show that use of the GADE machine for the degradation of garbage is practical and suitable for a family consisting of three to five persons.

Changes in the condition of contents of the container

Changes in temperature, pH level, and moisture content of the matrix are shown in Fig. 3. The temperature of the matrix rose precipitously to about 40°C initially and then

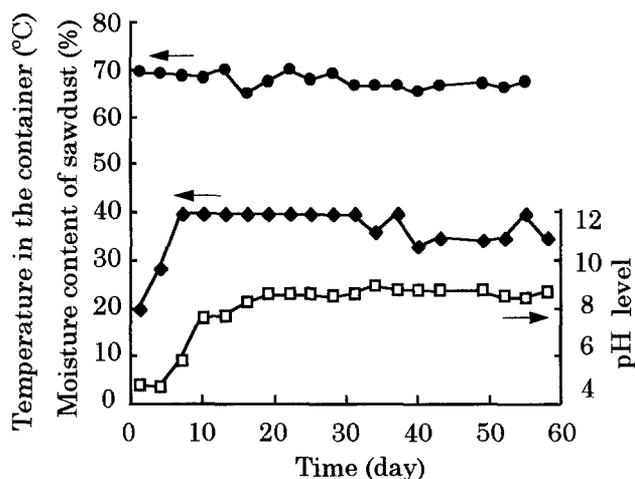


Fig. 3. Change in temperature (diamonds), pH level (squares), and moisture content (circles) of sawdust in the container

remained at 33°–39°C during the experimental period. This temperature, which was higher than room temperature, suggested the presence of microbial activity in the container.

The pH shifted to alkaline in about 10 days and remained constant at about 8.5. The pH level in the GADE machine was consistent with the fact that the composting process advances rapidly under alkaline conditions.^{10,11}

Moisture content was almost constant at 65%–70% during the experimental period (Fig. 3). Drainage water was produced after 7 days. Supposedly, the matrix maintained an aerobic atmosphere owing to adequate drainage. A bulking agent such as sawdust at more than 60% moisture content has been reported to prevent a decline of the reaction rate by restricting air supply to bacteria during composting.¹² Constant temperature, pH level, and moisture suggested that conditions in the container and the degradation were stable.

Residual sawdust and drainage water as fertilizer

Germination ratio and growth inhibition tests were conducted using komatsuna. There was no difference in the germination ratios (germinated/total) of seeds from the controlled plots and those from plots fertilized with residual sawdust and drainage water 3 days after seeding (Fig. 4). Growth inhibition was not recognized in the early growth (17 days after seeding) because the total weight of crops from fertilized plots were higher than those of the controlled plots (Fig. 4).

Total weight and stem height of the hatsukadaikon and bisai and the root weight of the hatsukadaikon varied significantly among plots when an analysis was conducted at the $P = 0.05$ level. Measurements of all fertilized plots were significantly different from the controlled soil except for D1 (20% drainage water), in terms of the root weight of the hatsukadaikon and D1 and S3 (pure residual sawdust) in terms of the total weight of the bisai at the $P = 0.05$ level as determined by LSD (least significant difference) tests (Fig.

Fig. 4. Test of suppression of residual sawdust and drainage water compared to germination and growth for komatsuna (*Brassica campestris*). Csk, control (pure soil); Sk1, 5:1 soil/sawdust; Sk2, 4:1 soil/sawdust; Sk3, 3:1 soil/sawdust; Sk4, 2:1 soil/sawdust; Cwk, control (tap water); Wk1, 1:1 tap water/drainage water; Wk2, 0:1 tap water/drainage water. Vertical lines show maximum and minimum values for two plots; filled circles, total weight; filled bars, germination ratio

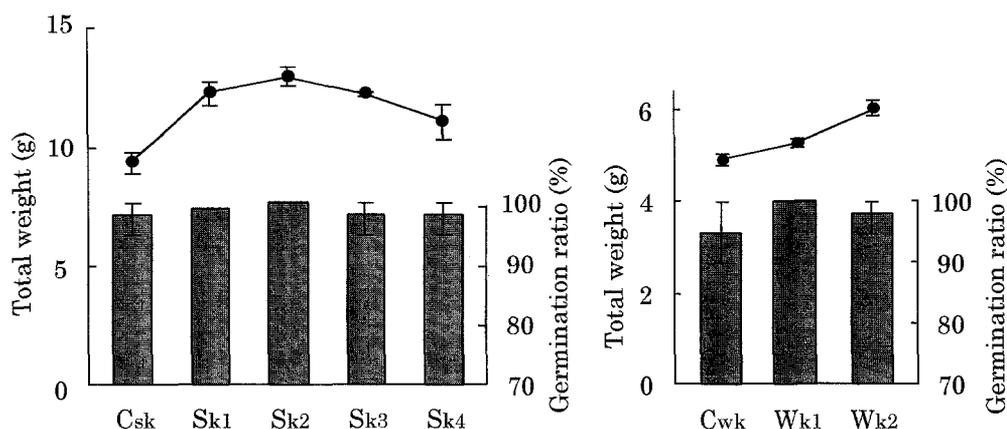
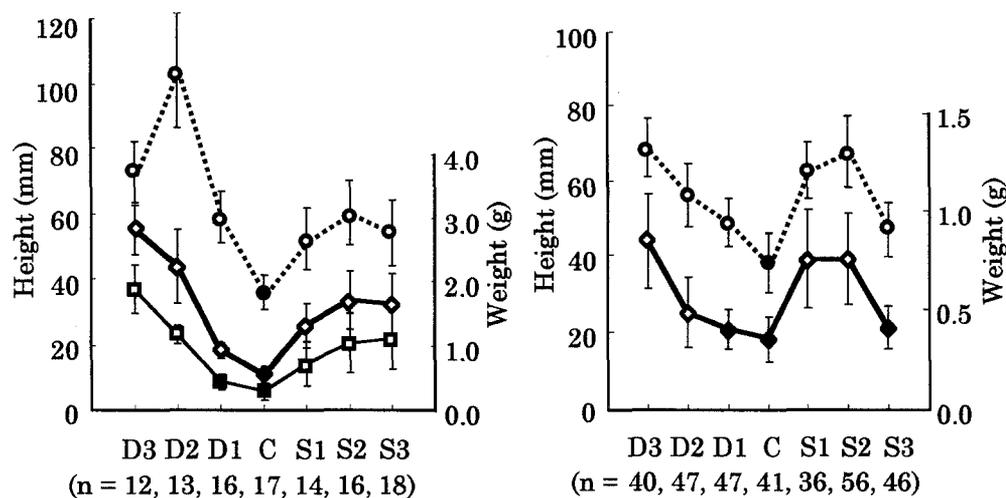


Fig. 5. Efficiency of the residual sawdust and drainage waste as fertilizer. **A** Hatsukadaikon (*Raphanus sativus* var. *radicula* DC.). **B** Bisai (*Raphanus* sp.). C, control (soil); S1, 5:1 soil/sawdust; S2, 1:1 soil/sawdust; S3, 0:1 soil/sawdust; D1, 4:1 tap water/drainage water; D2, 1:1 tap water/drainage water; D3, 0:1 tap water/drainage water. Vertical lines represent the standard deviation. Circles, height; diamonds, total weight; squares, weight of root. Open symbols show the significant difference from the control at $P = 0.05$ as determined by LSD (least significant difference) tests



5). The total weight of the hatsukadaikon showed the highest growth rate: at 3.1 times the growth of the control at 1:1 (soil/residual sawdust) and 5.1 times at 100% drainage water. The total weight of the bisai showed the highest growth rate: 2.1 times that of the control at 1:1 (soil/residual sawdust) and 2.4 times at 100% drainage water. In the case of bisai, inhibition of growth was observed at 100% residual sawdust. The effectiveness of residual sawdust and drainage water as fertilizer is considered to be due not only to the chemical components N, P, and K but also to the enhancement of nutrient availability in the soil by microorganisms¹³ and to the improvement of the physical properties of the soil.¹⁴

Conclusion

The GADE machine is able to degrade garbage from an average household. Residual sawdust and drainage water

were also shown to be effective as fertilizers. These results suggest that the GADE machine can be applied as an effective recycling system.

Widespread use of the GADE machines would help local governments introduce more freedom into the collection and management of urban waste, bringing with it many benefits, not the least of which would be a decrease in incinerator-related air pollution. The considerable benefits include eliminating odors produced by garbage waiting to be collected and allowing urban residents to deal effectively with their own waste. Other benefits include (1) the induction of many new works related to the GADE system operation; (2) activation of forest and wood industries through thinning the forest, thereby creating a large amount of sawdust; and (3) provision of a supply of nonhazardous organic fertilizer to farmers, allowing them to produce crops and vegetables safely.

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