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The effect of pH on composting of irradiated sewage sludge was discussed. Inorganic materials, such as activated alumina, Kanuma-soil, and Akadama-soil, were used as bulking agents. Na_2CO_3 was used as a pH adjuster. The fermentations were done isothermally at the optimum temperature, 50 °C.

The rate of CO_2 evolution increased initially with time, and then, decreased. The peak value of CO_2 evolution and the time to attain the peak varied by the addition of Na_2CO_3. When Kanuma-soil was used as the bulking agent, for example, the peak value became larger as the amount of Na_2CO_3 was increased to 1.0 % and became smaller over this value. From pH measurements, it was found that the optimum pH for fermentation was ranged from 6 to 8 when activated alumina was used. When other bulking agents were used, the maximum value of CO_2 evolution rate was obtained at pH 7 to 8.5. The peak value and the peak time also varied by the addition of NH_3 in the aeration gas.

Keywords: Sludge Treatment, Irradiation, Composting, Bulking Agents, pH, Sodium Carbonate, Fermentation

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汚泥のコンポスト化におけるpHの影響

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（1983年12月23日受理）

照射汚泥のコンポスト化におけるpHの影響を検討した。通気性改良材として無機物を用い，pHの調整には炭酸ナトリウムを用いた。最適温度である50℃で等温発酵を行い，次の事を明らかにした。

1. 発酵に伴なう炭酸ガスの発生は最初に増加し，その後減少するが，このピーク値およびピーク値に達する時間は炭酸ナトリウム添加量によって大きく変化する。
2. 通気性改良材として活性アルミナを用いる場合，発酵速度が最大となるpHは6～8，鹿沼土，赤玉土など，他の通気性改良材を用いる場合では7～8.5である。

Contents

INTRODUCTION

In the land application of sewage sludge, one of the important problems is the hazard to public health that may be posed by the presence of disease-causing organisms.[1)] Radiation treatment is one of the effective methods for disinfection.[2),3)] For example, coliforms in dewatered sludge are sterilized with 0.5 Mrad irradiation.[4)]

The direct land application of sewage sludge, however, may cause odor or sanitary problems to the neighbors even after irradiation, and plants may be harmed due to rapid fermentation of the sludge in soil. Stabilization of sewage sludge, for example composting, is considered to be necessary as well as disinfection in Japan.

Irradiated sludge can be stored for long time without change in quality. This fact leads to an experimental merit that the same sludge can be used in a series of experiments and the results are reproducible.

We have studied on composting of radiation disinfected sewage sludge. The studies were made on factors affecting on composting rate under isothermal condition and we have reported that the optimum temperature was about 50 °C.[5)] As it is not necessary to consider disinfection condition in the process using irradiated sludge, the composting can be carried out at the optimum temperature and finished in short time.

We have also studied on another important factor, pH, in isothermal composting using irradiated sludge and the results are reported here.

MATERIALS AND METHODS

Raw sludge

Dewatered sludge by centrifugation from purification plants in Maebashi city was used. The sludge contained a polymer floccurant. Water content of the sludge was about 76 - 82 % and volatile solid content 76 - 83 %. The sludge was irradiated at a dose rate of 1 Mrad/h for 3 hours using Co-60 source and stored at 4 °C. By this irradiation, the total count of coliform in the sludge is reduced to almost zero from $3x10^8$ counts/g and the total count of bacteria is reduced to 10^3 counts/g from 10^9 counts/g.6)

Bulking agents

Addition of bulking agent is necessary to maintain an aerobic condition. Inorganic materials were used as the bulking agents to avoid errors due to fermentation of the bulking agent itself. Kind, particle size, and amount of the bulking agents used in this experiment are shown in in short time.

We have also studied on another important factor, pH, in isothermal composting using irradiated sludge and the results are reported here.

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Table 1. All the bulking agents, except quartz sand, are porous and absorb moisture in the sludge.

Apparatus and procedure

The apparatus used is the same one as in the previous paper.5) The fermentor is a 50 ml glass ware which has a perforated plate in the bottom, and is placed in a water bath to keep the fermentation temperature constant.

Fermentation of irradiated sludge does not start even in aerobic condition, hence we added a commercial starter including seed bacteria (called Thomas-bacteria*) to initiate fermentation. The amount of the seed was 10 wt % of the sludge. 10 g of the irradiated sludge was mixed with the balking agent and seed, and put into the fermentors. In a part of experiments, certain amount of Na_2CO_3 was also mixed with raw materials as pH adjuster. Aeration was carried out at 50 ml/min using an air pump. The gas was previously passed through a humidifier to keep water content of the raw material constant. Refined water was used as bubbling solution in the humidifier, but in a part of experiments, NH_4OH aqueous solutions were used.

Concentrations of CO_2 and NH_3 in the exhaust gas were measured by an infrared analyzer (Beckman, Model B-64) and gas detector tubes (Komyo Rikagaku Kogyo, No. 105 SC),

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* Seed for composting composed of various bacteria.

respectively. The pH of the raw material was measured by a pH meter (Hitachi, M-5) in slurry by adding 5 times weight of water.

RESULTS AND DISCUSSION

Effect of bulking agent

We have previously carried out a liquid chromatographic study on water extracts from composts of various fermentation steps and reported that the concentration of easily decomposable organics decreased with CO_2 evolution in fermentation process and became almost zero when the carbon conversion exceeded 30 %.7) This fact shows that the rate of CO_2 evolution is an effective measure of fermentation.

Fig. 1 shows CO_2 evolution curves in composting when the various raw materials were used. The fermentations were done at the optimum temperature, 50 °C. As the optimum value of water content is known to be about 40 - 60 %,8) the amounts of the bulking agents were decided by considering the range of water content and to get a good aerobic condition. Among the bulking agents used, quartz sand only did not absorb water and large amounts were required to get a good aerobic condition. The overall water contents of raw materials are also shown in Table 1. The value of the water content of raw material respectively. The pH of the raw material was measured by a pH meter (Hitachi, M-5) in slurry by adding 5 times weight of water.

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Rate of CO_2 evolution is proportional to CO_2 concentration in exhaust gas and 1.0 % CO_2 concentration is equal to $5x10^{-2}$ g ($1.1x10^{-3}$ mol) CO_2 evolution per unit time (h).

As shown in Fig. 1, CO_2 concentration in exhaust gas increase initially, and then decrease. The peak value and the time to attain the peak vary by bulking agents. The peak value is the highest and the peak time is the shortest when the base type activated alumina is used. The rate of CO_2 evolution is also high in the case of the neutral-type activated alumina. For Kanuma-soil and quartz sand, the rates of CO_2 evolution are low and long times are necessary to attain the peak values. Fermentation scarcely proceeds for the case of Akadama-soil.

In Table 1, pH values of raw materials are also shown. The pH values of the sewage sludge used in these experiments are about 5.87 to 5.96 and additions of Kanuma-soil, Akadama-soil, and quartz sand scarcely affect on pH. On the other hand, the pH values decrease by the addition of acid-type activated alumina to 5.13 and increase to 7.59 and 8.02 by adding neutral-type and base-type, respectively.

Effect of Na_2CO_3 addition

Fig. 2 shows CO_2 evolution curves for various amounts of Na_2CO_3 added in M-5. In this case, Kanuma-soil was used as the bulking agent. The CO_2 concentration was initially high for large amounts of Na_2CO_3 and became almost zero within 1 hour in all cases. In the sewage sludge, organic acids are contained 9) and the initial CO_2 evolution may be induced by the reaction between Na_2CO_3 and the organic acids. The CO_2 evolution with fermentation is seriously affected by the amounts of Na_2CO_3 as shown in Fig. 2. Peak value of CO_2 concentration in the exhaust gas is about 0.5 % and peak time is 62 hours for without Na_2CO_3. Peak values increase to 0.7 % and peak times are significantly shortened to 20 hours by the additions of 0.5 and 1.0 % (4.5 and 9.0×10^{-4} mol). When the amount of Na_2CO_3 becomes larger than 1.0 %, the peak value becomes smaller and the peak time becomes longer again.

Fig. 3 shows CO_2 evolution curves of M-4 for various amounts of Na_2CO_3. In this raw material, 30 - 60 mesh activated alumina was used as the bulking agent. The peak value of CO_2 concentration is high even without adding Na_2CO_3 and the curves scarcely change by the increase of Na_2CO_3 addition to 1 %. When the amount of Na_2CO_3 becomes larger than about 2 %, the peak value remarkably decreases and the peak time becomes very long.

Initial pH values of raw materials are shown as functions of amounts of Na_2CO_3 in Fig. 4. When Kanuma-soil is used as the bulking agent, the effect of Na_2CO_3 addition on pH is large and the value is ranged from about 6.0 to 9.0 for the change of amounts of Na_2CO_3 from 0 to 2.0 %. On the other hand, when the activated alumina is used, the pH value is large even without Na_2CO_3 and the range is 8.2 to 9.5. From these results, it is shown that the fermentation rate remarkably depends on pH of raw materials.

Peak value and peak time as functions of pH

Fig. 5 shows the peak value and the peak time as functions of pH at the initial stage. The raw materials used in this plot are M-1 to 4. The initial pH was adjusted by using Na_2CO_3. The peak value, h_p, and the peak time, τ_p, are shown by the ratios to those of fermentation in which 30 - 60 mesh activated alumina was used without adding Na_2CO_3. The maximum value of h_p and the minimum value of τ_p are obtained at neutral pH and it seems that the optimum pH for fermentation is ranged from 6 to 8 in these experimental conditions.

The same plot for Kanuma-soil, Akadama-soil, and quartz sand is shown in Fig. 6. h_p and τ_p are also normalized to the values for the activated alumina.

Although h_p and τ_p are rather scattered in this figure, the similar curves as in Fig. 5 are obtained. The maximum value of h_p is seen at pH 7.5 to 8.0 and the minimum value of τ_p at 8.0. The maximum value of h_p is about 0.9 and smaller than that in Fig. 5. The minimum value of τ_p is about 1.2 and larger than that in Fig. 5. The optimum pH seems to be ranged from 7 to 8.5 and rather high compared with that for the activated alumina. In the fermentation process, NH_3 is always generated as will be mentioned in the next section and the absorbance of NH_3 increases pH of the mixture. The difference of the optimum pH between activated alumina and other bulking agents may be due to that of adsorptive power for NH_3.

Aeration by NH_3-contained gas

Fig. 7 shows CO_2 evolution curves of M - 7 obtained under aeration by NH_3-contained gas. In these experiments, various NH_4OH concentration solutions were used for the bubbling water as pH adjuster instead of Na_2CO_3. The NH_3 concentration in the air after passing through the humidifier varied with time, for example, from 340 to 80 ppm within 2 days, when the gas flow rate was 50 ml/min and 3.3×10^{-3} mol/l NH_4OH solution was used as the bubbling water. The summations of NH_3 evoluted from the solution were 6×10^{-4} and 9×10^{-4} mol after 1 and 2 days, respectively.

As shown in Fig. 7, the maximum CO_2 concentration increases for 3.3×10^{-3} mol/l NH_4OH solution, but decreases above this NH_4OH concentration. The peak time is short for the large peak value. Fermentation scarcely proceed when the concentration of NH_4OH in the bubbling water exceeds 1.7×10^{-1} mol/l.

NH_3 is always evoluted in the process of fermentation. Table 2 shows an example of NH_3 evolution with fermentation time. M - 4 was used without adding Na_2CO_3. It can be seen that NH_3 concentration in the exhaust gas is comparable with that when the 3.3×10^{-3} mol/l NH_4OH solution was used as the bubbling water and it may be useful to reuse the NH_3-contained exhaust gas from a fermentor, in which the fermentation is proceeding, as an aeration gas for another fermentor at the start up.

References

1. J.D. Donald, M. N. Guentzel, M.J. Ibarra, B. E. Moore, and B. P. Sagik, Appl. Environ. Microbiol., 39(1), 118 (1980).

2. I. Wizigmann, Proceeding of the First International Conference of ESNA Working Groupe on " Waste Irradiation ", Munich, 1976.

3. J.G. Trump, et al., Proceeding of the Second International Conference of ESNA Working Groupe on " Waste Irradiation ", Upsala, 1977.

4. H. Watanabe, H. Ito, H. Iizuka, and M. Takehisa, Hakkokogaku, 59(5), 449 (1981).

5. W. Kawakami, S. Hashimoto, H. Watanabe, K. Nishimura, H. Watanabe, H. Ito, and M. Takehisa, Radiat. Phys. Chem., 18(3,4), 771 (1981).

6. H. Watanabe, Private Comunication.

7. S. Hashimoto, H. Watanabe, K. Nishimura, and W. Kawakami, Hakkokogaku, 61(2), 77(1983).

8. K. C. Shin, Kogaitotaisaku, 16(2), 132 (1979).

9. S. Hashimoto, H. Watanabe, K. Nishimura, and W. Kawakami, Hakkokogaku, 61(2), 69(1983).

Table 1 Raw materials used for composting

Raw material	Bulking agent		Water content	pH
	kind	weight		
M - 1	Activated alumina (Acid-type, 70-230 mesh)	10 g	40 %	5.13
2	Activated alumina (neutral-type, 70-230 mesh)	10	40	7.59
3	Activated alumina (base-type, 70-230 mesh)	10	40	8.02
4	Activated alumina (30-60 mesh)	10	40	8.19
5	Kanuma-soil* (16-60 mesh)	3	61	5.86
6	Akadama-soil** (16-60 mesh)	7	46	5.83
7	Quartz sand (30-50 mesh)	15	32	5.91

Weight of sludge; 10 g, seed bacteria; 1 g.

* A yellow color pumice-soil made of clay.

** A red-brown color pumice-soil made of clay.

Table 2 NH_3 evolution with fermentation time

Time (h)	8	21	26	47	57	75
NH_3 conc. (ppm)	240	440	200	130	65	55

Raw material; M - 4, fermentation temp.; 50 °C, aeration rate; 50 ml/min.

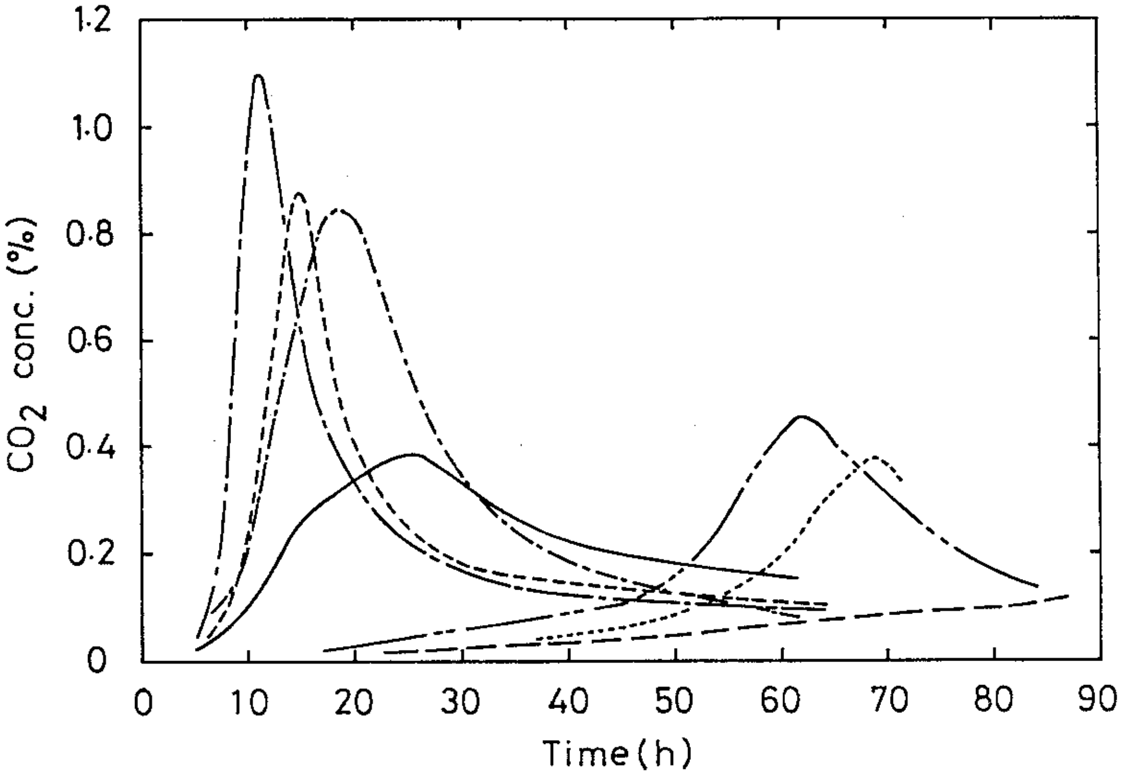

Fig. 1 CO_2 evolution curves for various raw materials

Fermentation temp.; 50 °C, aeration rate; 50 ml/min,
seed bacteria; 1 g.
Raw materials;
———— M-1, - - - - - - M-2, ——- —— M-3,
—·—·—·— M-4, ——·-·—— M-5, —— —— —— M-6,
············ M-7.

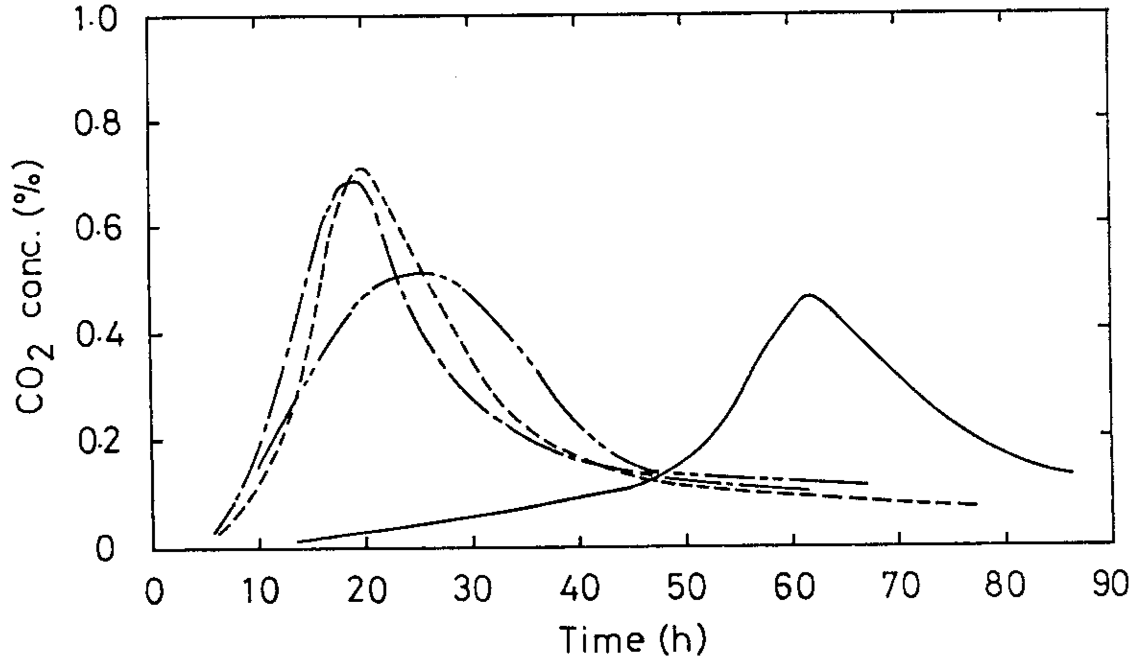

Fig. 2 Effect of Na_2CO_3 addition on CO_2 evolution (1)

Raw material; M-5.
Amounts of Na_2CO_3;
———— 0, - - - - - 0.5, ——-—— 1.0, ——-·—— 2.0%.
Other conditions are the same as in Fig. 1.

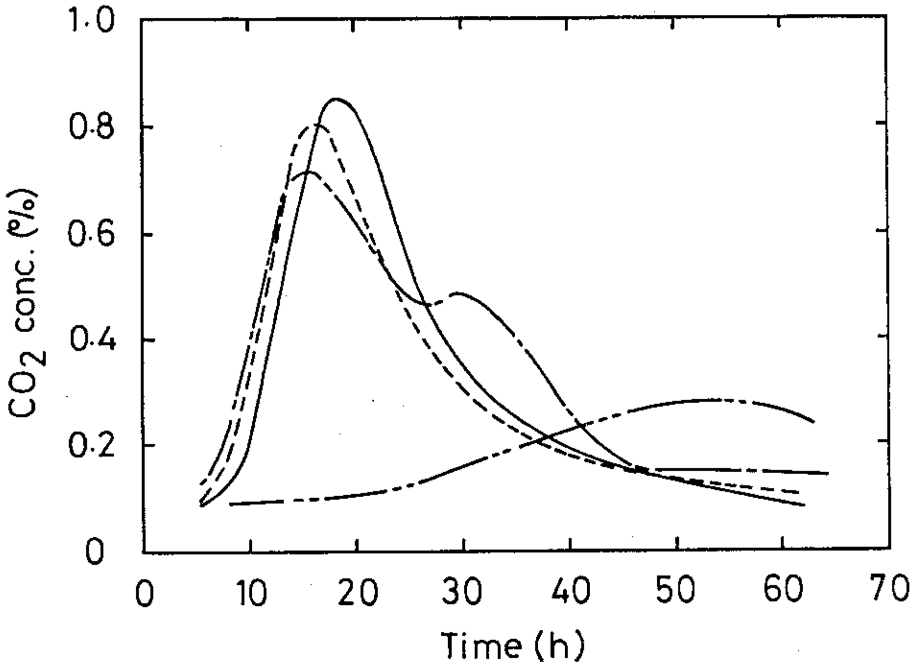

Fig. 3 Effect of Na_2CO_3 addition on CO_2 evolution (2)

Raw material; M-4.
Amounts of Na_2CO_3;
—— 0, – – – – 0.5, —·— 1.0, —··— 2.0%.
Other conditions are the same as in Fig. 1.

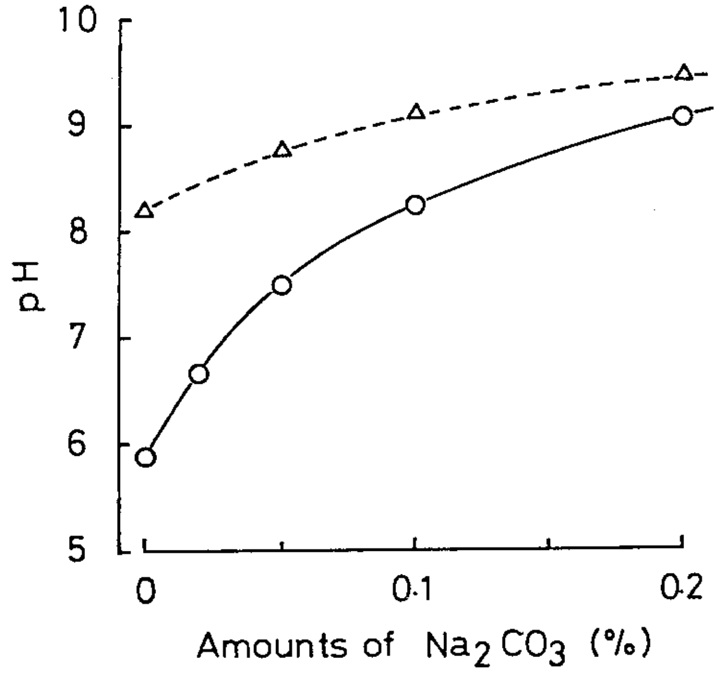

Fig. 4 Initial values of pH as functions of amounts of Na_2CO_3

Raw materials; —○— M-5, ---△--- M-4.

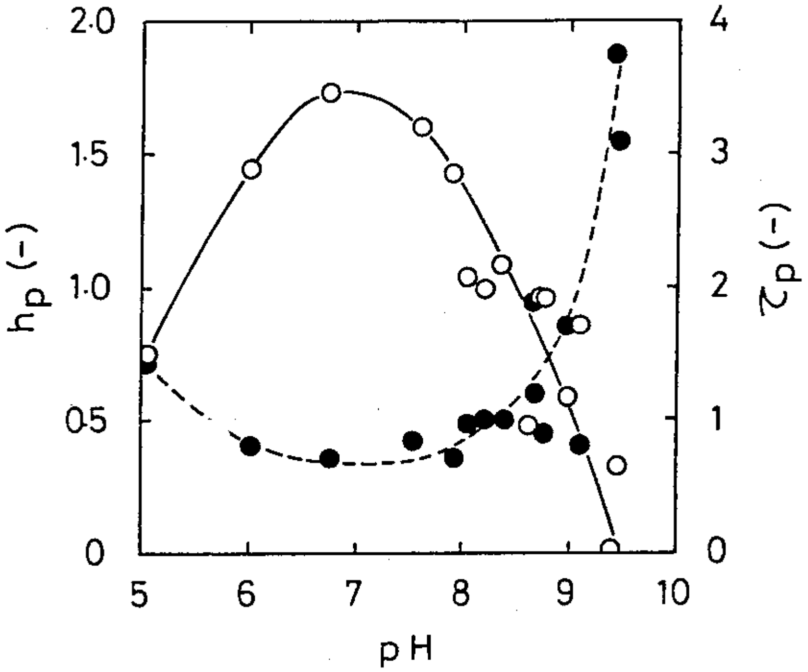

Fig. 5 Variations of peak value and peak time of CO_2 evolution rate with pH (1)

Raw materials; M-1 to 4.
—○— relative peak value h_p,
---●--- relative peak time τ_p.

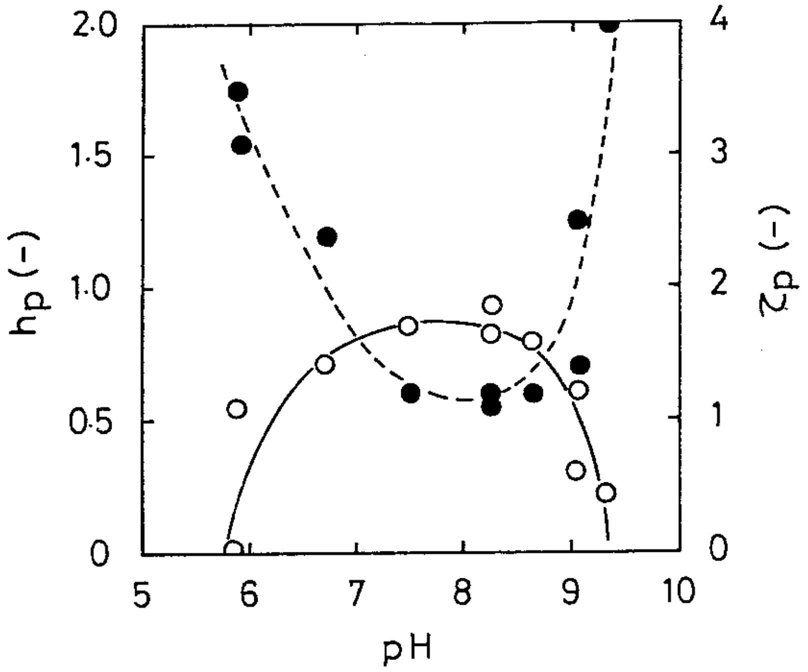

Fig. 6 Variations of peak value and peak time of CO_2 evolution rate with pH (2)

Raw materials; M-5 to 7.
—○— relative peak value h_p,
---●--- relative peak time τ_p.

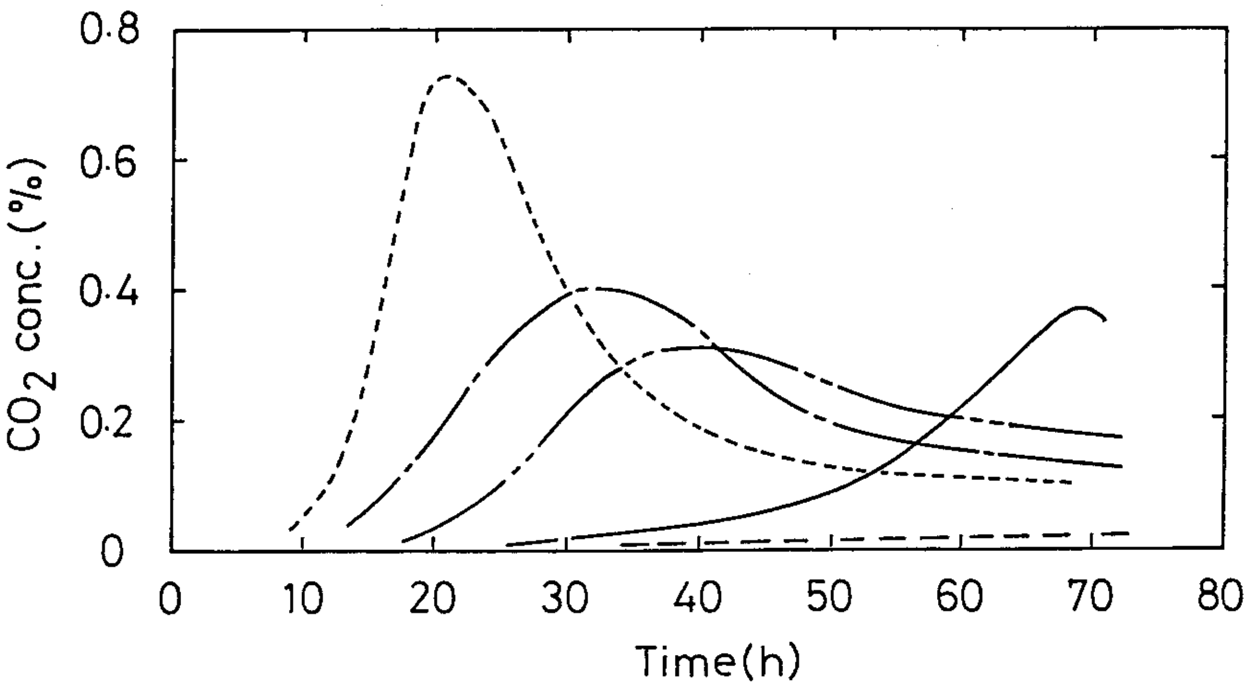

Fig. 7 Effect of NH_3 addition on CO_2 evolution

Raw material; M-7.
NH_3 concentration in the bubbling water;
——— 0, - - - - - $3.3x10^{-3}$, —— - —— $3.3x10^{-2}$,
——- - — $6.6x10^{-2}$, — — — $1.7x10^{-1}$ mol/l.
Other conditions are the same as in Fig. 1.