Detection of spoilage of cereal grain in storage bin

Kiyokazu GOTO[1], Yoshihiro MIWA[1] and Motohiro MORI[1]

Abstract

Recently, the incident of spoilage of grain during the storage occurs a few times a year at the drying and storage facilities in Japan. This causes the huge economic damage and the farmer's cooperative loses the reliance. If the sign of spoilage can be detected in the early stage, the damage will be prevented. There are some causes of grain spoilage during the storage, for example increase of respiration, dew condensation, fermentation, mold, microorganism, stored grain insect, mouse etc.. In any case, the concentration of carbon dioxide increases in the storage bin. So, the measurement of CO_2 concentration will be a one of the effective methods to detect the spoilage of stored grain. In this paper, the characteristics of CO_2 concentration change were investigated when the dew condensation occurs in the storage bin. The probability of spoilage detection was then considered

Introduction

In Japan, there are a few incidents of rice spoilage yearly during storage. The causes are the fermentation or breeding of the microorganism etc. When the rice spoilage occurs, the economic damage is huge and the credit of the farmers' cooperatives will be lost.

The causes of rice spoilage are as follows:

a) Paddy tends to be harvested in early stage in Japan, so the moisture content of received paddy in the facilities recently has been fairly high.

b) Early harvesting (August, September) has increased, so the temperature is high in the harvesting season.

c) When the concentration of paddy received is remarkable, a large quantity of wet paddy is piled in the temporary storage bin. The safe air-flow then can not be kept.

d) The final moisture content was set highly by government in comparison to the previous value So the moisture content of stored paddy may be fairly high.

e) The moisture content of stored paddy may become high suddenly by the dew condensation caused by weather condition.

f) Using the storage drying method, the drying rate is slow, so the duration of wet state is long.

In the drying and storage facilities, the rice spoilage lies in two aspects, one is the fermentation, another is the breeding of microorganism. In both cases, the respiration rate of rice or microorganism increases. So it can be said that the starting point of rice spoilage is the increase of respiration rate. We can prevent the significant spoilage by the detection of this condition.

The chemical formulas of respiration of rice are as follows:

aerobic: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

anaerobic: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

When the rice respires, carbon dioxide is generated. So, we can detect the respiration by the measurement of CO_2 concentration. Further, even if microorganisms, for example mold, or animal, for example mouse, etc., increase, we can notice that incident by the measurement of carbon dioxide. The CO_2 concentration of carbon dioxide is the useful index to detect the irregular condition during rice storage.

The rice spoilage during storage is mainly dependent on the moisture content and temperature of grain. The causes to become high moisture content are as follows.

a) A little high moisture paddy is mixed in the regular moisture paddy

b) Part of paddy is wetted rapidly for example by dew condensation.

We performed detecting the increase of respiration rate by the measurement of CO_2 concentration using the small size containers and the practical grain storage bin.

Experimental Method

Model experiment

Mixture of high moisture paddy

The model of paddy storage bin was set by piling 3 standard sieves (200mm diameter and 50mm height); upper and lower ends were sealed In the upper and lower sieves, paddy of regular moisture content (1 kg weight) was put, and moisture content was about 13.5 – 14.0 % W. B Putting the high moisture paddy (15 – 30 % W. B.) in the middle sieve, the change of CO_2 concentration at the upper and lower space as side of the model storage bin. The CO_2

[1]Faculty of Agriculture, Gifu University, 1-1 Yanagido Gifu-shi Gifu, 501-1112, Japan

concentration meter of infrared type was used.

Effect of dew condensation

Assuming that regular paddy is wetted suddenly by the effect of dew condensation inside the storage bin, some model experiments were carried out.

Experimental device was the same as the experiments of mixture of high moisture paddy. 2.8 kg of regular paddy was piled in the model bin. A little amount of paddy in the petri dish which absorbs water was put on the top of paddy layer instead of dew effect. Changing temperature and amount of water absorbing, the change of CO_2 concentration was measured in the upper and lower space inside of the model bin.

Practical bin experiment

Using the practical storage bin (capacity: 250t) in the grain drying and storage facilities, the experiment of detection of CO_2 concentration change was performed. Diameter and height of the bin were 10m and 7m, respectively.

Measuring method

Three CO_2 meters were set in the upper space of the bin; one of them was set near the surface of stored paddy, and two at the upper part in the space. Two CO_2 meters were set below the paddy layer; one was just below the perforated floor, and another was at middle point in the lower space.

Temperature and relative humidity were measured in the upper and lower space of bin and outside of the bin. The outline of measuring system is shown in Fig. 1.

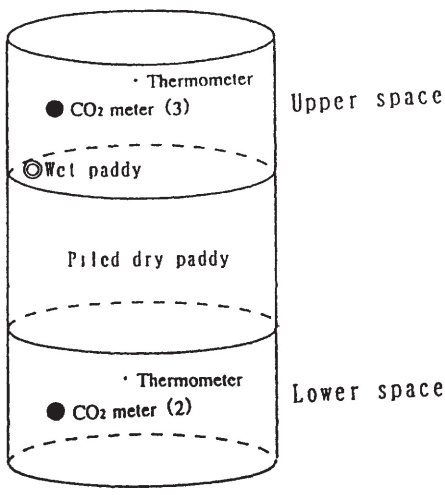

Fig. 1. Measurement of practical bin.

Experimental procedure

a) Experiment A

The change of CO_2 concentration in the upper and lower space of the bin was measured without putting the wetted paddy. Therefore, this experimental result is the standard for comparison of the change of CO_2 concentration of each experiment.

b) Experiments B

82 kg of water was added to 500 kg of regular paddy. This wet paddy, which is assumed to be affected by the dew condensation, was put on the surface of piled paddy. This type of experiment was done twice.

c) Experiment C

Putting CO_2 gas into the upper space of the bin, the changes of CO_2 concentration in the upper and lower spaces were measured. This experiment was done to investigate the diffusion of CO_2 gas through the piled paddy in the bin. If the change of CO_2 concentration can be detected at any point in the bin, one CO_2 meter is sufficient per bin for the detection

Results and Discussion

Model experiment

Mixture of high moisture paddy

a) Effect of moisture content

The changes of CO_2 concentration when the moisture content of high moisture paddy ranged from 15 to 20 %W. B. are shown in Fig. 2. When the moisture content was less than 16 %W. B. , the change of CO_2 concentration was very little; beyond 16 %W. B. , the increasing rate became high drastically. Moreover, the values of the upper and lower spaces were almost the same, so the measurement at one point per bin was aright.

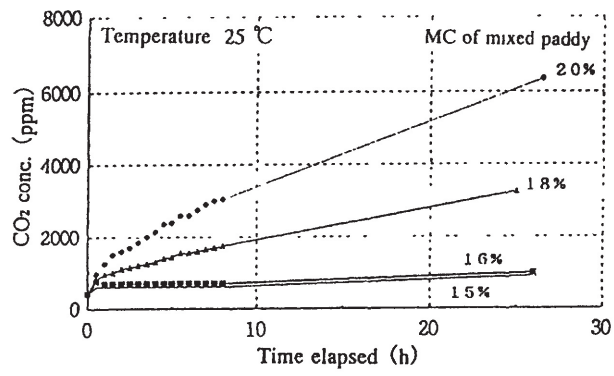

Fig. 2. Effect of MC of mixed wet paddy.

b) Effect of storage temperature

Paddy of 18 and 20 %W. B. was used as the high moisture paddy. The changes of CO_2 concentration were measured when the storage temperatures were 15, 25 and 35℃ ; the results are shown in Fig. 3 and Fig 4. The higher the temperature is, the higher the increasing rate of CO_2 concentration is; since the respiration rate increases. If the CO_2 meter is sensitive, even the mixture of half dried paddy, about 18 %W. B can be detected.

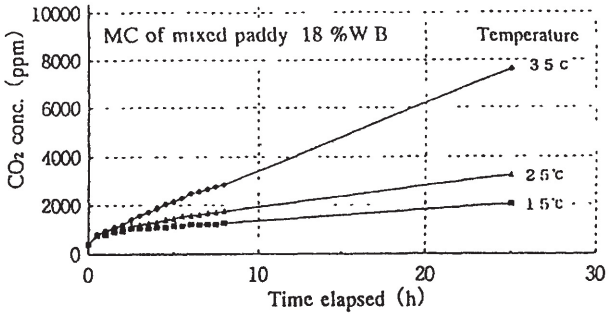

Fig. 3. Effect of storage temperature (1).

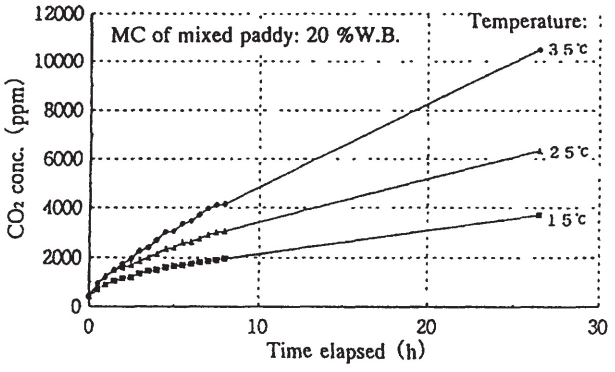

Fig. 4. Effect of storage temperature(2)

Effect of dew condensation

a)Effect of amount of added water

Adding 5, 10 or 20 g of water to 50 g of regular paddy, the changes of CO_2 concentration were measured and the results are shown in Fig. 5. Changes of 10 g and 20 g adding are similar, so we decided that the amount of added water to the regular paddy is 20 % of paddy.

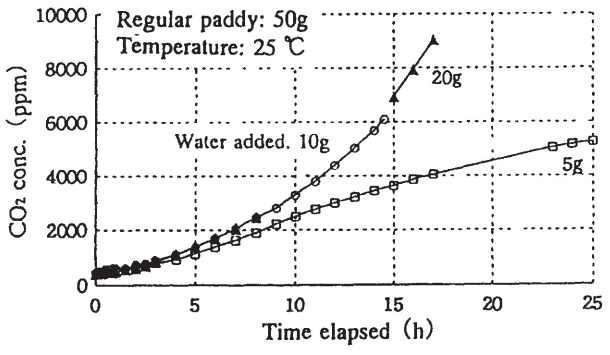

Fig. 5. Effect of quatity of water added.

b) Effect of storage temperature

The change of CO_2 concentration when 12 g of wetted paddy was put on the surface of piled paddy is shown in Fig. 6; temperatures were 10, 20 and 30℃. When the temperatures were 20 and 30℃, CO_2 concentration began to increase linearly. When 30℃, since the wetted paddy was dried gradually, the increase of CO_2 concentration stopped, and that started to decrease after that. When 10℃, since the respiration rate was low, it was difficult to detect the dew condensation.

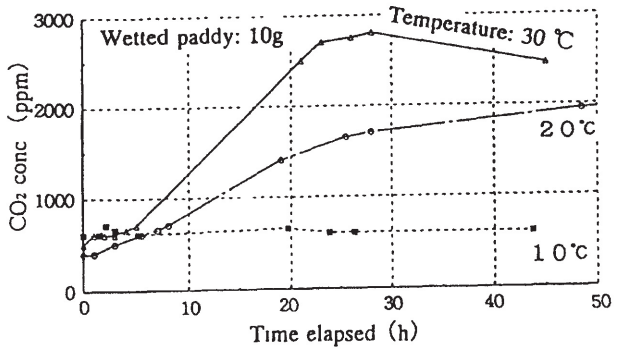

Fig. 6. Effect of storage temperature.

c) Effect of amount of wetted paddy

Putting the wetted paddy of 0, 1, 2.5, 5, 10 and 20 g on the surface, the changes of CO_2 concentration were measured; storage temperature was 20℃ (Fig. 7 and Fig. 8) As shown in Fig. 8, the increasing rate is in proportion to the wetted paddy amount.

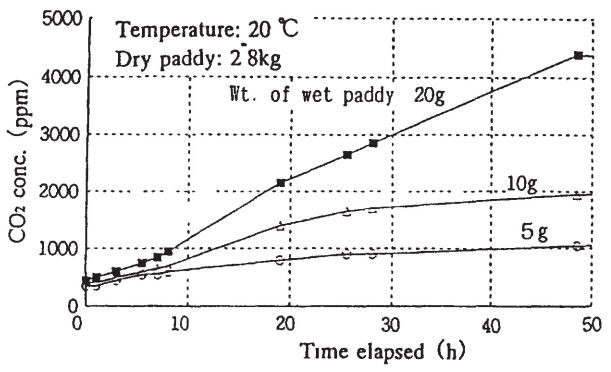

Fig. 7. Effect of quantity of wetted paddy (1).

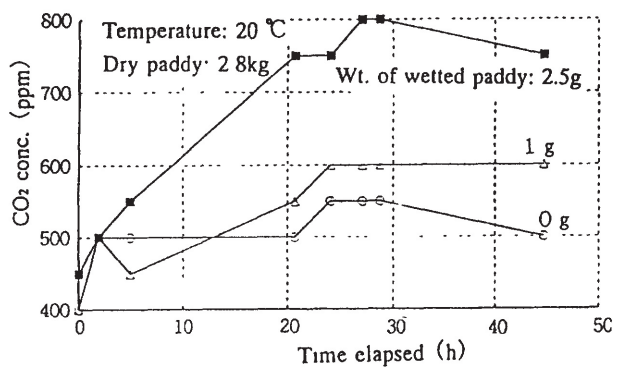

Fig. 8. Effect of quantity of wetted paddy (2).

The change of CO_2 concentration differs also according to bin capacity, and amount of stored paddy. In this model bin condition, if there is about 2.5 g of wetted paddy to 2.8 kg

of regular paddy (0.9% by weight), the generation of CO_2 could be detected. This rate is equal to that of 180 kg wetted paddy to 200 t of regular paddy.

This fact shows that even if the wetted paddy is so little, the detection is possible.

Practical bin experiment

Conditions of experiment

Moisture contents of the regular paddy and water added paddy were 13.8 % and 21.0 % W. B. respectively. Temperature and humidity during the experiment are shown in Figures 9 and 10 Since weather was cloudy during experiment, the change of ambient temperature was small; that was less than 2℃ (14.5 – 16℃) especially inside the bin.

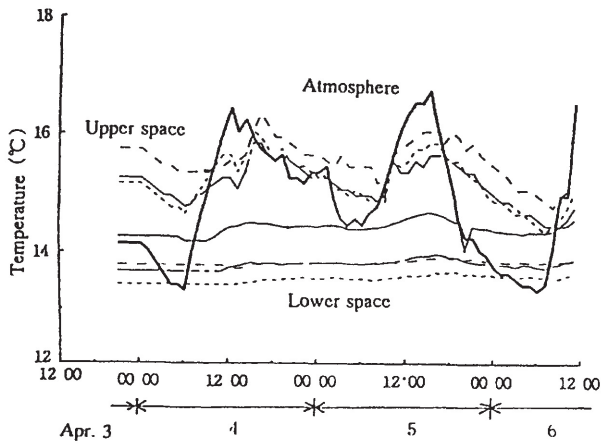

Fig. 9. Change of temperature inside and outside of the bin.

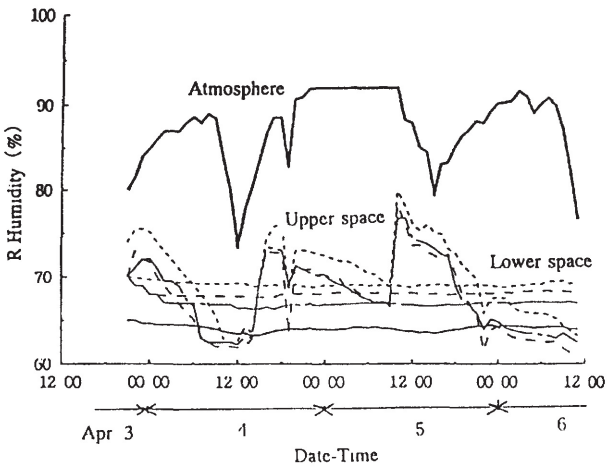

Fig. 10. Change of R/humidity inside and outside of the bin.

Detection of carbon dioxide

a) Experiment A

The change of CO_2 concentration when there was no wetted paddy in the bin is shown in Fig. 11. The value in the upper space was stable; however that of lower space decreased slowly. When only regular paddy existed in the bin, the increase of CO_2 concentration was not found at any position. It was clarified that CO_2 concentration just on the paddy surface was higher than that at upper location in the same space.

b) Experiment B

The change of CO_2 concentration when wetted paddy was put on the piled paddy are shown in Fig. 12 and Fig. 13. This type of experiment was done twice. The measured value of CO_2 concentration fluctuated for the first 3 hours since the CO_2 meter was set just above the wetted paddy. At every measuring point in the upper space, the CO_2 concentration started to increase about after 3 hours from the starting. Though the CO_2 concentration were different between upper and lower part in the upper space, the increasing rates were almost the same; those were about 100 ppm/10 hours.

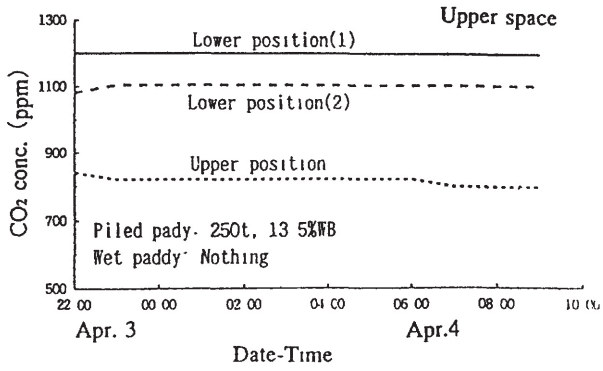

Fig. 11. Change of CO_2 concentration without wetted paddy.

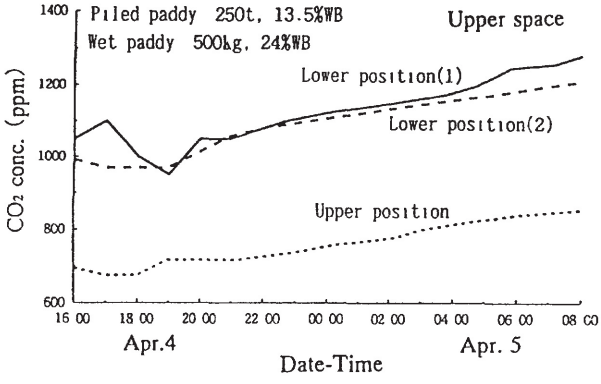

Fig. 12. Change of CO_2 concentration with wetted paddy (1).

The change of CO_2 concentration of Experiment B was quite different from that of experiment A, so that it was clarified that the existence of wetted paddy can be detected. Moreover, unless the storage bin is sealed tightly, detection is possible.

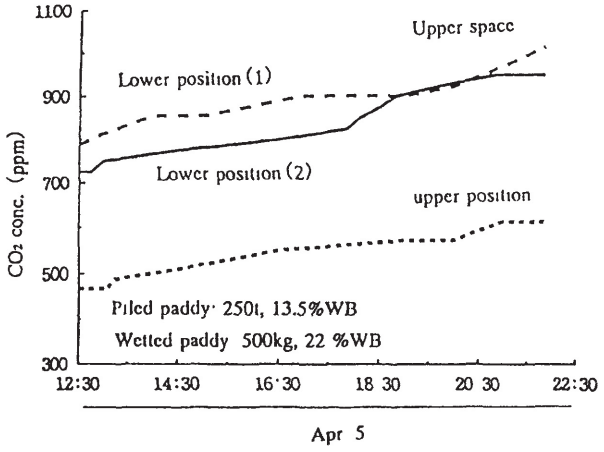

Fig. 13. Change of CO_2 concentration with wetted paddy.

c) Experiment C

The changes of CO_2 concentration in upper and lower space after putting carbon dioxide in the upper space are shown in Fig 14. The CO_2 concentration in the upper space decreased very slowly; the CO_2 concentration in the lower space did not change, so it was thought that the diffusion rate of carbon dioxide through piled paddy is very low.

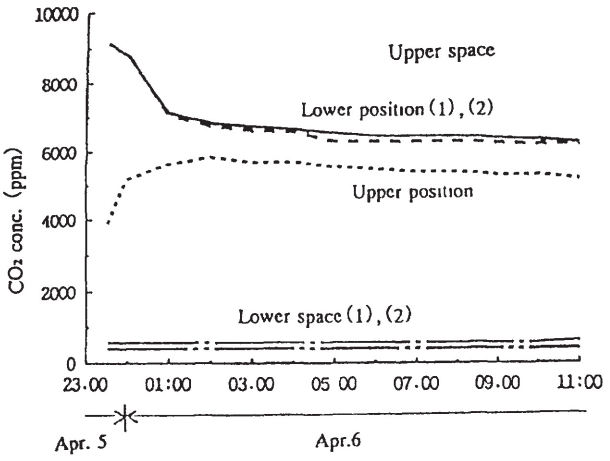

Fig. 14. Diffusion of carbon dioxide in the bin.

Summary

The increase of respiration is the sign of starting of rice spoilage. Carbon dioxide is generated by the respiration in both aerobic type and anaerobic type So the detection of carbon dioxide was performed during storage using the model storage bin and the practical storage bin.

When the high moisture paddy was mixed in the regular paddy, change of CO_2 concentration was detected according to moisture content and temperature

Assuming that a part of paddy is wetted suddenly by dew condensation, the generation of carbon dioxide by the respiration was surveyed Increasing rate of CO_2 concentration is dependent on the temperature and amount of wetted paddy. If 0.1 % of the regular paddy is wetted by dew condensation, it is possible to detect the generation of carbon dioxide. This change is quite different from that when there is no wetted paddy. Therefore it was concluded that detection of CO_2 generation is possible It was, however, found that the diffusion of carbon dioxide is very slow in the piled paddy. So, if the detection is done at only one location per bin, it is necessary to adopt some idea, for example the aeration before the measurement of CO_2 concentration.

References

Fujimaki M., 1984. Science and technology of post-harvest (in Japanese), Korin. Yamashita R., 1992. Physical property of cereal grain (in Japanese), Japanese Society of Agricultural Machinery.

Taguchi R., 1964. Outline of plant physiology (in Japanese), Yoken-do

Ebisawa I On the technical problems of country elevator (in Japanese), Journal of Agricultural warehouse and prevention of disasters, No. 39, 40 and 41.