Effect of Temperature Change on the Respiration Characteristics of Vegetables

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ABSTRACT

The effect of fluctuating temperature on the respiration of vegetables has been investigated. Spinach was selected as the experimental material because of its high respiratory activity and kept under the condition that temperature changed alternately at low and high levels every 4 hours. The low-high level temperature combination was set in 1-10°C, 1-20°C and 1-30°C. Respiration was evaluated in terms of quantity of CO_2 evolved from spinach. The evolution rate of CO_2 was determined by a change in its concentration. The evolution rate of CO_2 followed closely the temperature change. In the temperature combinations at 1-10°C and 1-20°C, the relationship between CO_2 evolution rate and temperature was found to be able to express by Arrhenius law, while at 1-30°C, it did not obey the law.

Key Word : Spinach, Respiration rate, Arrhenius law, CO_2 evolution rate, Fluctuating temperature

INTRODUCTION

Respiration process is the oxidative breakdown of more complex substrates present in the cell of a horticultural product, such as starch, sugars and organic acids, to simpler molecules (CO_2 and H_2O). Use of various substrates in respiration can result in loss of food reserves in the tissues and losses of taste, quality and food value to consumer. Controlled respiration can be used to delay senescence. The environmental conditions, such as temperature, humidity, gaseous components and light, affect respiration of vegetables after being harvested. Many papers have reported the characteristics of a respiration rate for many horticultural products under various storage conditions. Almost all results reported were obtained under the constant conditions of these environmental factors in order to investigate an optimum condition for maintaining the quality of fresh fruits and vegetables. However, the respiratory responses against dynamic change of environmental factors were considered to be important, especially for transportation, storage and ripening process of the produce. The objective of this study was to investigate the effects of a fluctuating temperature change on the respiration characteristics of vegetables, on the basis of Arrhenius law.

MATERIALS AND METHODS

Experimental apparatus Respiration rate was evaluated in terms of CO_2 evolution from the sample. Airtight chamber, 450x450x450 mm, composed of polyvinyl plates was used for controlling temperature and measuring CO_2 concentration. To accomplish the accurate data acquisition of CO_2 evolution rate, the chamber was covered with a tent made by polyvinyl sheets. Airtightness was achieved by immersing the skirt of tent into water in a base container. The chamber was equipped with a 200W electric heater for controlling temperature and a cross-flow fan for stirring air. The chamber was placed in a cold room maintained at the temperature of about 0°C. The concentration of CO_2 in the chamber was measured automatically by gas chromatography (Shimadzu, GC-14A) with automatic gas sample injector (GL Sciences, GS-5000A). TCD was used for gas analysis with a column of WG-100 (GL Sciences).

Material Spinach was used as the sample because of its high respiratory activity without climacteric pattern. It was obtained from the packaging house in Tochigi. After 24 hours of transportation to the laboratory of the University of Tokyo in low temperature condition, it was placed in a cold room maintained at the temperature of about 1°C for a few hours until the experiment was started.

Method Spinach was kept under the condition that temperature changed alternately at low and high levels every 4 hours as shown in Table 1. The low-high level temperature combination was set in 1-10 ℃, 1-20 ℃ and 1-30 ℃. Spinach of about 1kg in mass was used for each experimental run. It was placed in the airtight chamber, and CO_2

Table 1 Set temperature in each experimental run

Exp. Run	0-4h	4-8h	8-12h	12-16h	16-20h
1-10°C	1°C	10°C	1°C	10°C	1°C
1-20°C	1°C	20°C	1°C	20°C	1°C
1-30°C	1°C	30°C	1°C	30°C	1°C

concentration in the chamber was measured every 15 minutes. The evolution rate of CO_2 was calculated from its concentration change, basing on the mass of spinach and the volume of free space in the chamber. Average temperature of leaves were measured by using thermocouples every 15 minutes. When the temperature was changed from high level to low level, the ventilation of the chamber was performed to remove the accumulated CO_2 in the chamber so that the CO_2 evolution rate could be measured in the close to gaseous components of atmospheric condition.

RESULTS AND DISCUSSION

Fig. 1 shows the changes in average temperature of leaves and CO_2 evolution rate. In all experimental runs, the CO_2 evolution rate followed closely the temperature change. Fig. 2 shows the relationship between the CO_2 evolution rate and its concentration, by being grouped in each temperature combination. In all experimental runs, the plots of CO_2 evolution rate were shown except the values in transient stages illustrated in Fig. 1 so that the effect

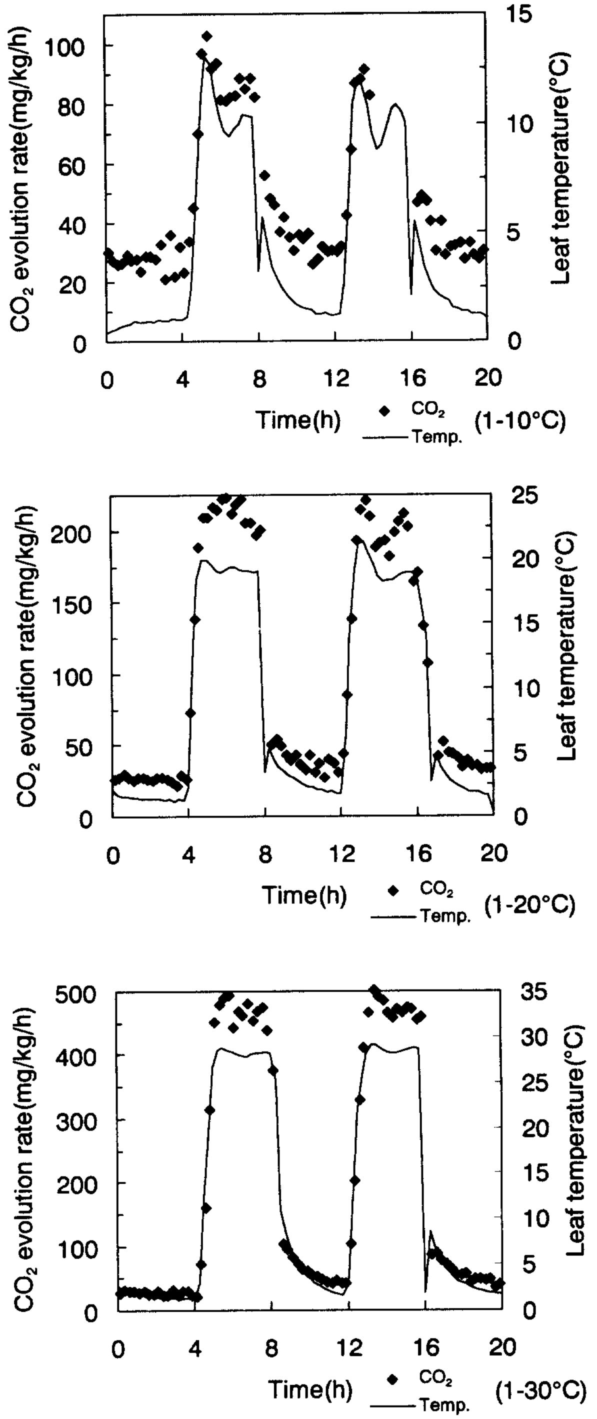

Fig. 1 Changes in leaf temperature and CO_2 evolution rate

of CO_2 concentration on its evolution rate could be observed. It was recognized from Fig. 2 that CO_2 concentration of about 1% did not affect the CO_2 evolution rate in contrast to the temperature effect on the CO_2 evolution rate seen Fig. 1. Since the CO_2 evolution rate was thus found to be expressed as a function of temperature in this experimental condition, the Arrhenius law, which is presented as follows, was applied to the experimental data.

$$\text{rate} \approx Z(T)\exp(-E_a/RT)$$

where Z(T) is the collision frequency, E_a is the activation energy, R is the gas constant and T is absolute temperature. The collision frequency varies with temperature, but its variation is normally dominated by the exponential value of temperature as described by Atokins (1982) and Nobel (1991). The logarithmic values of CO_2 evolution rate were plotted against reciprocal of absolute temperature as shown in Fig. 3. In the range up to $0.00355K^{-1}$ (9°C), a linear relationship was recognized to exist essentially between them, although some scattering in the plots were observed. In the range over around $0.00355K^{-1}$, some logarithmic values of CO_2

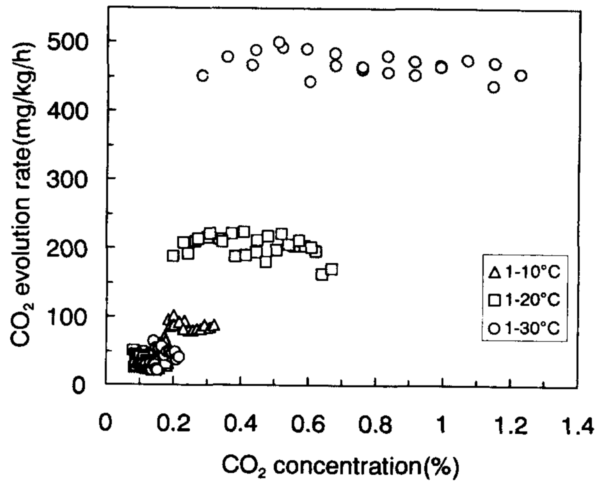

Fig. 2 Relation between CO_2 concentration in chamber and CO_2 evolution rate of spinach

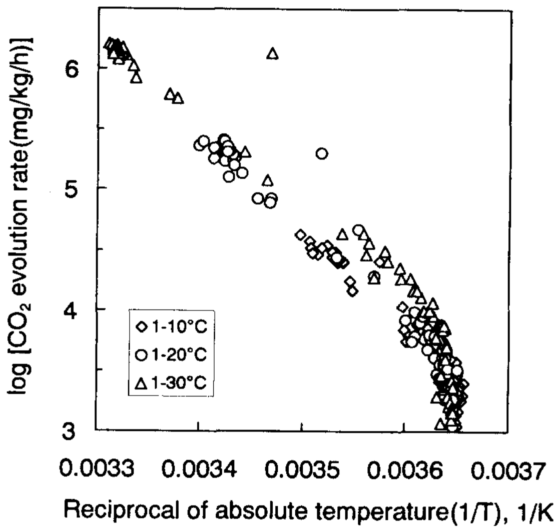

Fig. 3 Temperature dependency of CO_2 evolution rate in all experimental runs

evolution rate decreased steeply as the reciprocal of absolute temperature increased, i.e., the temperature decreased. In this regard, Ito et al. (1985) reported same pattern, i.e., under constant rate of falling temperature from 12°C to 2°C, the CO_2 evolution rate decreased slowly in the half period of falling temperature and then quickly in the later half.

In Fig. 4, plots of CO_2 evolution rate were connected by the time series line to show the temperature dependency in each experimental run so that a non-liner relationship could be examined. As shown in Fig. 4, it can be concluded from the temperature combinations of 1-10°C and 1-20°C that the relationship between CO_2 evolution rate and temperature was followed by a pattern of Arrhenius law, although a non-liner relationship was observed in the range near $0.00365K^{-1}$. In case of temperature combination of 1-30°C, however, it was observed that the logarithmic values of CO_2 evolution rate shifted towards higher and decreased steeply as the reciprocal of absolute temperature increased at around $0.00365K^{-1}$. It was also found that once spinach was kept at the temperature of 30°C, the CO_2 evolution rate did not change according to the Arrhenius law. From these results, the change in the CO_2 evolution rate of spinach was found to obey the Arrhenius law at ambient temperature levels less than 20°C, but it showed some deviation from this law at the temperature range of 30°C. This study indicated that the respiration rate could not be

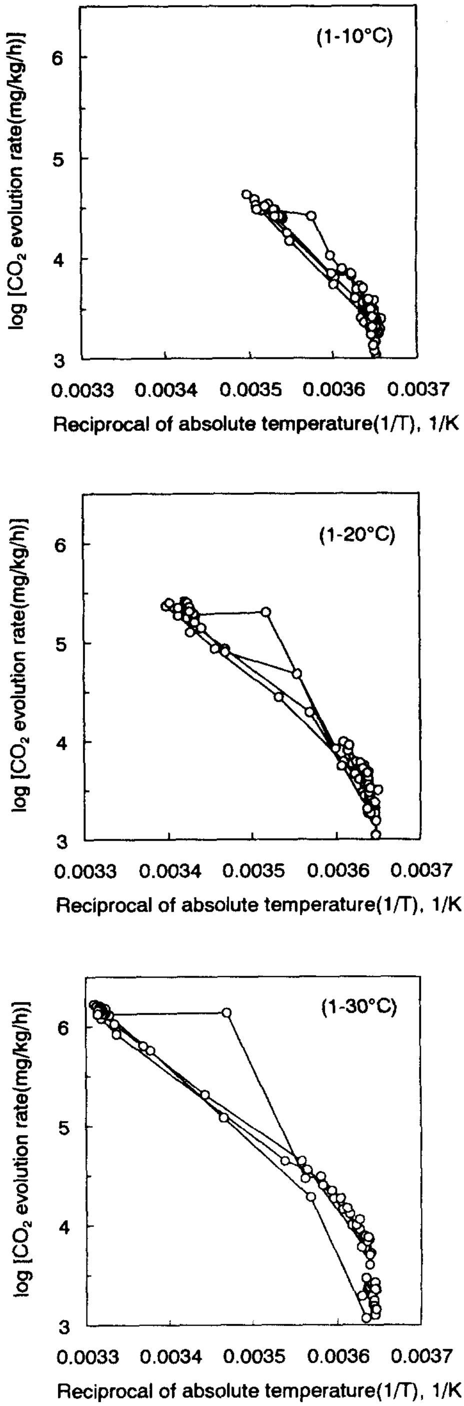

Fig. 4 Temperature dependency of CO_2 evolution rate in each experimental run

explained by Arrhenius law at the temperature of 30°C. It should be important to further examine the non-liner relationship between respiration rate and temperature in the temperature combination of 0-30°C. This will be contribute to analyze the respiratory metabolism of vegetables and fruits exposed to fluctuating temperature.

CONCLUSIONS

1) When spinach was kept under rectangle of fluctuating temperature, the CO_2 evolution rate followed increased or decreased gradually in direct relation with the temperature.
2) The evolution rate of CO_2 was not affected by its concentration level of about 1%.
3) In case of under 20°C, it may be concluded that the relationship between CO_2 evolution rate and temperature was expressed as in Arrhenius law.
4) Once spinach was kept at the temperature of 30°C, the CO_2 evolution rate did not change according to the Arrhenius law.

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