Physiological Function of Ethylene and Low Pressure Storage of Apple

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Ethylene is one of the phytohormones, such as auxin, gibberellin, cytokinin and abscisic acid. It plays an important role for plant growth and development. Particularly, ethylene is known to be involved in various growth phenomena of plants (Table 1).

Table 1. Physiological functions of ethylene

Breaking dormancy
Growth inhibition or promotion
Swelling
Epinasty
Floral induction
Rooting
Ripening
Abscission

A function to promote fruit ripening is one of the most important activities of ethylene. It has been reported that ethylene acts as a trigger for promoting fruit-ripening process. This function is already utilized as a practical technique in Japan. As an example green pre-mature bananas are imported, and treated with ethylene to induce yellow ripening for marketing.

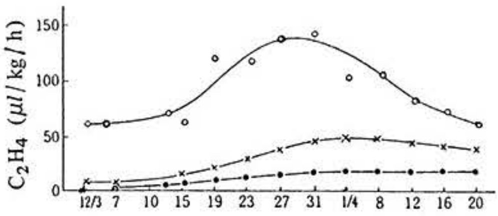

Fig. 1. Ethylene production in fruit of different varieties of apple during storage (15°C)

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This function of promoting ripening, however, induces promoted senescence for fruits after harvest. It is an undesirable function for long-term storage of fruits. Fig. 1 shows production of ethylene in apple fruit in storage. Fruit of a variety, Indo, which produced a large amount of ethylene, is less durable, while those of Fuji and Ralls Janet, which produced less ethylene can be stored for longer duration. This finding suggests that the problem of how to suppress ethylene production may be a key point in apple storage.

Storage condition and production of ethylene

As for apple storage, so-called CA (Controlled atmosphere) storage has already been practiced widely. In brief, the CA storage is to store fruits under the condition of low temperature, low oxygen tension, and high carbon-dioxide concentration. Therefore, we examined the effect of such a condition on ethylene production. The experiment was carried out as follows: At first, each lot of 4–6 apples was placed in a desiccator,

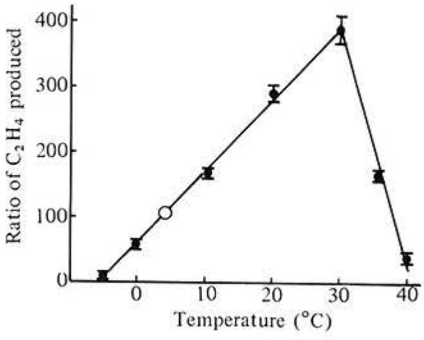

Fig. 2. Effect of temperature on ethylene production of apple during storage
(Value at 4°C is taken as 100).

and ethylene production was measured in the air at 4°C. Then, it was placed under a different condition with different temperature and concentration of O_2 and CO_2. In the next day, the desiccator at each condition was sealed, and accumulated ethylene was measured again 3 hr later. The amount of ethylene produced was expressed by taking the initial ethylene production measured at 4°C as 100.

The ethylene production of apple was the highest at ca. 30°C, and it decreased with decreasing temperature within a range of 30∼−5°C. However, it was inhibited at the temperature higher than 30°C (Fig. 2).

The ethylene production was reduced by decreased O_2 concentration, particularly it was markedly inhibited at the O_2 concentration lower than 2.5%. On the contrary, it was inhibited by higher concentration of CO_2 (Fig. 3).

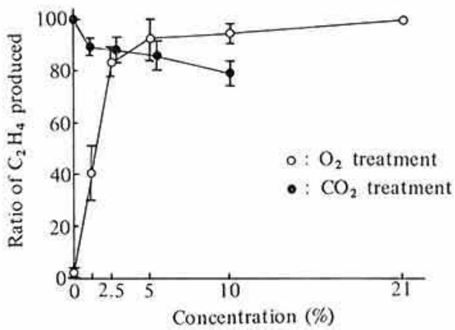

Fig. 3. Effect of O_2 or CO_2 concentration on ethylene production of apple
(Value at 21% O_2 or 0% CO_2 is taken as 100).

The CA storage technology was developed before the function of ethylene has come to be known. It is interesting that each of low temperature, low O_2 and high CO_2 tension, constituting the condition of CA storage, is inhibitive to ethylene production of fruits.

Burg et al.[2] demonstrated a method of fruit storage under reduced atmospheric pressure which can remove ethylene produced by fruits. Ethylene concentration in fruit is reduced in parallel to the reduced pressure of air surrounding the fruits.

Ethylene production was compared under different degree of evacuation. At the air pressure lower than 95 mmHg (1/8 of atmospheric pressure) ethylene production was markedly inhibited (Fig. 4). The curve of Fig. 4 is quite similar to the curve showing the effect of O_2 tension in Fig. 3. This fact suggests that the reduced air pressure results in a deficiency of O_2, which gives an inhibiting effect similar to that of reduced O_2 tension on ethylene production.

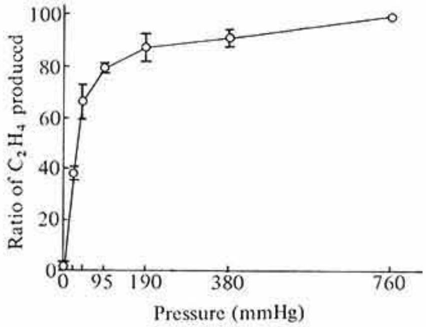

Fig. 4. Effect of low air pressure on ethylene production of apple
(Value at 760 mmHg is taken as 100)

The deficiency of O_2 occurring under the evacuation causes anaerobic respiration of fruits, and ethyl alcohol accumulates in the fruits. In addition, decrease of fruit weight is accelerated by evaporation under evacuation (Table 2).

Table 2. Accumulation of ethyl alcohol and weight loss occurred during the storage under different air pressures

Treatment mmHg	C_2H_5OH mg/100 m*l* juice	Weight loss %
760	8.08 ± 4.58	0.00
380	8.88 ± 0.62	0.61
100	9.71 ± 1.09	0.44
60	19.4 ± 0.95	0.81
0	42.2 ± 7.78	3.14
in N_2	34.6 ± 8.88	0.04

Apples were stored for 7 days at 4°C.

Therefore, it is necessary to supply fresh air continuously during the storage under reduced air pressure in order to keep normal respiration of fruits. To alleviate the weight loss of fruits, the fresh air to be used should be saturated or nearly saturated with moisture.

Low pressure storage of apples

Experiments on the low pressure storage

Table 3. Qualities of apples after five months of LPS (1976)

Treatment mmHg	Weight loss %	Firmness kg	Brix %	Acidity 0.1 N NaOH ml/10 ml juice	Acidity %	Ratio of browning apples %
725	1.30	6.1	12.5	1.2	(100)	47
160	1.30	6.0	12.5	1.2	(100)	33
80	0.72	6.0	12.5	1.9	(158)	0
40	2.14	6.2	13.1	2.4	(200)	0

(LPS) of apples (cultivar: Fuji) were conducted in 1976–1978. The storage conditions in 1976 were 725 mmHg (control plot), 160 mmHg (ca. 1/5 of atmospheric pressure), 80 mmHg (ca. 1/10), and 40 mmHg (ca. 1/20) of air pressure at 5°C. After the start of storage, sampling was made monthly to determine fruit quality.

The fruit quality after 5 months of LPS is shown in Table 3. From the table, it can be noted that the fruit are characterized by high acidity. The acidity was gradually decreased during the storage, but the fruit stored at 40 and 80 mmHg showed a less reduction of acidity (Fig. 5).

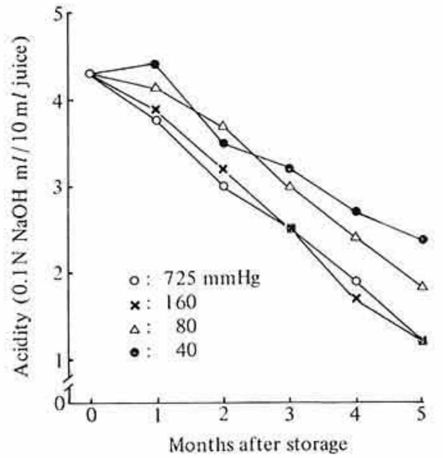

Fig. 5. Decrease of acidity in the apples stored in different air pressures (1976)

Some fruit stored at 725 and 160 mmHg showed the browning of core in a later stage of storage, but this damage did not occur at 40 and 80 mmHg. Of 3 years of experiment, there was a year without the occurrence of the browing.

As a result of the experiments in 3 years, it was confirmed that the lowering of acidity can effectively be suppressed by storing in low air pressure of about 1/10 of the atmospheric pressure.

Ethylene production and respiration of apples after LPS

In the 1978 experiment, ethylene production and rate of respiration of apples were measured at 30°C, after the end of LPS. The results are shown in Table 4 and Fig. 6. The fruit which had been stored at 725 mmHg (control plot) produced a large amount of ethylene particularly after 2 and 4 months of storage. They were not able to be stored for 8 months so that data after 8-month-storage are not available. On the contrary, the fruit stored at 60 mmHg showed a marked reduction in ethylene production. The

Table 4. Ethylene production and respiration of apples after LPS

	Treatment (mmHg)	Storage duration (month) 0.5	1	2	4	8
C_2H_4 μl/kg/day	725	170	196	738	804	
	60	4.68 (2.8)	4.50 (2.3)	2.97 (0.4)	2.01 (0.3)	1.07
CO_2 ml/kg/day	725	402	401	468	471	
	60	275 (68)	230 (57)	282 (60)	285 (61)	302
O_2 ml/kg/day	725	359	398	474	441	
	60	266 (74)	242 (61)	246 (52)	276 (63)	216

Ethylene production and respiration of apples were measured at 30°C.
Figures in parenthesis indicate % to 725 mmHg plot.

longer the storage period, the more was the reduction. In addition, they showed a low rate of respiration. Both O_2-absorption and CO_2-evolution were about 2/3 those of the control plot (Table 4). These retardations in ethylene production and respiration lasted for at least 7 days after the end of the storage (Fig. 6).

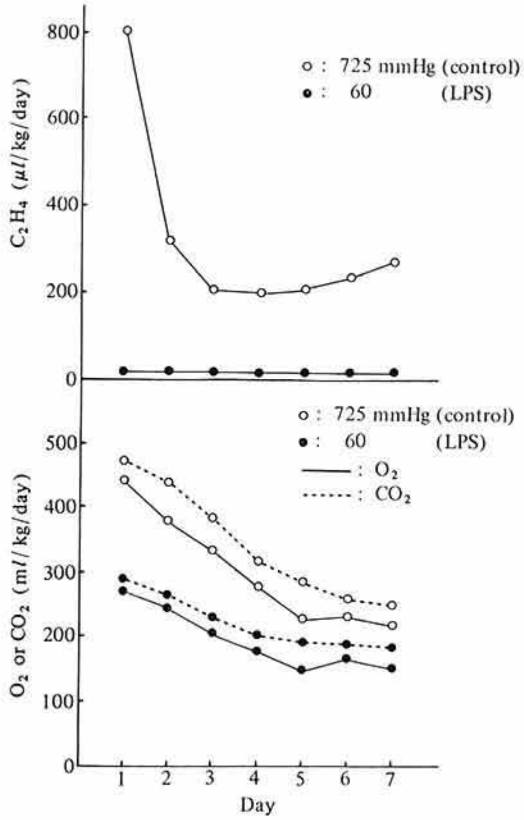

Fig. 6. Ethylene production and respiration of apples after stored for 4 months by LPS. Measurements were made at 30°C.

Physiological functions of ethylene were reviewed by Abeles,[1] and the LPS first developed by Burg[2] has already been employed for a variety of fruits, flowers and vegetables.[3] In the present paper, the role of ethylene in storage and the effectiveness of LPS are presented on the basis of our experiments using apples.[4] The result of our experiments clearly showed that the LPS is very effective in reducing ethylene production and respiration of fruit not only during the storage period but also after the storage. As the principle of storage is to prevent fruits from the exhaustion caused by respiration, it can be said that the LPS is an excellent storage method in this point of view.

References

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