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Changes in Respiration, Ethylene Formation and Quality of Imported Kiwi Fruit

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Abstract

Kiwi fruit (*Actinidia chinensis* Planch.cv.Hayward) was imported from New Zealand and then the fruit was stored at 20°C. In order to estimate their quality and physiological phase, we measured specific gravity, moisture, sugar, AIS, starch, free amino acids, pH and refractometer index of juice, titratable acidity, sugar/acid ratio, flesh firmness, Hunter L, a and b values of flesh, carbon dioxide production and ethylene evolution by whole fruit, 1-aminocyclopropane-1-carboxylic acid (ACC), and the activities of ethylene forming enzyme (EFE) and ACC synthase with the fruit stored at 20°C. Ethylene effect on the biosynthesis system of ethylene was also examined.

The results of chemical and physiological analyses have shown that the fruit imported has reached near to ripe stage. A marked change was observed for ethylene evolution and flesh firmness in the series of determination of the fruit during storage at 20°C. The ethylene evolution exhibited a peak as seen in climacteric, and the firmness of flesh gradually decreased during the storage. The ethylene treatment in the concentration of 10 ppm induced the increases of EFE activity and ACC content, within 24 hours of the treatment in the former and within 3 days in the latter. It was recongnized that, even in the kiwifruit ripened during low temperature storage, ethylene affected part of biochemical processes. Therefore, the inclusion of ethylene absorbent in packaging with polyethylene bags or polybutadiene bags (0.03 mm thickness) delayed softening and extended the shelflife of the fruit.

Introduction

The Chinese gooseberry (*Actinidia chinensis* Planch.) is a native to China and has been developed in New Zealand since it was introduced to the country, and the fruit is named kiwi fruit. Kiwi vine is now cultivated in many parts of world and the fruit is developing as a commercially important one. In Japan, kiwi has been introduced from New Zealand as a substitutive fruit for citrus unshiu, then it has passed a decade more and the production of kiwi fruit is increasing every year, and the production in the 1986 season mounted up to 28,300 tons. On the other hand, the amount imported in 1986 was 35,268 tons[1)]. It is expected that the amounts of both of production and import of kiwi fruit will increase further. The amount imported from New Zealand may increase steadily because the season of production in year is opposite to Japan and marketing of the fruit will be not compete each other. Kiwifruit is a sub-tropical fruit and exhibits a climacteric[2)]. Compositional and physiological changes during the development of kiwi fruit and after harvest has been investigated by many workers[2-8)].

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In this paper, we studied on changes in respiration, ethylene formation, and some compositions of imported kiwi fruit for obtaining information to keep their quality better after imported.

Materials and Methods

Kiwi fruit cv. 'Hayward' grown in New Zealand was harvested in April in 1985 and stored at 0 ± 1°C for about 6 months. They were taken out from the store on October 11, held for 12 hours at ambient temperature (about 25°C), and shipped on October 12 to Yokohama, Japan. They were kept at 0.5 ± 0.5°C during the shipment and landed on November 9, then transported to our laboratory under ambient temperature (15 ~ 20°C) on November 12, reaching about a month after taking out in New Zealand and experimental treatments were undertaken next day. Kiwi fruit, placed in pockets in a plastic tray covered within a sheet of thin polyethylene film in a wooden case, was stored at 20°C. Average weight of fruit was about 97 g. Carbon dioxide production and ethylene evolution of the fruit were measured according to the routine methods as described in the manual[9]. Refractometer index and pH value of fruit juice were measured with refractometer and glass electrode pH meter, respectively. Titratable acidity was determined by the titration of water extracts with 0.1N NaOH to pH 8.1 and was expressed as percent citric acid. The contents of reducing and non-reducing sugars were determined with ethanolic extracts by the use of SOMOGYI-NELSON reagent[9]. Alcohol insoluble substances (AIS) were also determined and starch was analysed with HCl-hydrolysate of AIS[9]. Content of free amino acid was determined with ethanolic extracts by the use of ninhydrin reagent[9] and the ninhydrin positive substance was expressed as percent glutamic acid. The color of outer pericarp tissue was determined with the Minolta color difference meter (model CR-100) and was expressed as Hunter L, a, and b values. Specific gravity of the fruit and moisture content of the tissue were also measured.

The content of 1-aminocyclopropane-1-carboxylic acid (ACC) was determined according to the method described by LIZADA and YANG[10], and the activity of ACC synthase was measured by the method of ADAMS and YANG[11]. The activity of ethylene forming enzyme (EFE) was shown by the capacity of coverting added ACC to ethylene by tissue slices (outer and inner pericarp). Tissue slices (approx. 5 X 5 X 2 mm, 3 g) were placed in a 100 ml Erlenmeyer flask containing 10 ml of 100 mM phosphate buffer (pH 6.0), 200 mM sucrose, and 0.2 mM ACC (not contained in control). The flasks were sealed with silicon rubber caps and kept at 30°C. Aliqouts of the headspace gas in the flask were assayed for produced ethylene by gas chromatography. The effect of 10 ppm ethylene treatment on the biosynthesis of ethylene of kiwi fruit used in this experiment was also examined.

The use of polyethylene bags, or polybutadiene bags (0.03 mm thickness) and ethylene absorbent was examined to extend the shelf life of the fruit.

Results and Discussion

Quality changes Kiwifruit used in this experiment has been stored for about six months after harvest at low temperature before shipping to Japan. During this period, the maturity of the fruit has proceeded close to eating quality as described by

MANAGO[12] and TANAKA[13]. This is noted by the initial values of refractometer index, starch content and sugar content as shown in Fig. 1 and 2, although acid content was somewhat high showing lower sugar/acid ratio than that above 15 for excellent-eating quality of 'Hayward' fruit as reported by TANAKA[13] (Fig. 3 and 4). The contents of non-reducing sugar, titratable acid, and free amino acids decreased slightly during storage at 20°C (Fig. 1 and 3). The reduction of acidity was reflected in a slight increase of pH values in juice of the fruit during storage. Changes in values of Hunter L, a, and b may

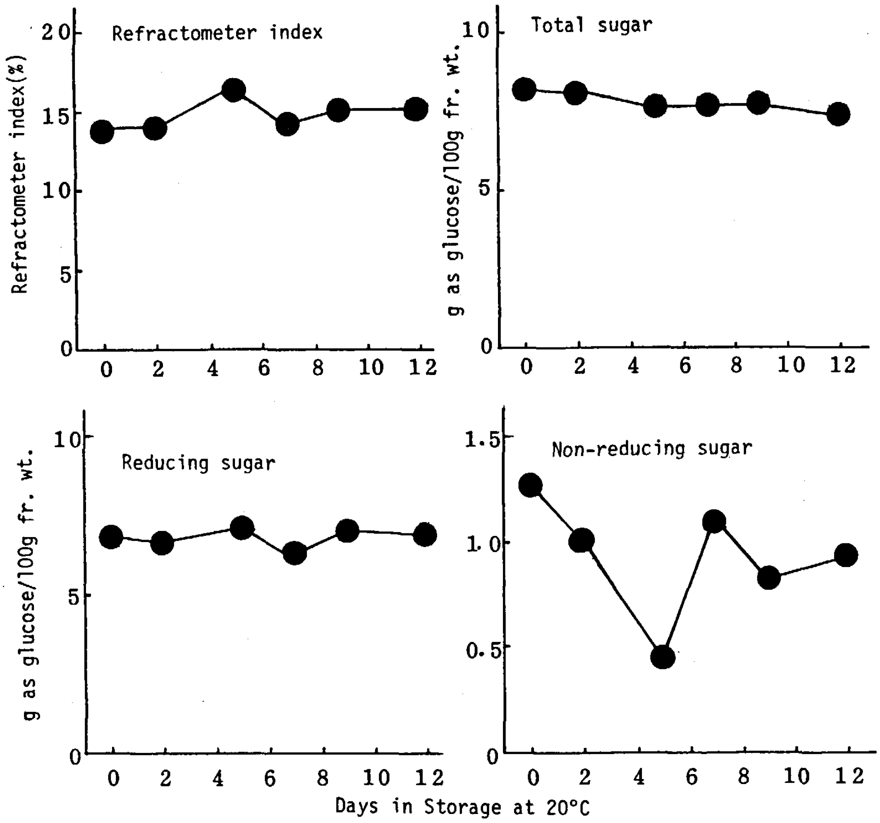

Fig. 1 Changes in refractometer index and sugars content of imported kiwi fruit during storage at 20°C

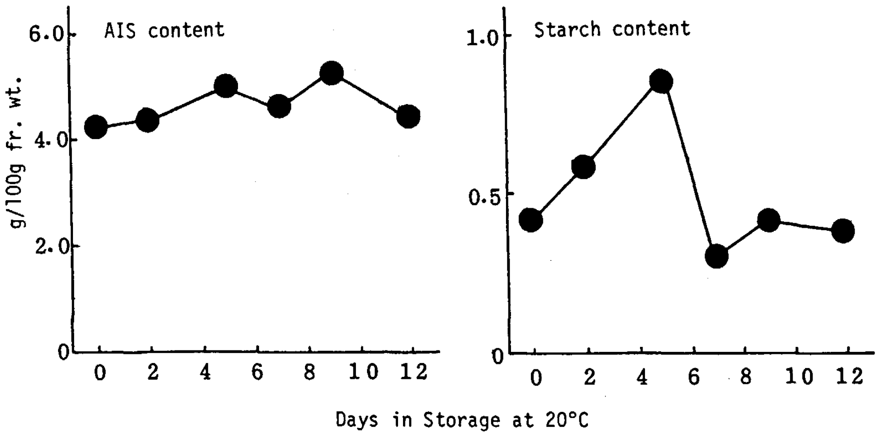

Fig. 2 Changes in the content of AIS and starch of imported kiwi fruit during storage at 20°C

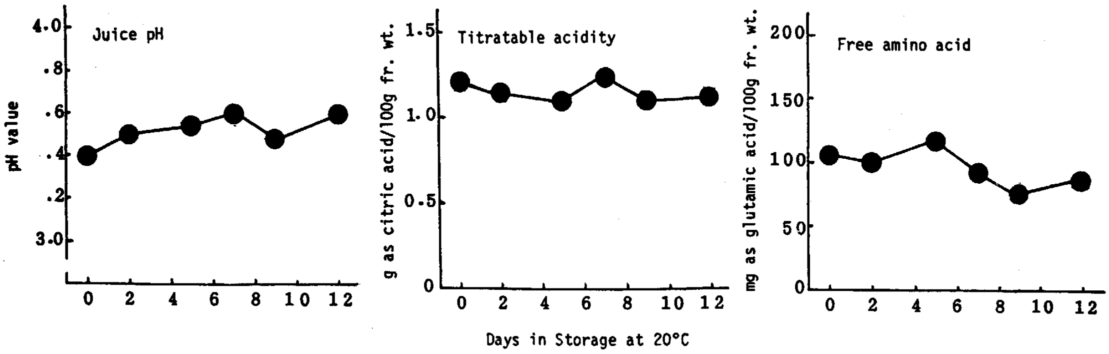

Fig. 3 Changes in pH of juice, titratable acidity, and amino acids content of imported kiwi fruit during storage at 20°C

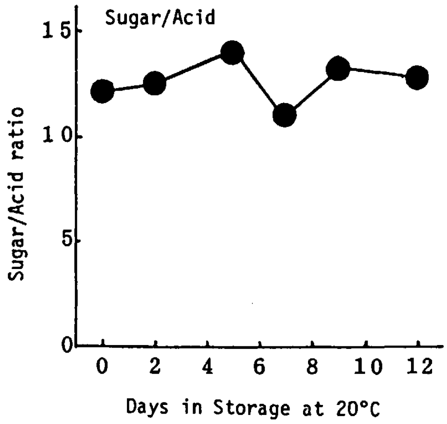

Fig. 4 Changes in sugar to acid ratios in imported kiwi fruit during storage at 20°C

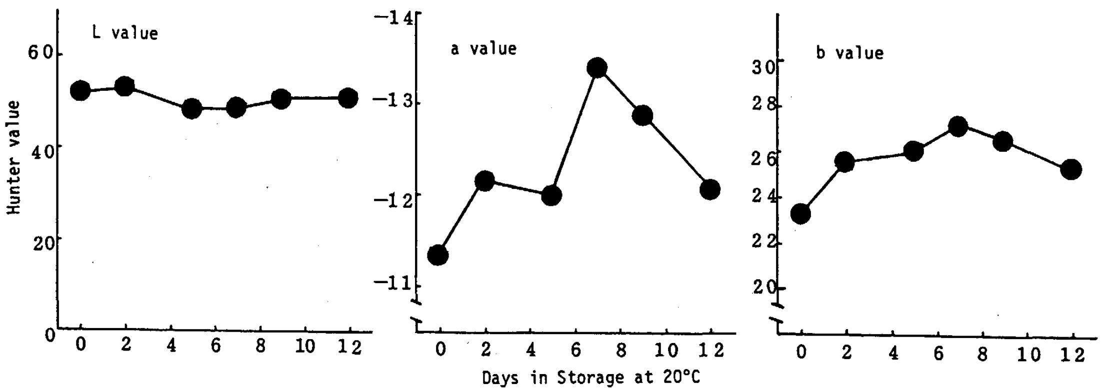

Fig. 5 Changes in Hunter values of flesh of imported kiwi fruit during storage at 20°C

express the color change of flesh of the fruit during storage (Fig. 5), but there was almost no difference among samples with visual observation, except slight darkening and being transparent of the flesh around the end of the storage which the fruit became over-ripe. The lowering of curdmeter readings exhibits further softening of the flesh of the fruit during storage (Fig. 6). The moisture content seems to decrease slightly during storage, while specific gravity lowered somewhat at the end of storage (Fig. 7). The lowering of specific gravity might depend on the accumulation of carbon dioxide produced in the

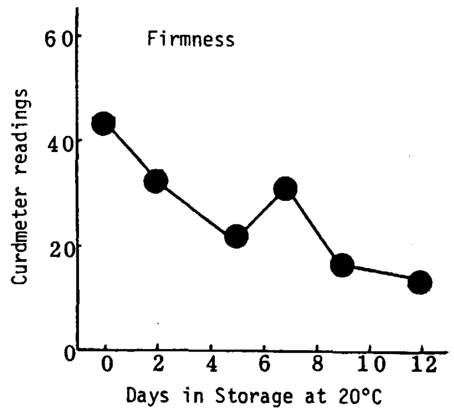

Fig. 6 Changes in firmness of imported kiwi fruit during storage at 20°C

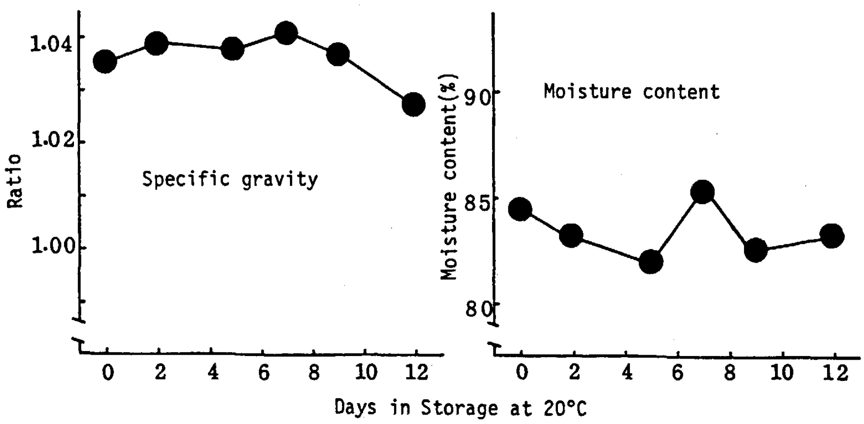

Fig. 7 Specific gravity and moisture content of imported kiwi fruit stored at 20°C

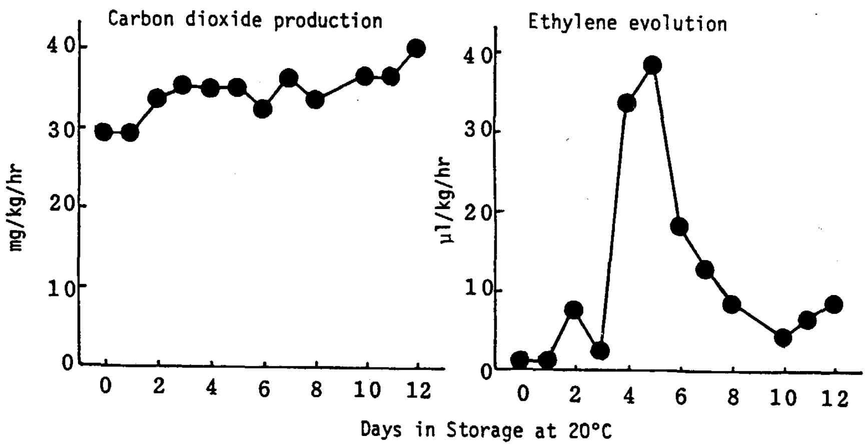

Fig. 8 Carbon dioxide production and ethylene evolution by imported kiwi fruit stored at 20°C

tissue of over-ripe fruit (see Fig. 8). Overall, the fruit stored for about a week at 20°C was favorable for eating.

Carbon dioxide production and ethylene evolution PRATT and REID[2] reported that kiwi fruit is one of climacteric type but, although associated with a peak of ethylene production, the respiratory pattern was atypical, and they also showed that ethylene treatment stimulated ripening in fruits of all ages tested. The imported kiwi fruit tested in this study has already reached around ripe stage. However, the fruit showed a typical peak of ethylene evolution with a slight increase of carbon dioxide production during storage. The carbon dioxide production showed a continuous increase thereafter (Fig. 8). The results suggest that an unbalanced suppression of the metabolism occurred in the fruit by low temperature storage.

ACC content and activities of enzymes related to ethylene formation In this experiment, we examined whether the fruit tested responds to ethylene, or not, to see the ripening stage of the fruit. A group of fruit was treated with 10 ppm ethylene at 20°C. The effects were observed on ACC content, and the activities of ACC synthase and EFE. Fig. 9 shows the effects on these items during the first 24 hours of the ethylene treatment. It appears that ACC content was drifting and the activity of ACC synthase was too low to estimate the ethylene effect as reported by HYODO and FUKASAWA[14]. On the other hand, the EFE activity showed a trend to increase following several hours of the treatment. The activation of EFE was greatly enhanced when the treatment was continued for 2–3 days and ACC content also increased during the time, but the activity of ACC synthase did not (Fig. 10). Control samples in the Fig. 10 showed a little changes in both ACC content and EFE activity and the latter trended to increase slowly, and ACC synthase activity in control samples was also very low.

Thus, the ripening stage of imported kiwi fruit used in this experiment has already proceeded at the initial time of the experiment, but they temporarily produced a relatively large amount of ethylene during storage at 20°C as that in climacteric and also showed a response to ethylene as shown in the results of ACC increase and EFE activation. However, we could not estimate from the above results whether ethylene affected the quality of the fruit, or not. Then, we examined the effect of ethylene absorbent on the quality of the fruit packaged with plastic bags.

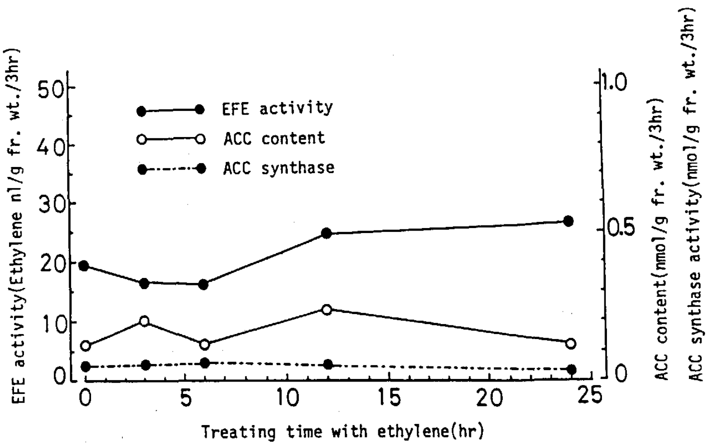

Fig. 9 Effects of 10 ppm ethylene treatment on ACC content and activities of ethylene forming enzyme (EFE) and ACC synthase of imported kiwi fruit (the treatment was performed for 24 hours at 20°C)

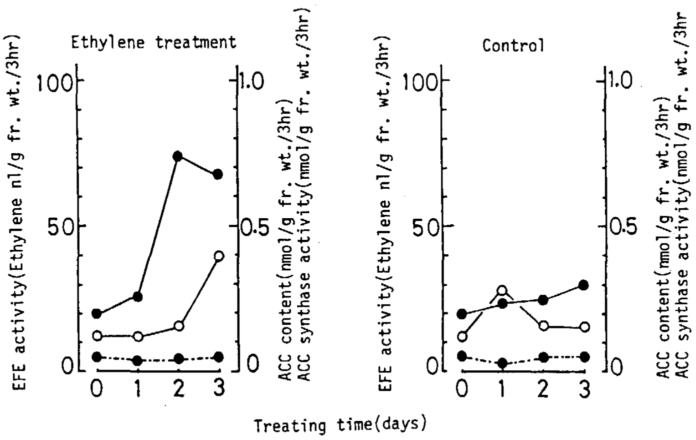

Fig. 10 Effects of 10 ppm ethylene treatment on ACC content and activities of ethylene forming enzyme (EFE) and ACC synthase of imported kiwi fruit (the treatment was performed for 3 days at 20°C). Symbols are shown in Fig. 9.

Effect of ethylene absorbent on fruit quality Five fruits were packaged with two kinds of plastic bags, low density polyethylene bags and polybutadiene bags, with or without an ethylene absorbent, and they were kept at 20°C. Each test was duplicated. The inclusion of ethylene absorbent in packaging with both of plastic bags delayed softening and maintained the quality of the fruit better as reported by SCOTT *et al.*[15] Kiwi fruit is very sensitive to ethylene. ARPAIA *et al.*[16] have reported that even very low concentration at ppb levels of ethylene in CA storage of Kiwi fruit enhanced softening of the fruit and induced white inclusions in the core. Then, ethylene absorbent can be used to keep the quality better in kiwifruit which its ripening stage relatively advanced.

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