Kasetsart J. (Nat. Sci.) Vol. 19 : 145—150 (2528)

Effect of CO_2 and Temperature on Postharvest Quality Changes of Broccoli[1]

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ABSTRACT

Chiang Mai-grown broccoli was bought and shipped to Bangkok by truck within 30 hours. Broccoli was stored at 3 temperatures; room temperature (31° C), 1° and 4° C under the following conditions: plastic basket, unsealed plastic bag and sealed plastic bag without and with adding 10% CO_2. Storage life of broccoli held in sealed plastic bags with initial 10% CO_2 at 1° and 4° C could be extended up to 28 days and broccoli still remained green and fresh like newly harvested vegetable and it could be stored further. It is therefore strongly recommended that broccoli be stored at 4° - 5° C in plastic bags with initial 10% CO_2.

INTRODUCTION

Broccoli is an important commodity of Highland Agricultural Project and hilltribe people can make money from growing this opium substituted crop. Postharvest quality of broccoli has been a great problem because under normal atmospheric conditions, broccoli will turn yellow within 2 to 3 days after harvest at temperature of 25° C or higher (Kosiyachinda and Ketsa, 1981). It is the floral organ plus stem or tender stalk which are harvested and consumed. They should be bluish green in color, mild in flavor and free of fiber. This is a very transient condition during the normal development of the broccoli head, which can rapidly become commercially unsalable if the bud scales turn yellow, some buds open and show yellow flower petals, or buds become wilted and the stalk is tough, or unpleasant odors develop as occasionally happens with closed shipments (Morris and Kader, 1977; Ryall and Lipton, 1972).

Smith (1940) reported that 10% CO_2 retarded yellowing and extended the shelf-life of broccoli by 1 - 2 weeks at 0 ° C. but 15% CO_2 induced an abnormal odor. Lieberman and Hardenburg (1954) found that yellowing of broccoli during 3 days at 24° C was inhibited by an O_2-free system and was retarded under 1% CO_2 or 7 to 22% CO_2 + 10 to 21% CO_2. Lieberman *et al.* (1968) found that respiration rate of broccoli was reduced by increased CO_2 and decreased O_2. Visual color and chlorophyll retention were improved by progressive increase in CO_2 to 20% and decrease in O_2 to 2%. Lipton and Harris (1973) reported that low O_2 (1% or lower) or 10% CO_2 + 21% O_2 inhibited yellowing of broccoli florets during storage at 5° or 7.5° C. Off-flavor upon cooking was noticed only in curds previously held at $\frac{1}{4}$ to $\frac{1}{10}$% O_2. Recently, Kosiyachinda and Ketsa (1981) reported that broccoli in sealed plastic bag with initial 10% CO_2 gave the best result at keeping temperature of 5° C, but higher CO_2 concentrations at higher temperatures produced off-odor and off-flavor.

This paper reports how CO_2 affected nutritional value and visual quality of broccoli stored under modified atmosphere at different temperatures.

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1 Financially supported by ARS, USDA contract *No* 53 - 32 - Rb - 3 - 208

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MATERIALS AND METHODS

Plant Materials. Freshly harvested broccoli (*Brassica oleracea* var. italica cv. Mikado) from Sarapee, Chiang Mai was shipped by truck to Bangkok within 30 hours. Upon arrival only high-quality broccoli was selected for the study. One to two cm. of stems of broccoli were cut off and the cut surface was smeared with lime paste. After trimming, each head of broccoli consisted of 8 – 10 inches of stem and 3 to 4 jacket leaves.

Experimental Procedures. Broccoli was kept in the following conditions : (1) plastic basket without cover, (2) unsealed plastic bag, (3) sealed plastic bag and (4) sealed plastic bag with initial 10% CO_2.

Three heads of broccoli were placed in each plastic basket or plastic bag of 14 × 22 inches and 2 mil thick. Broccoli was stored at 3 temperatures : room temperature (31°C and 72% RH), 1° C (82% RH) and 4° C (82% RH). Each treatment was done in 3 replications.

Chlorophyll content of florets was analyzed by the method of Witham *et al* (1971) and vitamin C content of stem tissue and florets was analyzed separately by the method described in Rangana (1978).

All experiments were carried out during January – February, 1982 at Postharvest Horticulture Laboratory, Department of Horticulture, Kasetsart University, Bangkok.

RESULTS

Chlorophyll content. At room temperature (31° C and 72% RH), chlorophyll content of broccoli in plastic basket and unsealed plastic bag was reduced from 32.4 to 11.6 and 18.8 mg/100 gm fresh weight (fr.wt.) after 4-day storage, respectively (Fig. 1a). All florets became yellow. Broccoli in sealed plastic bags without and with adding 10% CO_2 had chlorophyll content reduced to 16.7 and 27.7 mg/100 gm fr.wt. after 2-day storage.

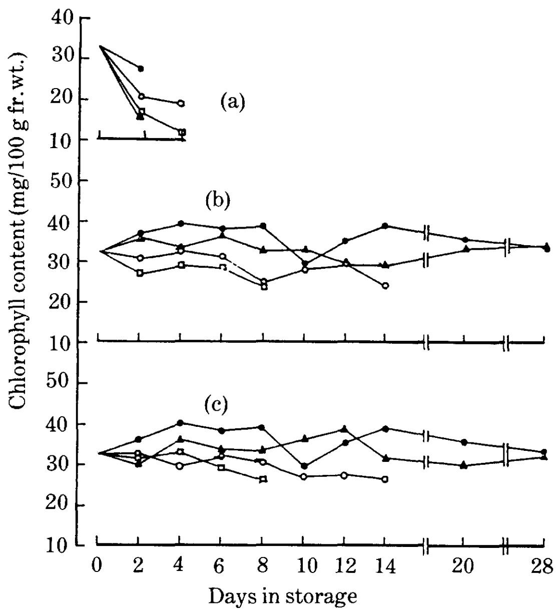

Figure 1. Changes of chlorophyll content of broccoli held at room temperature (a), 1° C (b), and 4° C (c) in plastic basket (□), unsealed plastic bag (○), sealed plastic bag (△), and sealed plastic bag with initial 10% CO_2(●).

However, cut surface of broccoli began to show soft rot infection and off-odor.

At 1° C (Fig. 1b), broccoli in plastic basket had chlorophyll content reduced slowly from 32.4 to 23.3 mg/100 gm fr.wt. after 8-day storage and its marketability was terminated. While broccoli in unsealed plastic bag had chlorophyll content reduced from 32.4 to 24.0 gm/100 gm fr.wt. after 14-day storage and all florets became yellow. Broccoli in sealed plastic bag without and with adding 10% CO_2 still had very high chlorophyll content, 33.8 and 33.0 mg/100 gm fr.wt. after 28-day storage, respectively. All broccoli still remained green and fresh.

At 4° C (Fig. 1c), broccoli in plastic basket and unsealed plastic bag had chlorophyll content reduced to the same extent, from 32.4 to 26.1 mg/100 gm fr.wt. after 8- and 14-day storage. All broccoli in plastic basket and unsealed plastic bag became yellow after 8-

and 14-day storage, respectively. The vegetable in sealed plastic bag without and with adding 10% CO_2 had rather high chlorophyll content; 32.0 and 32.5 mg/100 gm fr.wt. after 28-day storage respectively. All broccoli still remained green and fresh.

Vitamin C content. At room temperature (Fig. 2a), broccoli in plastic basket and unsealed plastic bag had vitamin C content in flower stalk reduced from 122.3 to 61.1 and 64.9 mg/100 gm fr.wt. after 2-day storage, and reduced to 40.0 and 42.0 mg/100 gm fr.wt. after 4-day storage. Broccoli in sealed plastic bag without and with adding 10% CO_2 had vitamin C content in flower stalk reduced from 122.3 to 66.7 and 62.3 mg/100 gm.fr.wt. after 2-day storage, respectively and could not be kept longer.

At 1° C (Fig. 2b), the vegetable in plastic basket had vitamin C content in flower stalk reduced from 122.3 to 92.7 and 63.4 mg/100 gm fr.wt. after 2- and 8-day storage

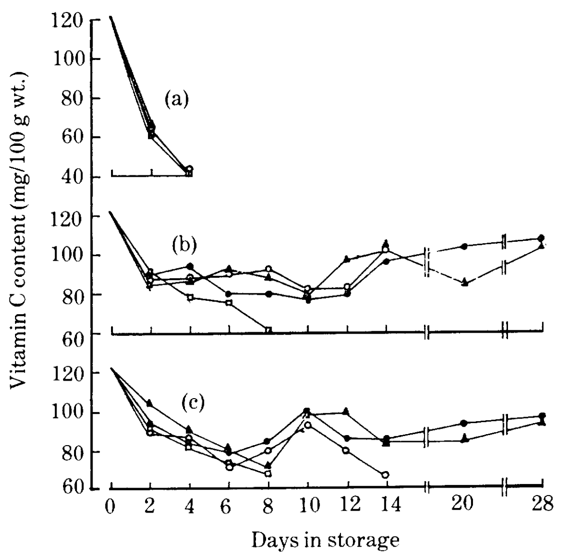

Figure 2. Changes of vitamin C content in flower stalks of broccoli held at room temperature (a), 1° C (b), and 4° C (c) in plastic basket ( ), unsealed plastic bag (○), sealed plastic bag ( ), and sealed plastic bag with initial 10% CO_2 (●).

respectively. Stems became soft after 8-day storage and were not salable.

Broccoli in unsealed plastic bag had vitamin C content in flower stalk reduced from 122.3 to 101.4 mg/100 g fr.wt. after 14-day storage. Their florets became wilted but stems still remained firm and fresh. Broccoli in sealed plastic bag with and without 10% CO_2 had vitamin C content in flower stalk reduced from 122.3 to 103.0 and 108.2 mg/100 g fr.wt. after 28-day storage respectively.

At 4° C (Fig. 2c), broccoli in plastic basket had vitamin C content in flower stalk reduced from 122.3 to 68.8 mg/100 gm fr.wt. after 8-day storage and could be no longer stored. Broccoli in unsealed plastic bag had vitamin C content in flower stalk reduced from 122.3 to 66.9 mg/100 gm fr.wt. after 14-day storage and could be no longer stored. The commodity in sealed plastic bag without and with adding 10% CO_2 had vitamin C content in flower stalk reduced from 122.3 to 96.0 and 98.6 mg/100 gm fr.wt. after 28-day storage, respectively, and broccoli still remained fresh and could be stored further.

At room temperature (Fig. 3a), broccoli in plastic basket and unsealed plastic bag had vitamin C content in florets reduced from 34.0 to 5.1 and 6.3 mg/100 gm fr.wt. after 2-day storage, respectively. Broccoli in sealed plastic bag without and with adding 10% CO_2 had vitamin C content in curds reduced from 34.0 to 16.7 and 15.1 mg/100 gm fr.wt. after 2-day storage, respectively.

At 1° C (Fig. 3b), broccoli held in plastic basket had vitamin C content in florets reduced from 34.0 to 25.4 and 10.9 mg/100 gm fr.wt. after 2- and 8-day storage, respectively. Broccoli held in unsealed plastic bag had vitamin C content in florets reduced from 34.0 to 14.9 mg/100 gm fr.wt. after 14-day storage. Broccoli held in plastic bag without and with adding 10% CO_2 had vitamin C content in florets reduced from 34.0 to 25.4 and 28.1 mg/100 gm

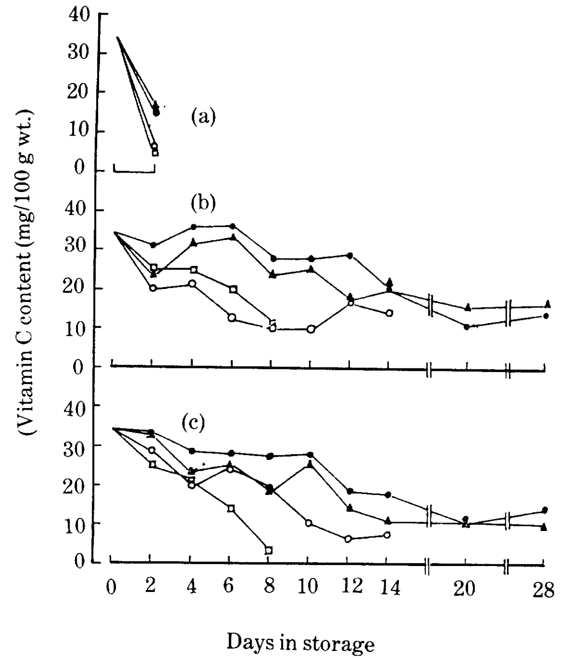

Figure 3. **Changes of vitamin C content in florets of broccoli held at room temperature (a), 1° C (b), and 4° C (c) in plastic basket (□), unsealed plastic bag (○), sealed plastic bag (△), and sealed plastic bag with initial 10% CO_2 (●).**

fr.wt. after 10-day storage and reduced to 16.5 and 14.8 mg/100 gm fr.wt. after 28-day storage respectively.

At 4° C (Fig. 3c), broccoli held in plastic basket had vitamin C content in florets reduced from 34.0 to 25.4 and 3.6 mg/100 gm fr.wt. after 2- and 8-day storage, respectively and broccoli was unsalable. Broccoli held in unsealed plastic bag had vitamin C content in florets reduced from 34.0 to 19.1 and 7.3 mg/100 gm fr.wt. after 8- and 14-day storage and broccoli became unsalable. Broccoli held in sealed plastic bag without and with adding 10% CO_2 had vitamin C content reduced from 34.0 to 25.4 and 28.1 mg/100 gm fr.wt. after 10-day storage and reduced to 10.5 and 14.8 mg/100 gm fr.wt. after 28-day storage, respectively.

Weight Loss. At room temperature (Fig. 4a), broccoli held in plastic basket and plastic bag had weight lost 44.44 and 43.40% after 4-day storage, respectively and broccoli became wilted and unsalable. Broccoli held in sealed plastic bag without and with adding 10% CO_2 had weight lost O and 1.67% after 2-day storage, respectively and broccoli became unsalable. At 1° C (Fig. 4b), broccoli held in plastic basket had weight lost 33.33% after 8-day storage; wilting was serious and stem tissue became tough. Broccoli in unsealed plastic bag had weight lost only 1% after 14-day storage; stem tissue still remained firm and fresh but curds became yellow. Broccoli held in sealed plastic bag without and with adding 10% CO_2 had weight lost 6.25 and 2.35% after 28-day storage, respectively. Broccoli still remained fresh and could be kept further. At 4° C (Fig. 4c), broccoli held in plastic basket had weight lost 27.0% after 8-day storage while that in unsealed plastic bag had weight lost

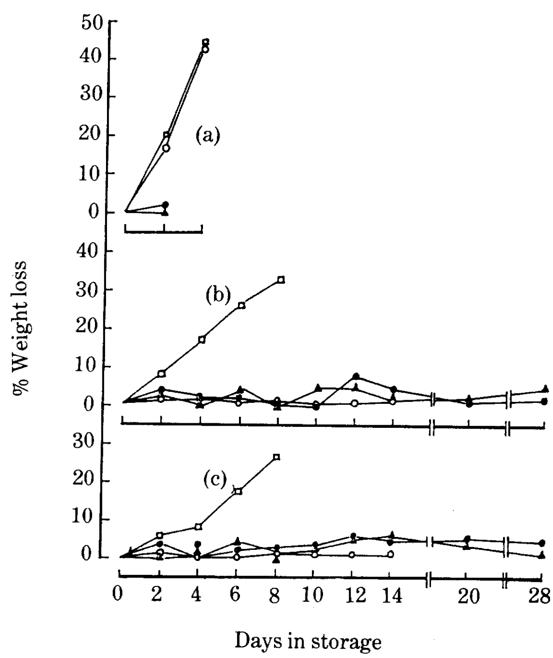

Figure 4. **Weight loss of broccoli held at room temperature (a), 1° C (b), and 4° C (c) in plastic basket (□), unsealed plastic bag (O), sealed plastic bag (△), and sealed plastic bag with initial 10% CO_2 (●).**

only 1.72% after 14-day storage. Broccoli held in sealed plastic bag without and with adding 10% CO_2 had weight lost 2.14 and 5.85% after 28-day storage, respectively.

DISCUSSION

Broccoli loses quality very rapidly after harvest if postharvest handling is not done properly (Ryall and Lipton,1972). Poor storage and shipment lead to yellowing, loss of desirable flavor and toughness, particularly under temperature substantially above 0° C (Lieberman *et al.* 1964 a and 1964 b). Deterioration of broccoli such as loss of vitamin C and chlorophyll content could be slowed down very effectivelly by holding broccoli in a sealed plastic bag with intial 10% CO_2 and storing at the temperature of 1° or 4° C. Under these conditions storage life of broccoli could be extended up to 28 days, broccoli still remained fresh and green and could be stored further. The quality of stored broccoli at 1° and 4° C was not different. Maintenance of desirable temperature near 0° or at 0° C costs energy. Therefore, broccoli should be stored at 4° C in order to save production cost. Kasmire *et al.* (1974) also found that added 10% CO_2, especially above 2.5° C was very effective in retarding the yellowing of broccoli heads.

Regardless of CO_2, loss of vitamin C and chlorophyll content of broccoli apparently related to the degree of weight loss (Ezell and Wilcox, 1959). It was shown clearly that broccoli held in plastic basket had higher percent weight loss than broccoli held in unsealed plastic bag. There should not be different in CO_2 concentration surrounding broccoli under these conditions. Whether this was because of water stress which induces oxidase system capable of oxidizing vitamin C is not known.

Surprisingly we found that vitamin C content in flower stalk of broccoli, and probably also in stem was 3-to 4-fold higher than in florets. This might be because flower stalk of broccoli acted as a storage organ. However, no one has paid much attention to the difference of vitamin C content in flower stalk or stem tissue and in florets of broccoli. Most Westerners and some Thais consume only broccoli florets and short tender flower stalk. Though freshness and greenness of florets are indices of broccoli quality, nutritional values, particulary vitamin C is more highly localized in stem tissue than in florets. Thai farmers harvest broccoli with 8 to 10 inches of stem intact instead of 3 – 5 inches as practiced in the Western region. The skin of the stem which is fibrous must be peeled off before cooking. This harvest practice indicates that our farmers have made contribution in adding another source of nutrition to mankind.

Although prestorage of during storage treatment with high CO_2 concentration of many vegetables can retard the losses of chlorophyll and vitamin C (Isenberg, 1979), so far no one knows how CO_2 does it.

CONCLUSION

Broccoli in sealed plastic bag with initial 10% CO_2 and stored at 1° or 4° C, considerably reduced losses in weight, chlorophyll and vitamin C of broccoli during storage as compared to the broccoli stored in plastic basket at room temperature.

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