THE EFFECTS OF CA ON DETERIORATION OF BROCCOLI

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This research is being conducted in an effort to characterize senescence in broccoli in terms of some of the metabolic activities that occur during aging and deterioration. Involved are studies of sugars, organic acids, ethylene, respiratory carbon dioxide and the ascorbates, ascorbic acid (AA) and dehydroascorbic acid (DHAA) as influenced by temperature, ethylene inhibitors and controlled atmospheres.

Lipton (6) reported on high CO_2-low O_2 treatments to retard deterioration in broccoli. MacLean (7) reported on respiratory activity of broccoli treated with N-benzyladenine. Numerous workers (5, 3, 4, 8, 2, 11) have reported the influence of ethylene (C_2H_4) on senescence. Saltveit (9) studied the effect of vitamin K5 (4-amino-2-methyl-1-naphthol) on ethylene and carbon dioxide production of fruit. Silver nitrates' ethylene inhibition characteristics have been known for years (1, 2).

Our real interest in this work started in 1984 as we tested $AgNo_3$ and 8 hydroxyquinaline on broccoli to determine their ability to inhibit floret opening.

For these tests we are using 4.2 cu. ft. stainless steel atmosphere chambers that will hold 3 shelves of 12 heads of broccoli. Identical sets of chambers are set up in 7°C and 14°C storages. Modified atmosphere treatments are 2% O_2+10% CO_2 at each temperature. Control chambers utilized compressed air. Continous flow of the gases at 5 ml/min were used. Silver nitrate and vitamin K5 were vacuum infused from 250 ppm aqueous solution.

During the 1984 study with 8-hydroxyquinaline and silver nitrate and from earlier studies of wholesale, retail and simulated consumer held broccoli several things became apparent. Florets are higher in AA initially but about the 9th day the levels are the same as in the stems. Thereafter stems have more AA and retain it better. Figure 1 shows the relationship of broccoli florets and stems to changes in AA level over a 12 day period. The analyses were taken over a 2-year period from wholesale, retail and stored (3 days at 4°C) samples. $AgNO^3$ and 8 hydroxy treated samples were of good color with tight florets after 3 days storage at 4°C + 4 days storage at 10°C.

However, after 3 days storage at 4°C + 11 days storage at 10°C untreated broccoli had yellow loose florets with considerable browning, while 8 hydroxy treated heads were still dark green in color with semi tight florets. After treatment with $AgNO_3$ one lot of samples had very tight dark green florets. In other $AgNO_3$ treated samples broccoli had yellow petals and loose florets and some bacterial decay.

Sugars in these tests were determined by high performance liquid chromatography using a LC-NH_2 column, 75:25 acetotrile: water mobile solution and determined at 192 nm on a UV detector (12). AA and DHAA were determined by Technicon's method (10).

Samples analyzed the day of arrival at New Yorks Hunt's Point Market averaged 88 mg ascorbic acid/100g, 1.8 mg DHAA/100g, 0.05 mg/g fructose, 0.021 mg/g glucose and 0.017 mg/g sucrose. The color of the florets were medium to dark green. Florets were medium tight to compact. There was no bacterial soft rot (Table 1).

After 7 days storage at 7°C untreated control samples were wilted with light green, swollen florets; the vitamin K5 treated samples were turgid with medium to dark green swollen florets; the $AgNO_3$ treated samples had turgid dark green swollen florets (Table 2). The untreated CA samples had medium green, tight florets; Vitamin K5 and $AgNO_3$ CA samples had turgid dark green tight florets; there was no decay in CA treated samples at 7°C.

Results were dramatically different for samples stored 7 days at 14°C (Table 3). The untreated control had all florets open but there was no decay. Vitamin K5 treated samples had yellow florets and much decay on unopened florets. $AgNO_3$ treated samples were dark green but about 45% of the heads had soft rot decay developing. The CA untreated sample had medium to dark green slightly swollen florets. No decay was present. Vitamin K5 and $AgNO_3$ treated CA samples were dark green with tight florets but were severely decayed.

After 14 days storage at 7°C the control untreated samples had semi tight florets with yellow petal tips showing. K5 and $AgNO_3$ treated control samples had medium to dark green tight florets. There was no decay after 14 days at 7°C in the control samples. The CA treated control samples held 14 days at 7°C had light green semi tight florets without decay. K5 and $AgNO_3$ samples had dark green tight florets with slight bacterial decay.

At 14°C all samples were severely decayed. Control untreated samples were mostly yellow and decayed. CA $AgNO_3$ treated samples were mostly dark green and K5 treated samples were dark green tight with 100% decay. The CA control treated samples had yellow unopened florets with less than 10% of the florets still green.

The influence of temperature, controlled atmosphere and chemical treatment of broccoli on levels of fructose, glucose, sucrose AA and DHAA are shown in Figure 2-6. The analyses were made after 7 days storage under the respective conditions. The normal air control at 14°C had more sugars than at 7°C. In controlled atmospheres the sugar content was approximately the same. In controlled atmospheres at 7°C fructose from chemically treated samples was lower than in the untreated CA samples. In normal air at 7°C fructose was higher after chemical treatment than in untreated samples. Vitamin K5 treated samples had more glucose than untreated or $AgNO_3$ treated samples. In normal air at 7°C the untreated broccoli had more glucose than the chemically treated samples. Sucrose levels were about the same after 7 days at 7°C for all treatments.

Apparently the chemical reaction involved in the formation of fructose is reduced by CO_2 in broccoli treated with vitamin K5 and to a lesser extent by the $AgNO_3$ treatment. In air, fructose increased in broccoli treated with Vitamin K5 and $AgNO_3$.

The glucose level in broccoli was greatly increased by the CO_2 treatment at 7°C, however, CO_2 had little effect on glucose in broccoli treated with $AgNO_3$. In air, glucose changed only a small amount by treatment with vitamin K5 or $AgNO_3$.

Ascorbic acid levels were reduced by both storage temperature and chemical treatment. Broccoli stored at the higher temperature had less AA. Probably due to metabolism difference. CO_2, K5, and $AgNO_3$ reduce the AA content at 7°C. This was probably caused by a reduced metabolic rate. Dehydroascorbic acid increased dramatically during storage. Since DHAA is formed during the oxidation of AA this is probably what happened during the storge of broccoli during these tests.

In conclusion, temperature, CA, vitamin K5 and $AgNO_3$ influence the metabolite levels observed in these tests and thus probably influence senescence.

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Table 1. Initial metabolite analyses and condition of broccoli

ARRIVAL CONDITION OF WESTERN BROCCOLI	
Analysis	Content
Ascorbic acid	88 mg/100 g
Dehydroascorbic acid	1.8 mg/100 g
Fructose	0.05 mg/g
Glucose	0.021 mg/g
Sucrose	0.017 mg/g
Color of head	med. to dark green
Floret condition	medium tight

Table 2. Condition of broccoli after storage for 7 days at 7°C

BROCCOLI CONDITION	
Treatment	Condition
Air	
Untreated	wilted, light green, swollen florets
K5	dark green, swollen florets
$AgNO_3$	dark green, swollen florets
CA	
Untreated	medium green, tight florets
K5	dark green, tight florets
$AgNO_3$	dark green, tight florets

Table 3. Condition of broccoli after storage for 7 days at 14°C.

BROCCOLI CONDITION	
Treatment	Condition
Air	
Untreated	light green, open florets, no DK
K5	yellow, swollen florets, BSR
$AgNO_3$	dark green florets, BSR
CA	
Untreated	medium green, swollen florets, no DK
K5	dark green, tight florets, BSR
$AgNO_3$	dark green, tight florets, BSR

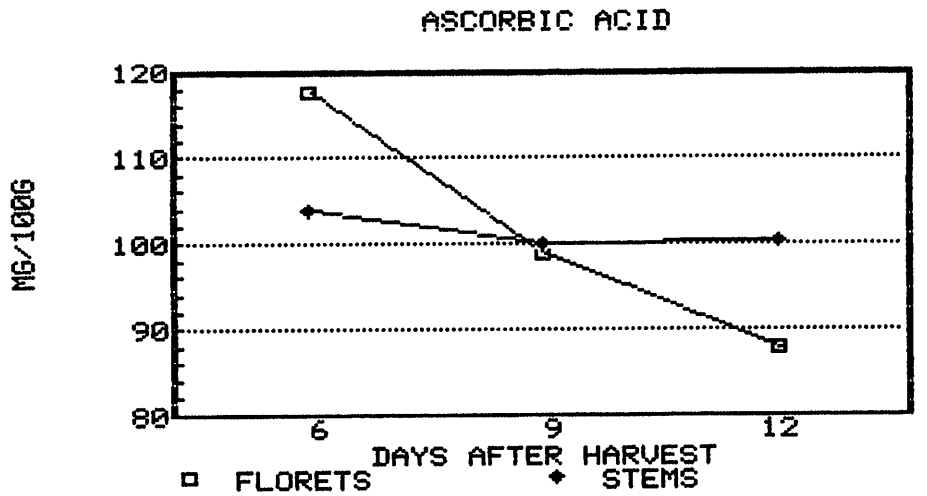
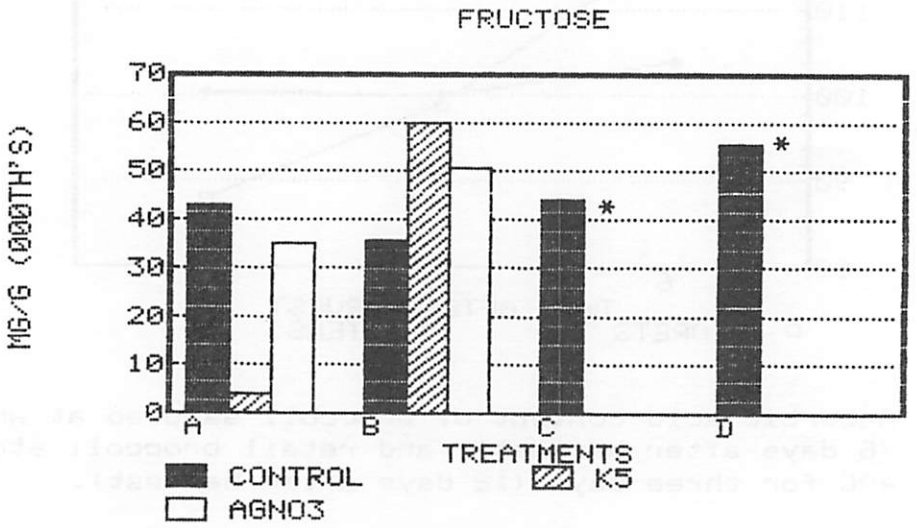


Figure 1. Ascorbic acid content of broccoli sampled at wholesale (6 days after harvest), and retail broccoli stored at 4°C for three days (12 days after harvest).



A. 7°C 2% O_2 10% CO_2
B. Normal air
C. 14° 2% O_2 10% CO_2
D. Normal air

*100% Decay of $AgNO_3$ and K5 samples at 14°C

Figure 2. The influence of temperature, controlled atmosphere and chemical treatment on the fructose content of broccoli.

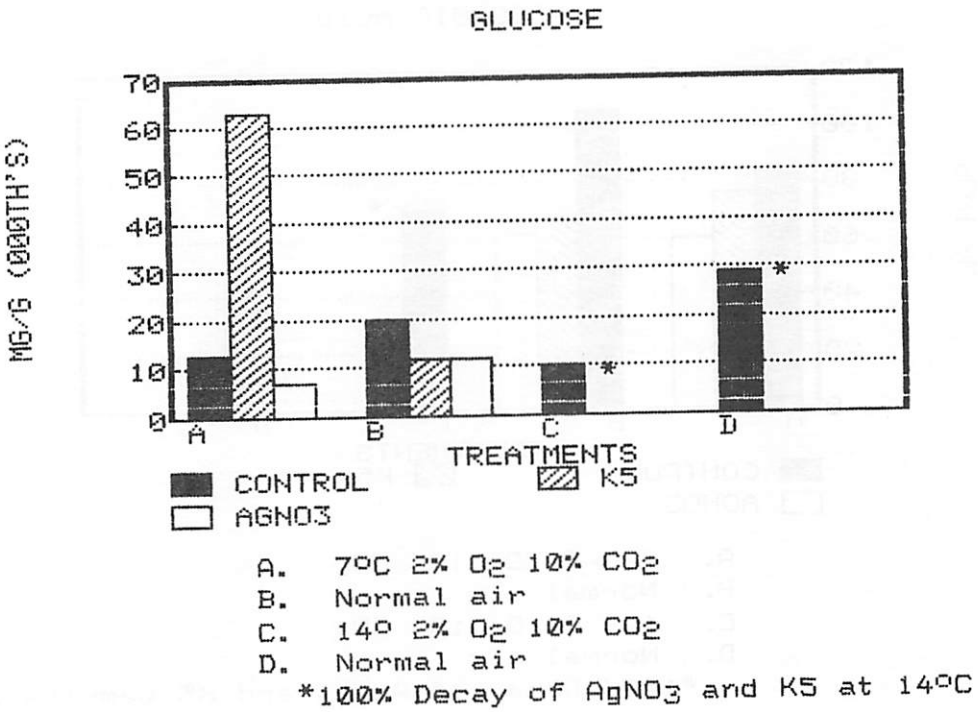


Figure 3. The influence of temperature, controlled atmosphere and chemical treatment on the glucose content of broccoli.

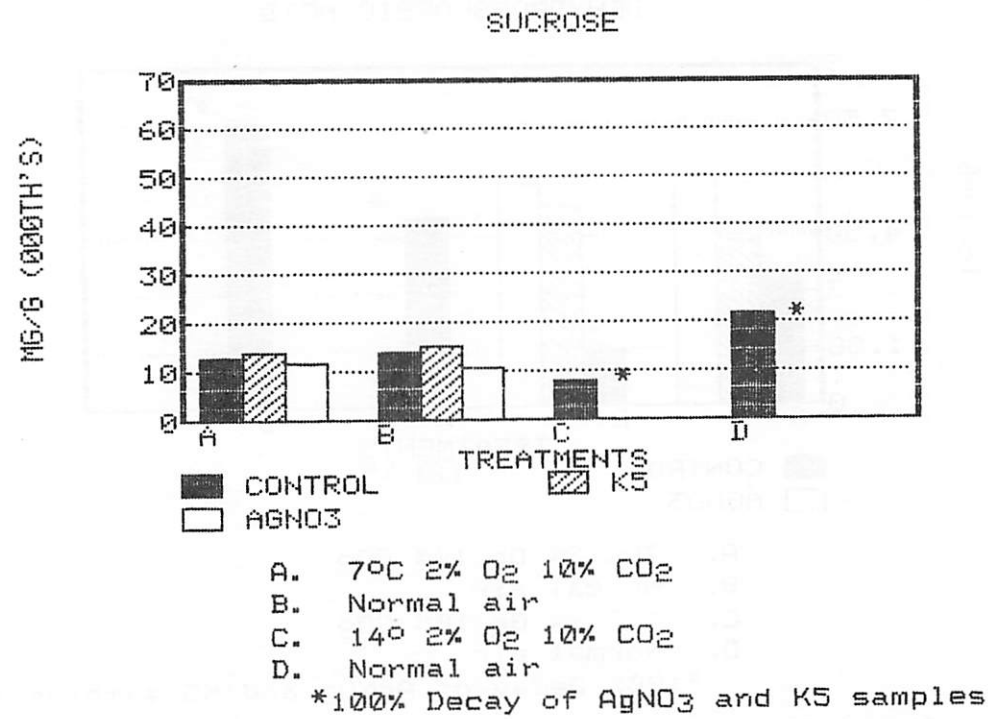
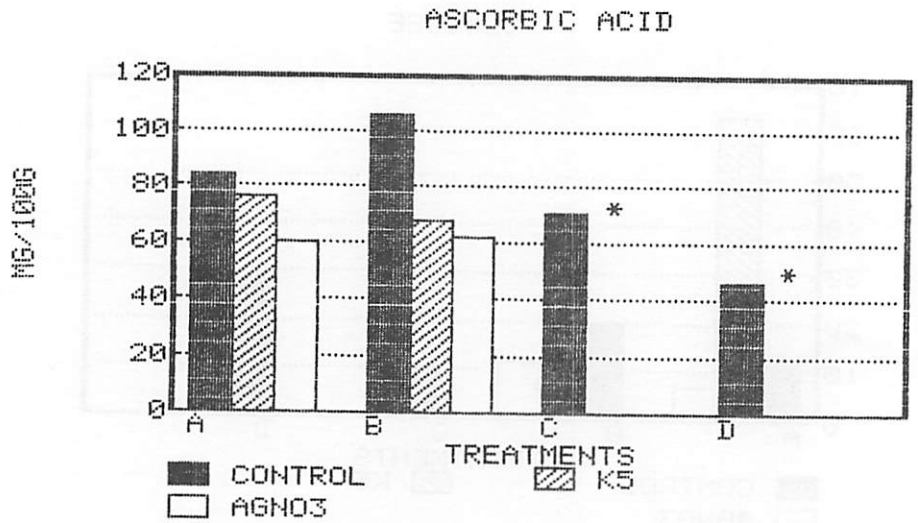
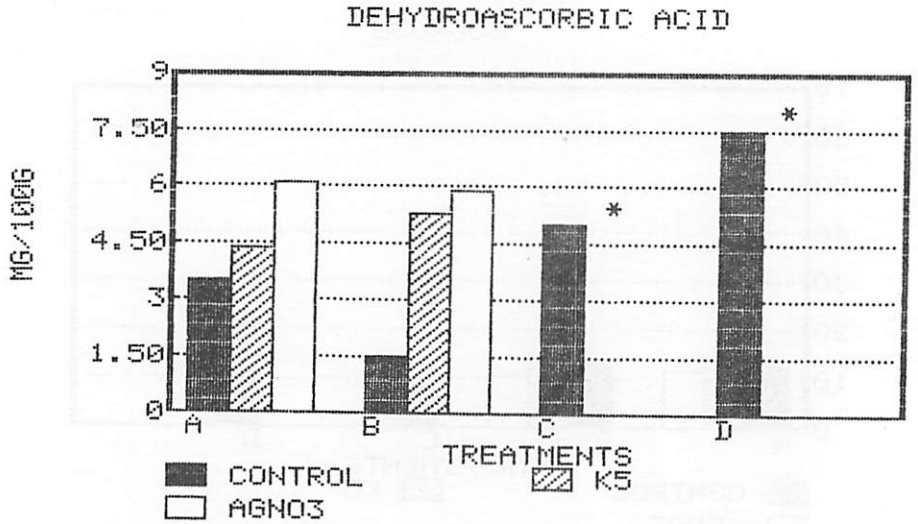


Figure 4. The influence of temperature, controlled atmosphere and chemical treatment on the sucrose content of broccoli.



A. 7°C 2% O_2 10% CO_2
B. Normal air
C. 14° 2% O_2 10% CO_2
D. Normal air
*100% Decay of $AgNO_3$ and K5 samples at 14°C

Figure 5. The influence of temperature, controlled atmosphere and chemical treatment on the ascorbic acid content of broccoli.



A. 7°C 2% O_2 10% CO_2
B. Normal air
C. 14° 2% O_2 10% CO_2
D. Normal air
*100% Decay of $AgNO_3$ and K5 samples at 14°C

Figure 6. The influence of temperature, controlled atmosphere and chemical treatment on the dehydroascorbic acid content of broccoli.