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Effects of Water Hardness on Processed Quality of Carrots, Sweet Cherries, and Apricots

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EFFECTS OF WATER HARDNESS ON PROCESSED QUALITY OF CARROTS, SWEET CHERRIES, AND APRICOTS

by

Jack C. Chiang

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ABSTRACT

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by

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The Honey Sweet carrots were canned with Ethyienediamine tetracetic acid ($CaNa_2EDTA$) and Sodium hexametaphosphate (Ha-HMP) at five different water hardness (0, 20, 40, 80, 160 ppm of calcium and 20 of magnesium), then stored at temperatures of 70 and 100 F. Evaluations were made at sixty-day intervals for six months. Firmness and color degradation decreased significantly when water hardness or storage time increased. Under storage at 100 F and 0 hardness of water, the decrease of color and firmness was constantly accelerated.

When hard water (above 80 ppm or below 40 ppm) was used for canning Van sweet cherries and Large Early Montgament apricots, the firmness, volatile reducing substances, and pH decreased. Sensory acceptability was maximum at 40 and 80 ppm. However, when either $CaNa_2EDTA$ or Na-HMP was used at the 500 ppm, it was found that they counteracted the effects of hard water and the quality of canned sweet cherries and apricots improved, when compared with control.

(58 pages)

INTRODUCTION

Foreign constituents in water supplies affect the turbidity, color, odor, taste, corrosiveness, hardness, and safety of the water. All of these characteristics are important to food processors. In the processing of fruits and vegetables, unpleasant taste, off-odors, turbidity, and color from water are obvious factors in decreasing the quality of the finished product. Less obvious are the changes brought about by the interaction of compounds in the food with some of the usually innocuous ions present in potable water supplies. For instance, calcium or magnesium salts present in the water in sufficient concentration cause hardening in processed foods. This firming is desirable in certain canned fruits such as apricots and sweet cherries. On the other hand, the hardness of water may have an adverse effect on the texture of cooked beans (Masters and Garbutt, 1920); it also influenced the blanching process of canned fruits and vegetables (Salunkhe and Hamson, 1959).

EDTA (Ethylenediamine tetracetic acid) salts and Na-HMP (Sodium Hexametaphosphate) are "sequestering agents." The term sequestration was introduced to describe the phenomenon in which offending metal ions are bound within the complexing molecule. This chelating action has been used for water-softening since 1934, and for removing deposits after evaporation of hard water. EDTA salts and Na-HMP, which have been employed in the canning of fruits and vegetables as well as in meat and other products, can suppress enzyme activities and synergize the antioxidant properties of ascorbic acid, thus inhibiting color

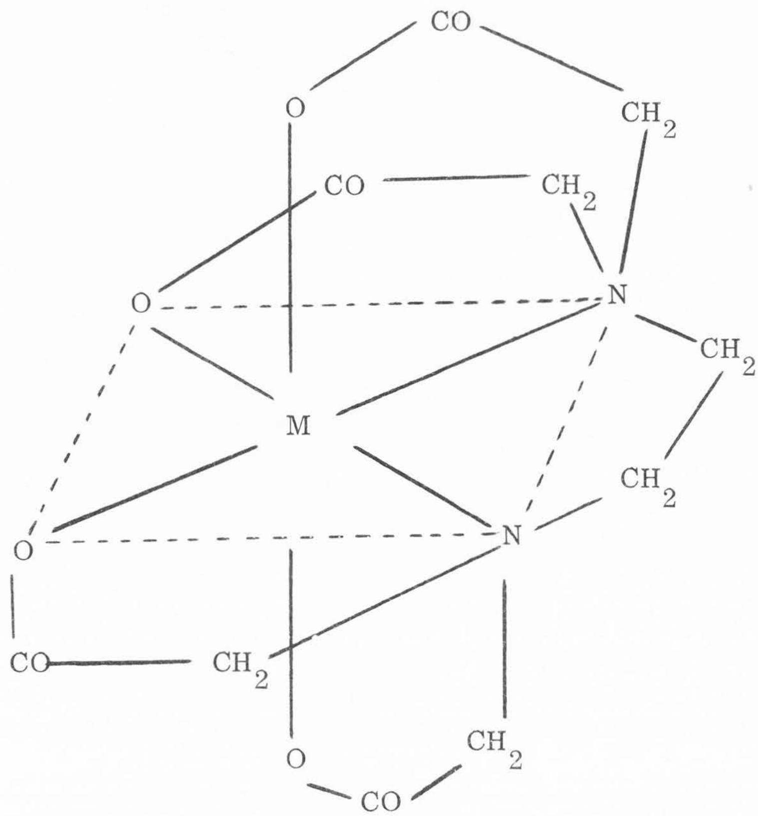

Figure 1. Structure of Ethylenediamine tetraacetic acid.

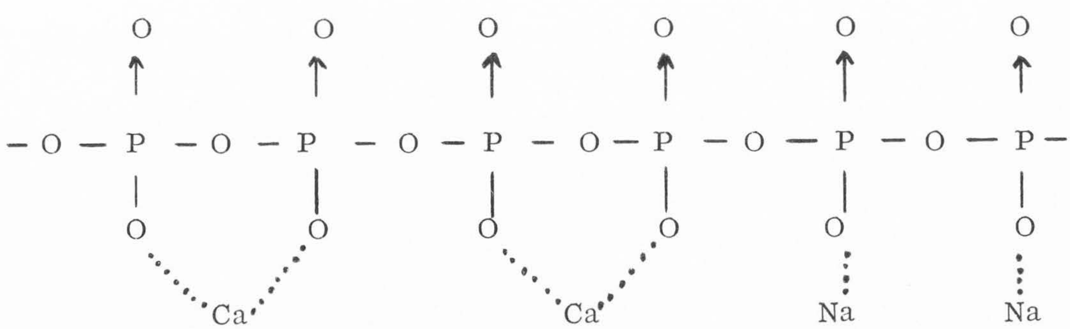

Figure 2. Strucutre of Sodium hexametaphosphate.

REVIEW OF LITERATURE

When beans were canned in water with 70 ppm hardness, they were firmer than those canned in distilled water (Huenink and Bartow, 1915). The cooking time for butter beans was less in distilled water than in London tap water of 12- ppm (Masters and Garbutt, 1920). The cooking time for navy beans decreased about 20% by cooking or soaking in distilled water as opposed to cooking or soaking in tap water (Loucks, 1967).

Hardness in water tends to cause firmness in fruits such as ripe apples, pears, apricots, and peaches (Joslyn, 1963). Tomatoes canned with calcium chloride are rendered firmer and show better preservation of natural structure during canning than do untreated fruits. Polygalacturonic acid, or demethoxylated pectin, combines with calcium and other elements to produce gels such as calcium pectate. These compounds lend additional firmness to the tissues and thus result in better preservation of the original structure (Kertesz, 1938). Calcium salts were used for firming canned green and red sweet bell peppers (Hoover, 1960), and canned cauliflower and blanched apple slices (Hoogzand and Doesburg, 1961). Calcium treatment of canned shrimp likewise prevents discoloration and maintains firmness of the pack. Untreated shrimp usually soften in three months whereas treated packs retain firmness for several years (Ladenburg, 1959).

Canned fruits stored at temperatures above the freezing point often undergo chemical degradation, such as decomposition of esters, oxidation of aldehydes, destruction of carotenoid and anthocyanin pigments, possible intermolecular oxidations, reaction between products and metals, etc., all of which may cause deterioration of the products (Pederson et al., 1947).

EDTA salts often prevent or inhibit discoloration of canned fruits and vegetables. They synergize the antioxidant activity of ascorbate in apple, pear and peach canning, and prevent surface darkening of sweet potatoes, yams, cauliflower, egg plant, asparagus, brussel sprouts, sliced beets, and turnips (Furia, 1964). Blue-green or grayish discoloration of canned, frozen, and fresh shellfish and crustacea is prevented by treating them with 0.5% EDTA salts solution (Ladenburg, 1959).

EDTA salts inactivate the pro-oxidant catalytic activity that has been observed under certain conditions for metal complexes, and synergize the effect of antioxidants, such as butylated hydroxy anisole (BHA) butylate hydrozy toluene (BHT), propyl gallate and nordihydroguairaretic acid (Dutton et al., 1948), during the storage of oil, fat, and shortening. EDTA also inhibits the thickening of stored condensed milk, enhances the foaming properties of reconstituted milk, and controls the heat coagulation of milk used in manufacturing confections. Milk coagulation by pepsin is unaffected (Maeno et al., 1965). The tendency of whole eggs to coagulate during pre-freeze heat sterilization is reduced by adding Na_2H_2EDTA in a soaking operation; sufficient chelating agent is absorbed to inactivate trace metals and prevent discoloration during retorting and subsequent storage (Furia, 1964). Oxidative effects in beer stored at 70 F temperature and oxygen-enhanced gushing are inhibited by EDTA (Kneen, 1956). In nondistilled vinegar, precipitation of protein or metallic tannates and phosphates can occur during storage. The addition of 6.7 ppm of Na_2H_2EDTA per part of copper or iron prevents cloudiness and precipitation without affecting flavor and color (Joslyn et al., 1953).

In meat products, the anticoagulation properties of EDTA salts are used advantageously in processing blood in the manufacture of sausages (Faust and Ender, 1940). EDTA supresses calcium activated enzymes that cause coagulation and discoloration of meat surface. A combination of ascorbic acid and Na_2H_2EDTA stabilizes the color and flavor of frozen ground beef (Caldwell et al., 1960).

Darkening of oil-blanched french-fried potatoes is prevented by pre-blanching for a few minutes in 0.1% aqueous solution of Na_2H_2EDTA (Hawkins et al., 1959). Greening of potato tubers exposed to fluorescent light is reduced by spraying with EDTA salts (Fellers and Morin, 1962). The vitamin C content of tomatoes and other juices is protected by adding EDTA salts early in the processing operation (Niadas and Roberts, 1959). Dry food products and pharmaceutical preparations containing oil-soluble vitamins, A, D, E, and K are often stabilized by a mixture of EDTA salts (Watts and Wang, 1951).

Improved sugar crystallization and recovery through decomposition of carbohydrate metal complexes are obtained with Na_2H_2EDTA (Rao and Ramaiah, 1957). When used with BHA, 60 ppm Na_2H_2EDTA promotes color and flavor retention in soluble spice extracts (Peat, 1963). Na_2H_2EDTA is of considerable value in improving the clarity and whipping quality of gelatin and in retarding rancidity in instant desserts containing pre-gelatinized starches (Korth, 1959).

Polyphosphates are well known as chelating or sequestering agents for metallic ions. The chain phosphates chelate strongly, the ring phosphates weakly, while orthophosphates do not chelate at all. Since long chain phosphates such as Na-HMP form the most stable complexes, they are widely used in the food industry.

Na-HMP and citric acid have been employed to prevent irons casse (Joslyn et al., 1953). Ions in the skin of legumes give firm calcium pectate gels, which are prevented by the complexing action of Na-HMP (Holmquist et al., 1948). The Na-HMP aids release of pectinaceous materials during juice extraction and acts as a dispersing agent for pulp in the juice. The resulting juice has a higher viscosity and contains more ascorbic acid than the untreated juice (Morse, 1952). Condensed phosphates are found to aid molasses color retention (Gururaja and Ray, 1946). A portion of Na-HMP's activity is attributable to the complexing of transition metal ions, and it is used as an antioxidant synergist (Watts and Wang, 1951).

Fruits and Vegetables

Sweet cherries (Cultivar: Van) and apricots (Cultivar: Large Early Montgament) were harvested at optimal maturity based on visual appearance for canning. These fruits were then processed with $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm), respectively, under commercial conditions with the following proportion of fruit and sugar solution: Sweet cherries, 410 grams of fruit and 350 ml of 40^{o} Brix sugar solution per can (size 401 x 411). Apricot, 500 grams of fruit and 300 ml of 40^{o} Brix sugar solution were added per can (size 401 x 411). Canned fruits were stored for six months at 70 F. Samples were evaluated at sixty-day intervals.

Carrots (Cultivar: Honey Sweet) were bought from a local supermarket. Carrots were sliced into 1/4 to 3/8 inch thick pieces and canned with $CaNa_2EDTA$ (800 ppm) under commercial conditions and with Na-HMP (800 ppm). The canned carrots were stored at room (70 F) temperature and at 100 F for six months. At sixty-day intervals random samples of the canned products were removed from each storage condition and evaluated for the following subjective and biochemical attributes.

Firmness

Carrot and apricot firmness was determined with the Magress Pressure Tester 1/8 inches in diameter (Magress and Allen, 1929). Firmness of sweet cherries was measured by the Automatic Pressure Test Machine No. 3034 from Bridge Machinery Company (pound per square inches).

Color

Anthocyanins (sweet cherries) and carotenoids (carrots) were determined colorimetrically using procedures outlined by Sondheimer and Kertesz (1948) and A. O. A. C. (1965).

Apricot color was measured with a Hunter Color and Color-Difference Meter (1950). This instrument has three photo cells which are so filtered as to measure lightness (L), redness (aL) and yellowness (bL). The reading of the yellow standard color plate is prepared by the National Canners Association. The ones used for apricot measurement were L = 54, aL = 1, and bL = 32.

Titratable acidity and pH

These values were determined with a Beckman pH meter. Twenty-five grams of fruit were homogenized and diluted to 250 ml with distilled water. Samples were titrated to pH 8.1 with 0.1 N sodium hydroxide. pH readings were made directly on blended, diluted (25 grams per 100 ml) samples (Ruck, 1956).

Volatile reducing substance (VRS)

VRS of the fruits was determined by a potassium permanganate oxidation method as outlined by Luh et al., 1960.

Sensory quality

The quality of the processed products was made by a selected panel using a 9 point Hedonic Scale (Peryam and Pilgrim, 1957).

RESULTS

Experiment 1. Canned Carrots (Cultivar: Honey Sweet)

Effect of adding $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) to water (0, 20, 40, 80, 160 ppm) hardness on firmness and color of canned carrots during storage

The decrease in firmness at 100 F was much faster than at 70 F. Sample treated with $CaNa_2EDTA$ (800 ppm) degraded slower than those treated with Na-HMP (800 ppm). Samples stored at 100 F consistently lost firmness during the six-month storage period, while the samples held at 70 F decreased slower at the beginning and more rapidly during the fourth to sixth month (Figures 3 and 4).

A decrease in firmness was accompanied by a loss of color in samples under both (70 and 100 F) storage conditions. The samples treated with $CaNa_2$-EDTA retained better color than Na-HMP (Figures 5 and 6).

Applying statistical analysis of variance, significantly better effects on color and firmness were demonstrated among chemical treatment, storage time, and different water hardness, when compared between both chemicals (Figures 3, 4, 5 and 6; Tables 1, 2, 3, 4, and 20 in the Appendix).

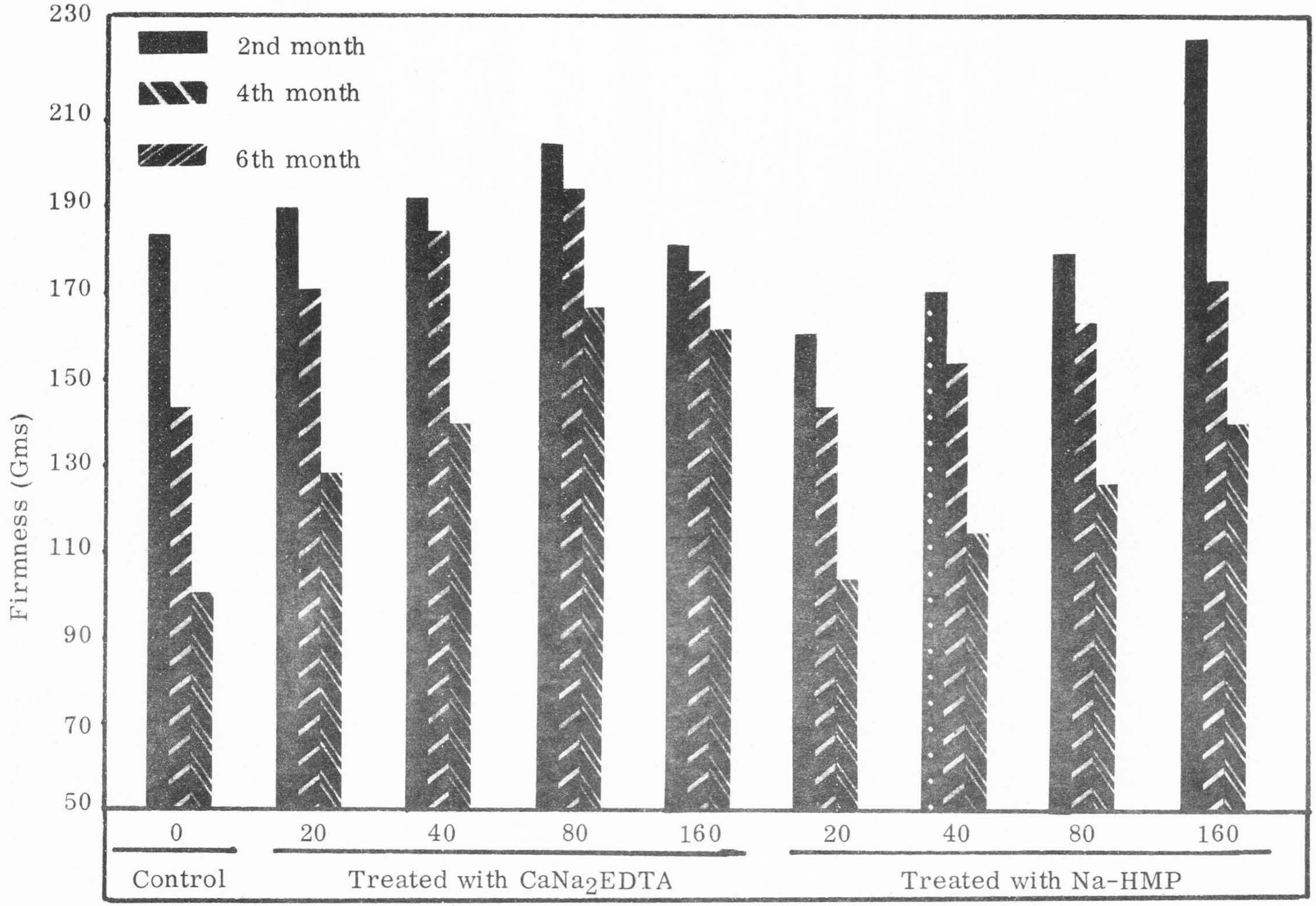

Figure 3. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on firmness of canned carrots during a six-month storage period at 70 F.

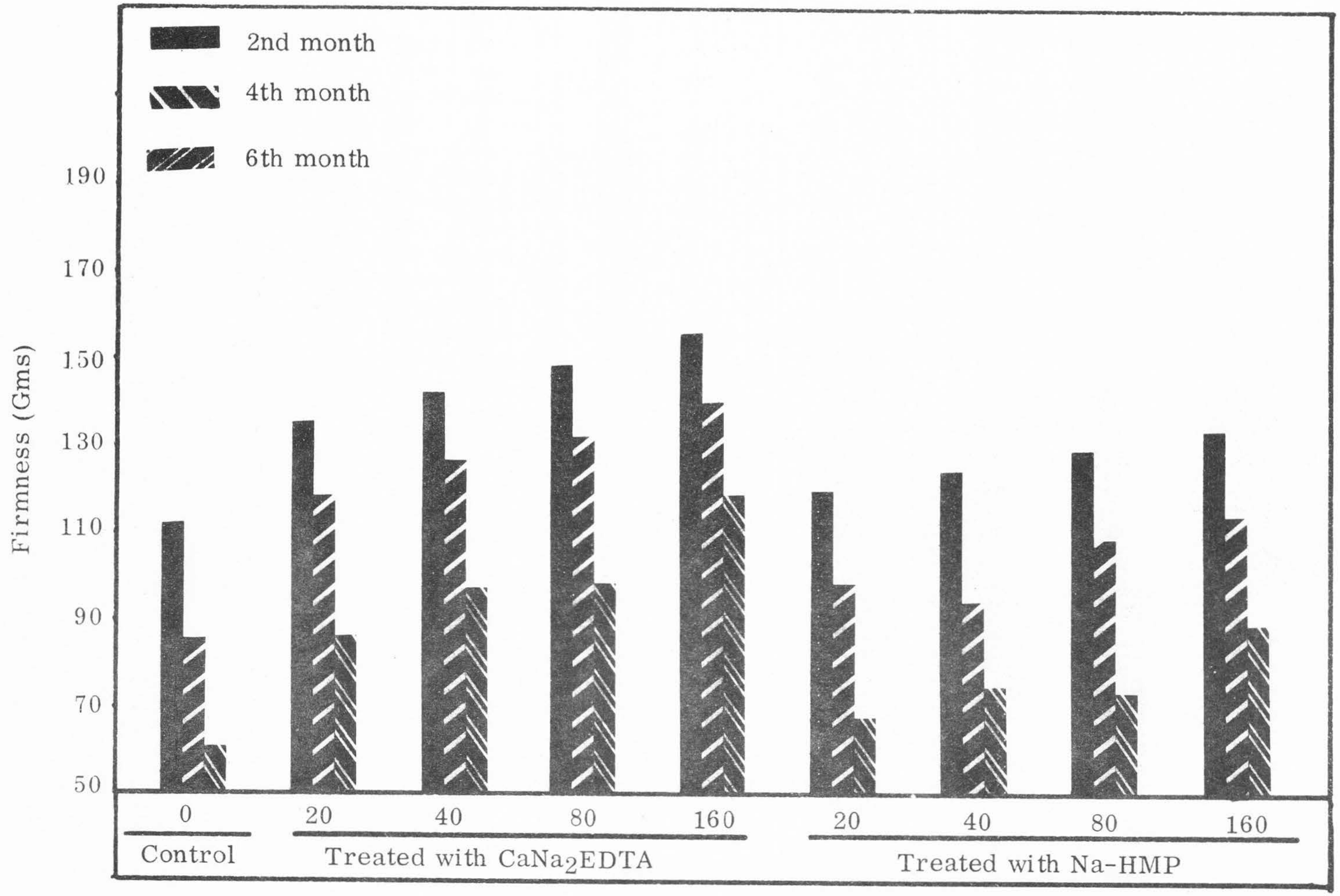

Figure 4. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on firmness of canned carrots during a six-month storage period at 100 F.

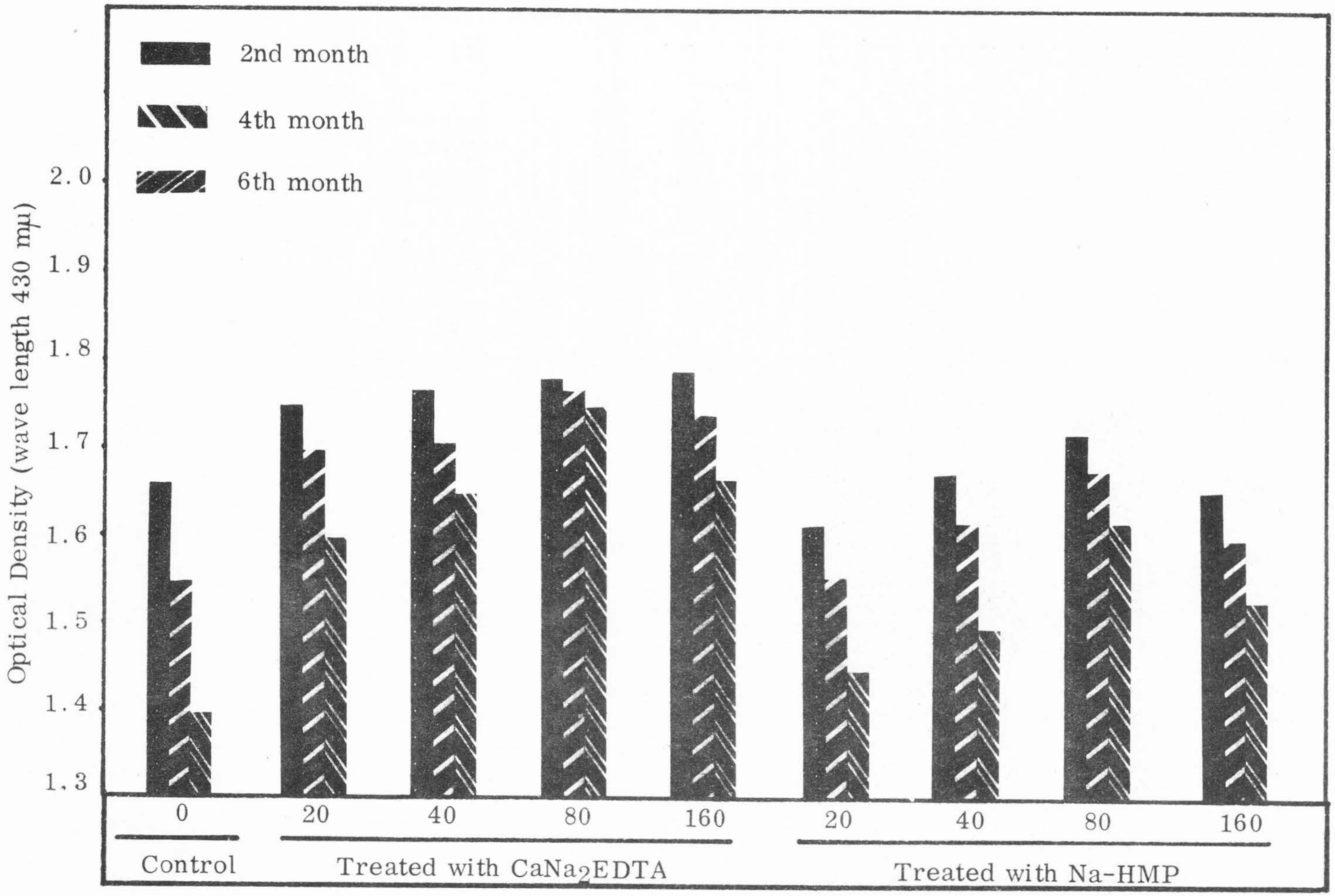

Figure 5. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on color of canned carrots during a six-month storage period at 70 F.

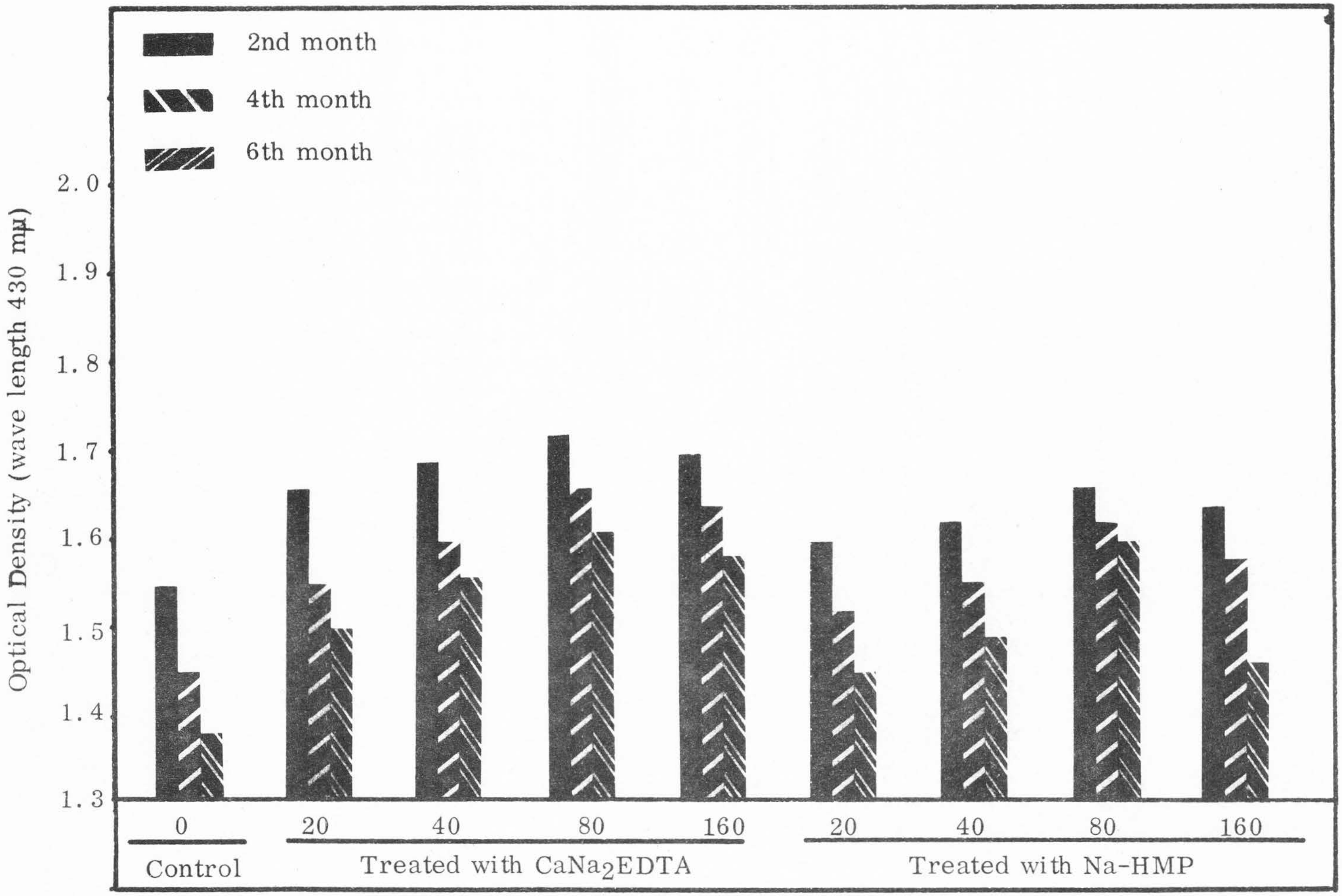

Figure 6. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on color of canned carrots during a six-month storage period at 100 F.

Experiment 2. Canned Sweet Cherries (Cultivar: Van)

Effect of adding $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) to water (0, 20, 40, 80, 160 ppm) hardness on canned sweet cherries during storage at 70 F

After six months of storage, canned sweet cherries with 160 ppm and 80 ppm of water hardness were softest and those with 40 ppm the firmest in both treatments (Figure 7). In samples treated with $CaNa_2EDTA$ and Na-HMP, firmness, volatile reducing substances, pH, and sensory acceptability decreased less and titratable acidity increased less than the controls during storage (Figures 7, 8, 9 and 10; Tables 5, 6, 7 and 8 in the Appendix).

Applying statistical analysis of variance, significantly better effects on color, firmness, volatile reducing substances, and titratable acidity were demonstrated among chemical treatments, storage time, and different water hardness, when compared with control (Table 18 in the Appendix).

Experiment 3. Canned Apricots (Cultivar: Large Early Montgament)

Effect of adding $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) to water (0, 20, 40, 80, 160 ppm) hardness on canned apricots during storage at 70 F

After six months of storage, canned apricots with 160 ppm of water hardness had a more rapid loss in firmness, color, and volatile reducing substances than samples canned at other levels (40 or 80 ppm). There was little change in pH and titratable acidity in all samples. Canned apricots, which were treated with 500 ppm of $CaNa_2EDTA$ or 500 ppm of Na-HMP (Figure 11), with

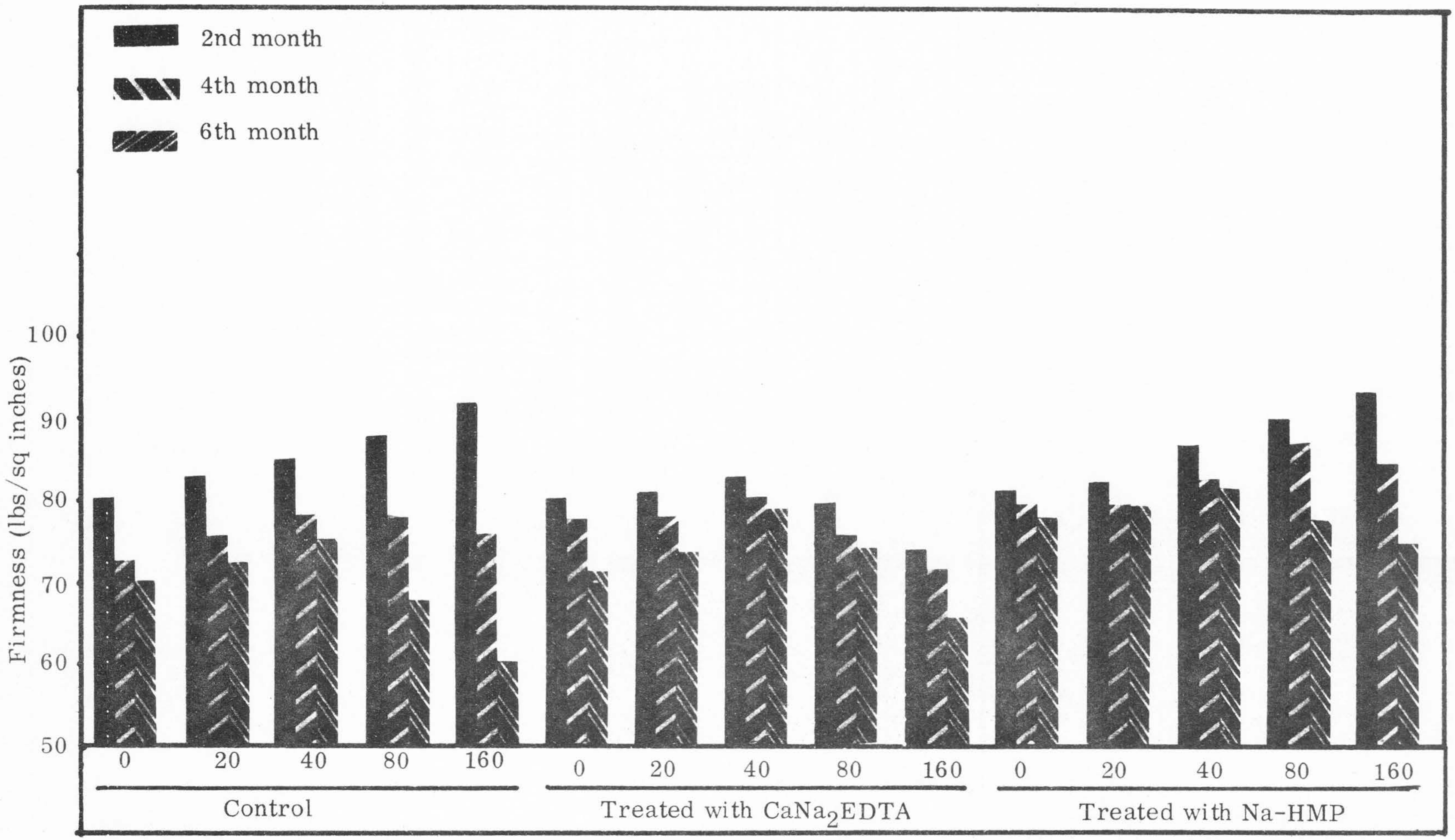

Figure 7. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on firmness of canned cherries during a six-month storage period at 70 F.

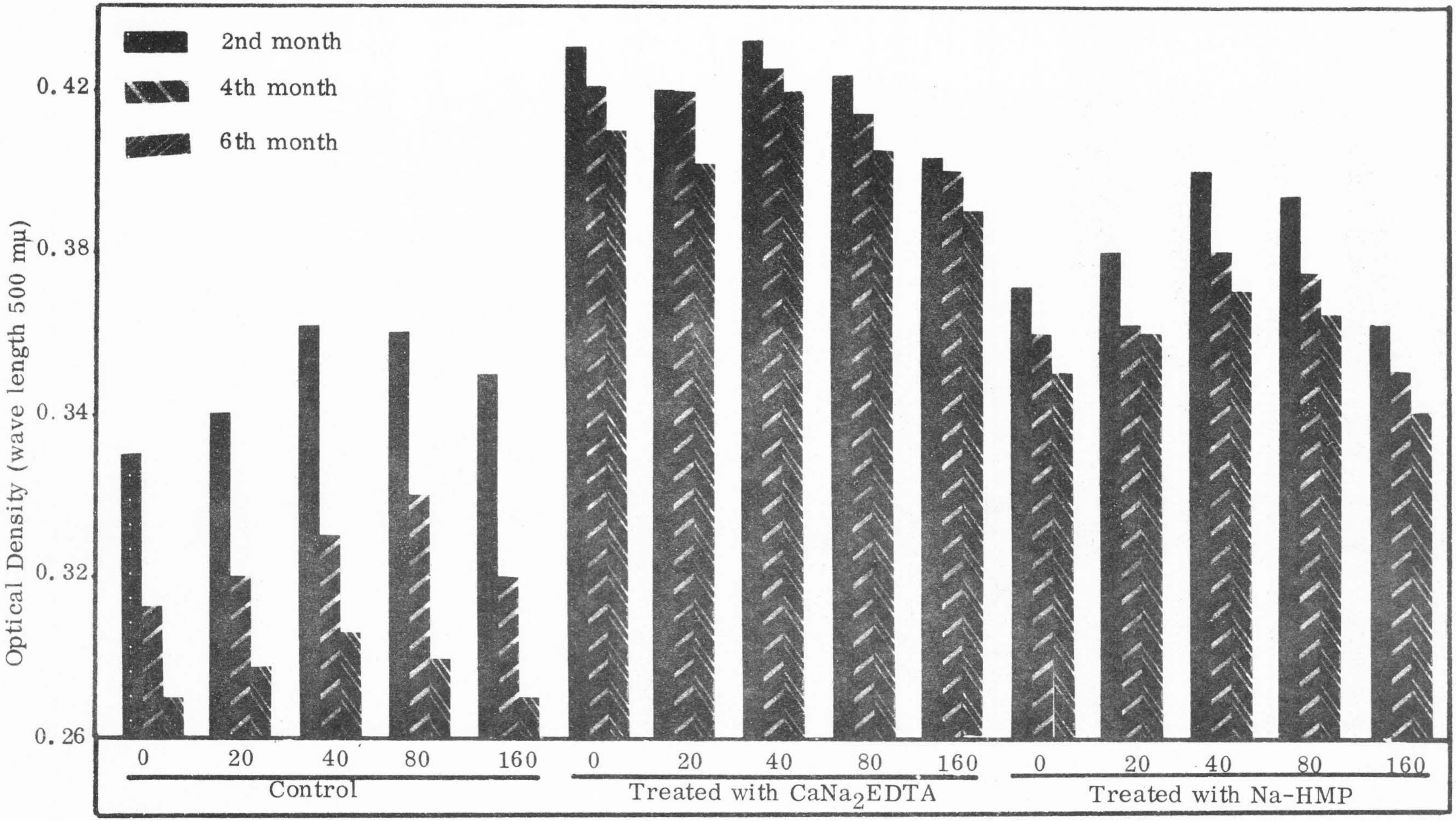

Figure 8. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on color of canned cherries during a six-month storage period at 70 F.

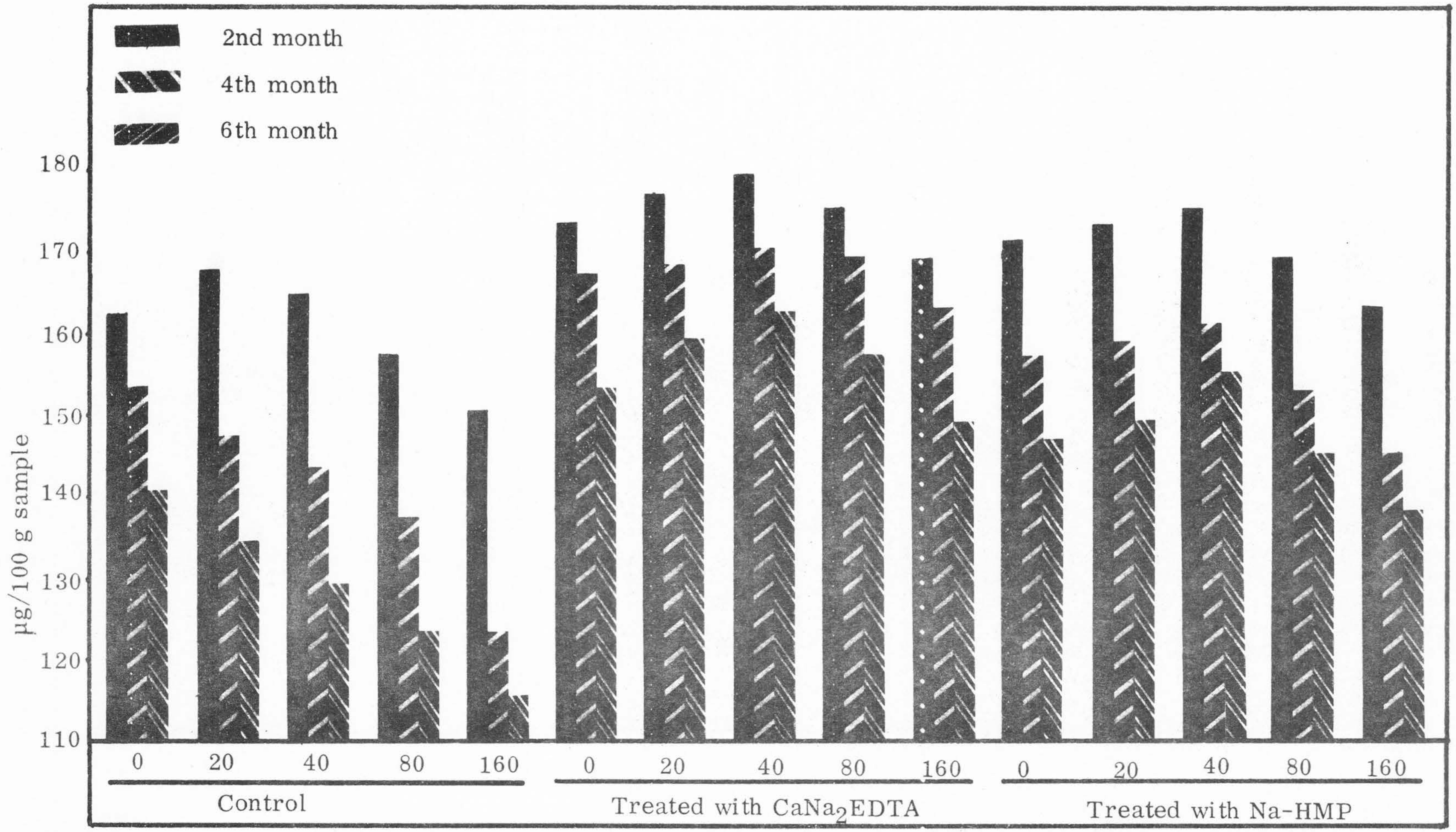

Figure 9. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on volatile reducing substances (VRS) of canned cherries during a six-month storage period at 70 F.

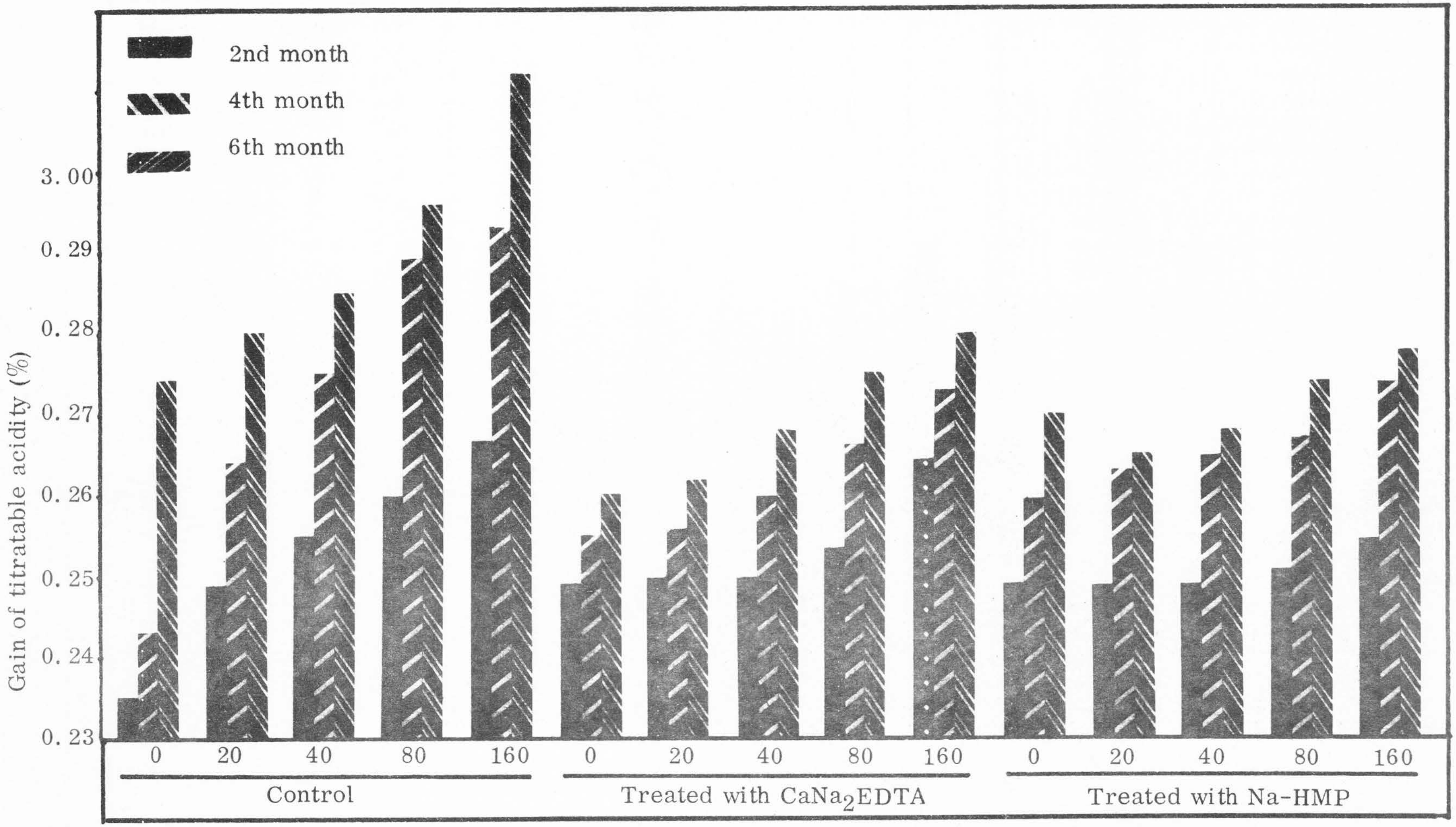

Figure 10. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on titratable acidity of canned cherries during a six-month storage period at 70 F.

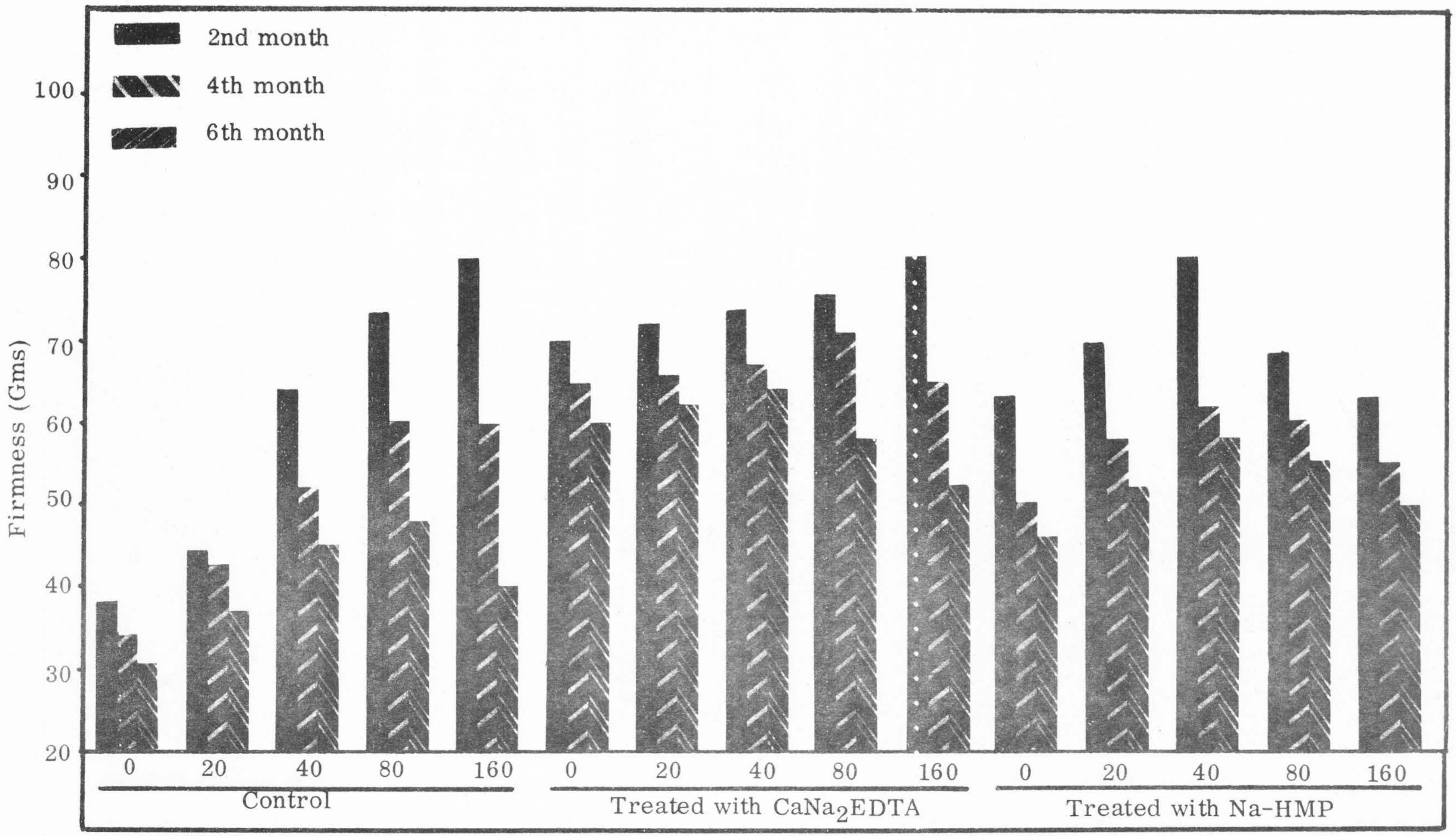

Figure 11. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on firmness of canned apricots during a six-month storage period at 70 F.

40 ppm were the firmest. There was only a slight change in pH and titratable acidity of the 0 ppm canned apricots (Figure 12). The firmness, volatile reducing substances, color, and pH decreased less in the chemically treated samples, and the titratable acidity increased less (Figures 11, 12, 13 and 14).

Applying statistical analysis of variance, significantly better effects on color, firmness, volatile reducing substances, and titratable acidity were demonstrated among chemical treatments, storage time, and different water hardness, when compared with control (Table 19 in the Appendix).

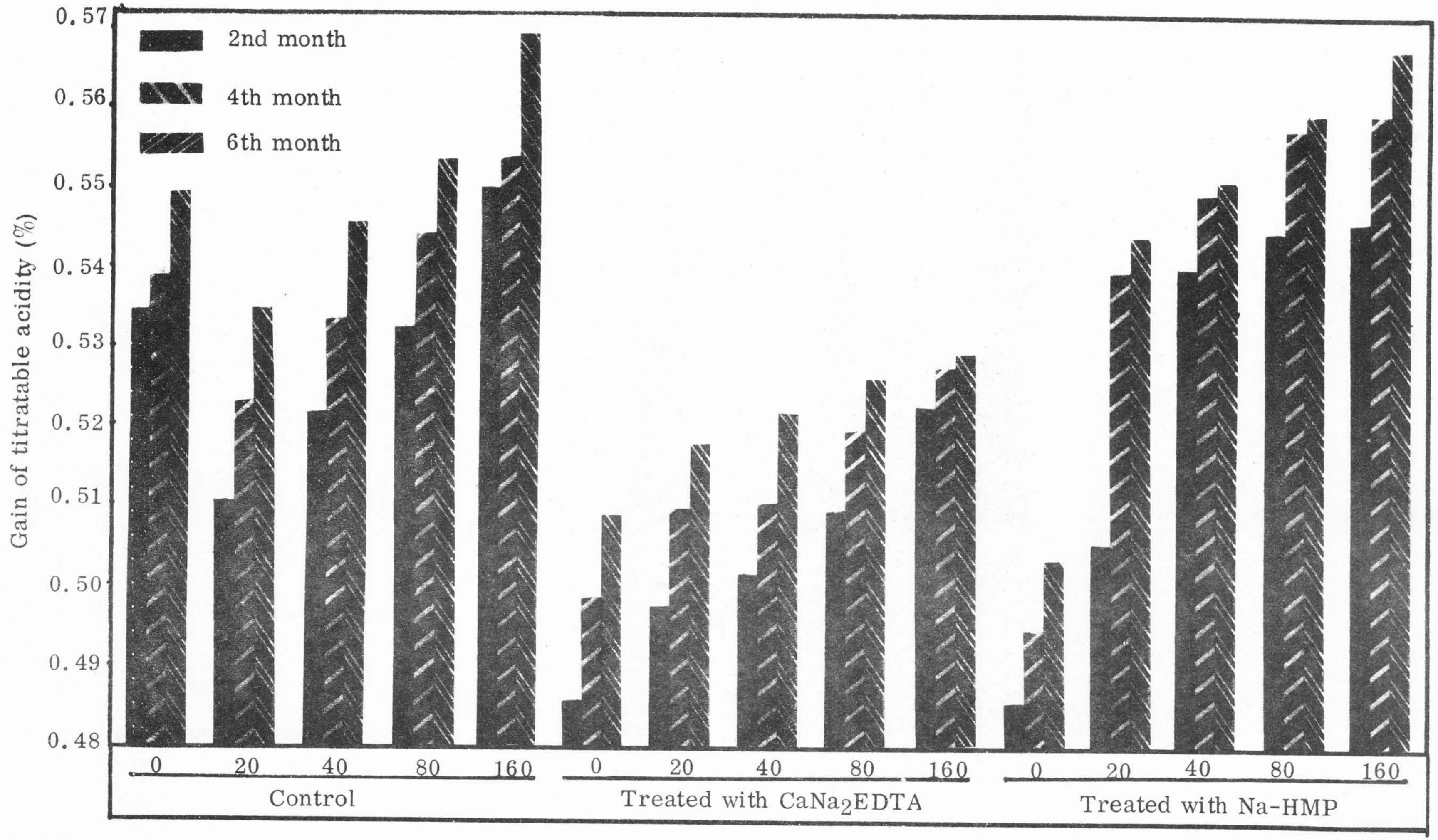

Figure 12. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on titratable acidity of canned apricots during a six-month storage period at 70 F.

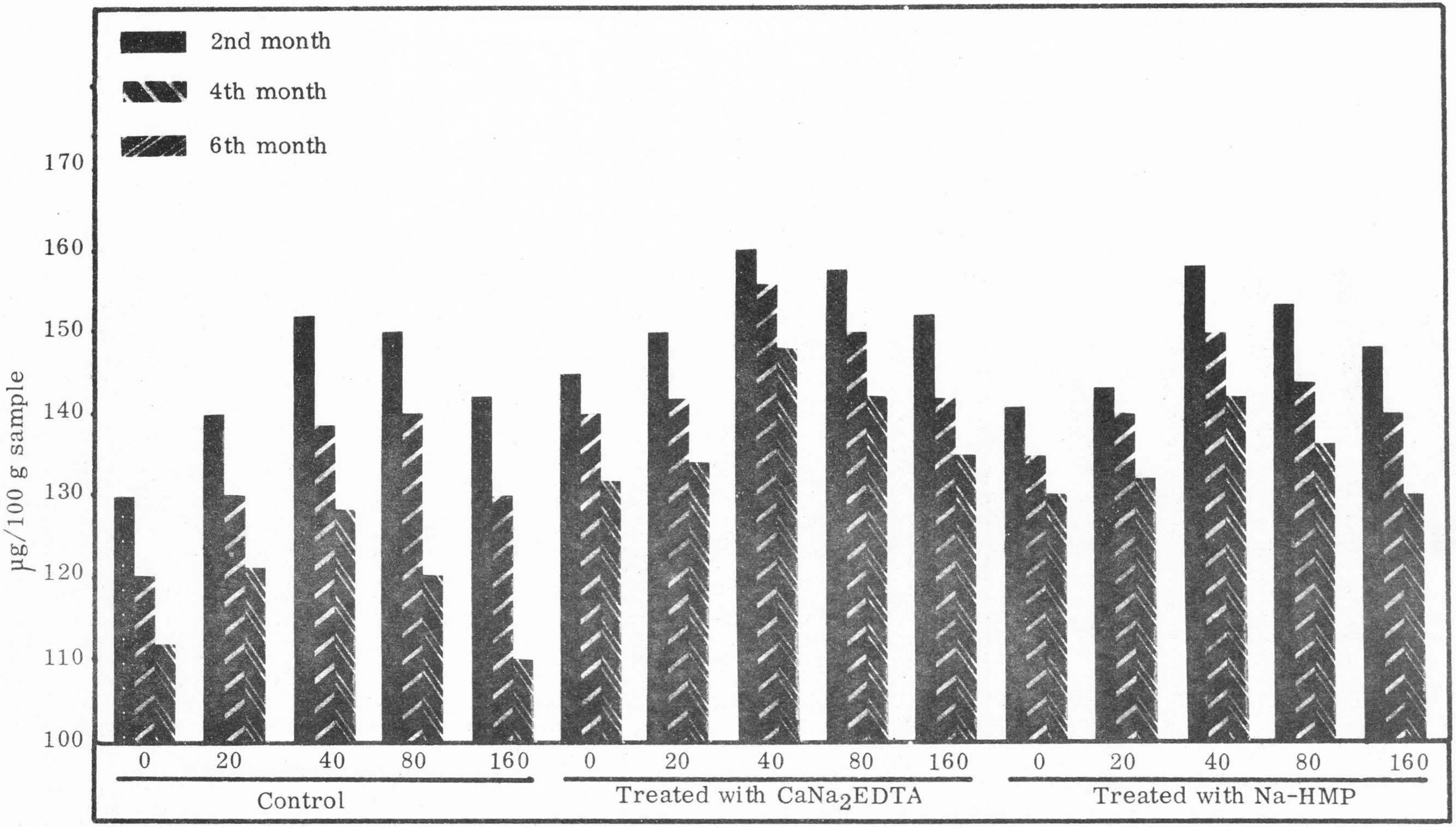

Figure 13. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on volatile reducing substances (VRS) of canned apricots during a six-month storage period at 70 F.

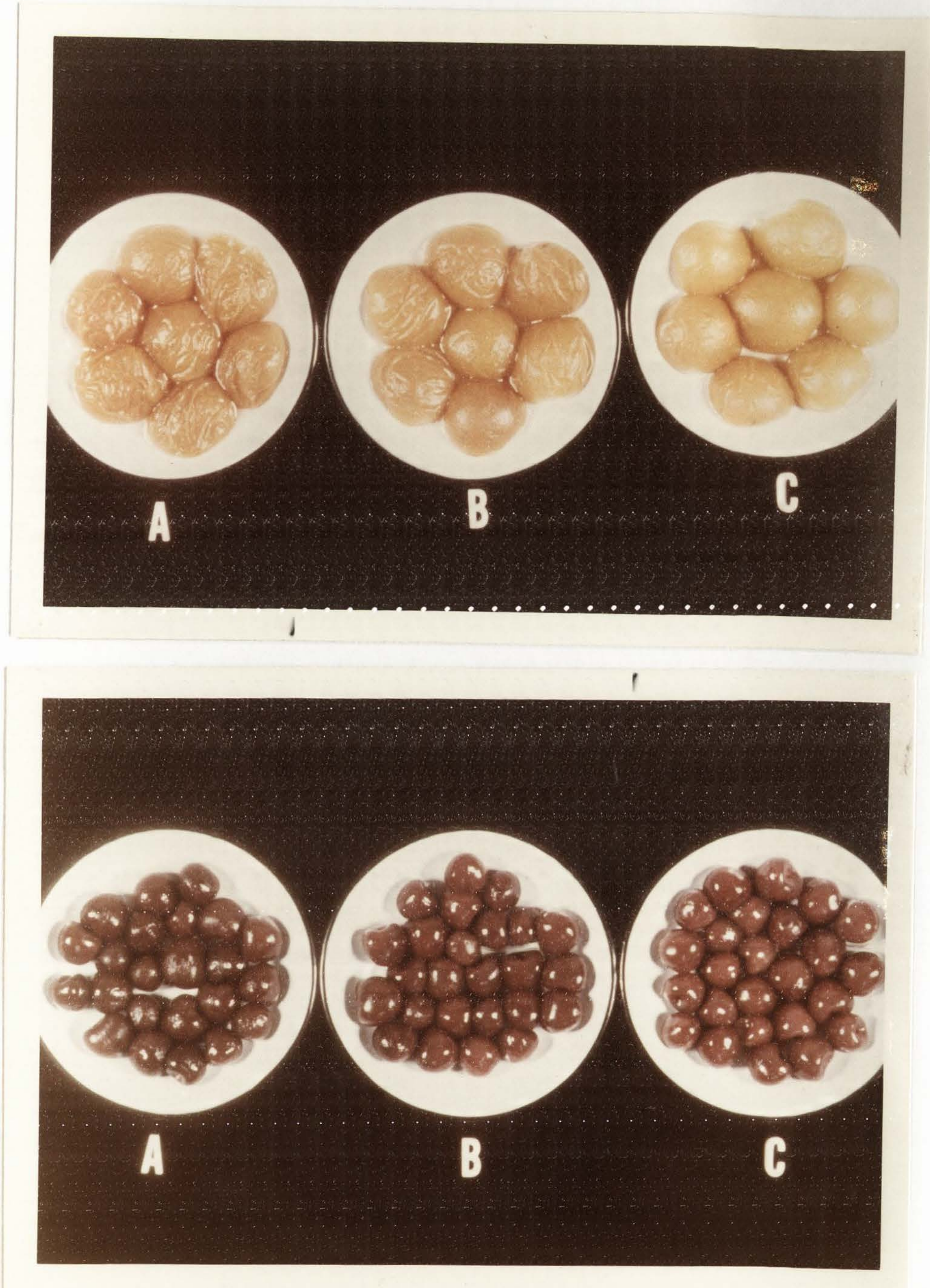

Figure 14. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at 40 ppm of water hardness on appearance of sweet cherries and apricots after a six-month storage period at 70 F.
A is control (40 ppm of water hardness)
B is treated with 500 ppm of Na-HMP
C is treated with 500 ppm of $CaNa_2EDTA$

hydrogen as rapidly as it is deposited on the metal surface (Cruess, 1958). Furthermore, oxygen in the head space of the can is responsible for the breakdown of anthocyanins through the hydrolysis or polymerization of pseudobase pigment to insoluble red-brown and soluble brown compounds. In both reactions the red-brown compounds may rise from sugar (Sondheimer and Kertesz, 1948).

Color degradation in apricots was reported due to Maillard type of reactions (Liggett and Ellenberg, 1959) which involves chemical interaction of a sugar with acid to form furfuraldehyde. These unsaturated aldehydes may polymerize and yield brown resinous compounds due to the carmelization of sugar itself or to acid-base catalyzed decomposition of reducing sugar causing non-enzymatic browning in apricots during the period of storage. A striking increase in rate of deterioration of pigments with decrease in pH is noticed in the samples of 80 and 160 ppm water hardness. However, in the samples treated with sequestering agents, either $CaNa_2EDTA$ (500 ppm) or Na-HMP (500 ppm), the rate of deterioration of pigments (anthocyanins and carotenoids) was not so pronounced as the control during a six-month storage period (Figures 6 and 7). Therefore, in addition to their water softening ability, EDTA and Na-HMP inhibit the degradation of pigments in canned cherries and canned apricots. The changes of carotene in canned carrots (Figures 3 and 4) may result from cis-tran isomerization (Sheft et al. , 1949).

As a result of increase in hydrogen ions in the canned fruits solution, the hydrolysis and oxidation of flavor compounds such as aldehydes, alcohol, and terpene are accelerated gradually in a change to their corresponding acids

(Figures 8 and 9) and increasing the total acidity (Figures 10 and 11) of the products which causes a decrease in acceptability (Table 12).

In the control samples of 0 ppm hardness of water there was a constant degradation of firmness, volatile reducing substance, pH values, acceptability, and an increase in total titratable acid which result in the hydrolysis of calcium chloride. This was not pronounced as in the samples with high content of calcium and magnesium. Texture degradation of the control samples was not affected by the presence of calcium ions. Of the five levels of water hardness investigated (0, 20, 40, 80 and 160 ppm) the 40 ppm level was found to have optimum quality, in terms of firmness, color, volatile reducing substances, and acceptability scores. Between those treated with 500 ppm of $CaNa_2EDTA$ and 500 ppm of Na-HMP, the $CaNa_2EDTA$ showed the best results in this experiment.

SUMMARY AND CONCLUSIONS

Carrots (Cultivar: Honey Sweet) were canned with $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm), respectively, using commercial methods at different levels of water hardness (0, 20, 40, 80, 160 ppm of calcium and 20 ppm magnesium). The canned carrots were then stored for six months at temperatures of 70 and 100 F. At sixty-day intervals random samples of the canned carrots were removed from each storage and evaluated for retention of firmness and color. At the end of six months differences in firmness and color degradation had decreased significantly for each level of water hardness under both storage conditions. The control samples in distilled water showed increased degradation at four and six months storage.

Sweet cherries (Cultivar: Van) and apricots (Cultivar: Large Early Montgament) were canned with $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) in 40^{o} Brix sugar solution using commercial methods and stored six months at room (70 F) temperature. At sixty-day intervals random samples of canned sweet cherries and apricots were evaluated. They showed a significant decrease in pH, firmness, volatile reducing substances but titratable acidity increased. However, when either $CaNa_2EDTA$ or Na-HMP was used at the 500 ppm level, the effect of water hardness on canned cherries and apricots was considerably reduced and the quality of canned products improved. Acceptability was greatest at 40 and 80 ppm of water hardness. The effect of hard water in the canning of sweet cherries and apricots was counteracted by $CaNa_2EDTA$ and Na-HMP by chelating the minerals in the water.

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APPENDIX

Table 1. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on firmness of canned carrots during a six-month storage period at 70 F

Months/water	Control	$CaNa_2EDTA$ (800 ppm)				Na-HPM (800 ppm)			
hardness →	0	20	40	80	160	20	40	80	160
2	183	189	192	205	182	162	172	181	230
4	143	171	184	195	176	145	155	165	174
6	100	128	141	167	163	107	116	127	141

Table 2. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on firmness of canned carrots during a six-month storage period at 100 F

Months/water	Control	$CaNa_2EDTA$ (800 ppm)				Na-HPM (800 ppm)			
hardness →	0	20	40	80	160	20	40	80	160
2	112	135	142	149	156	120	125	129	133
4	86	119	126	132	140	98	104	109	114
6	60	86	97	108	119	67	73	80	89

Table 3. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on color of canned carrots during a six-month storage period at 70 F

Months/water hardness →	Control	$CaNa_2EDTA$ (800 ppm)				Na-HMP (800 ppm)			
	0	20	40	80	160	20	40	80	160
2	1.66	1.75	1.77	1.78	1.79	1.62	1.68	1.72	1.66
4	1.55	1.70	1.71	1.77	1.74	1.56	1.62	1.68	1.60
6	1.40	1.60	1.65	1.75	1.67	1.45	1.50	1.62	1.53

Table 4. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on color of canned carrots during a six-month storage period at 100 F

Months/water hardness →	Control	$CaNa_2EDTA$ (800 ppm)				Na-HMP (800 ppm)			
	0	20	40	80	160	20	40	80	160
2	1.55	1.66	1.69	1.72	1.70	1.60	1.62	1.66	1.64
4	1.45	1.55	1.60	1.66	1.64	1.52	1.55	1.62	1.58
6	1.38	1.50	1.56	1.61	1.58	1.45	1.49	1.60	1.46

Table 5. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on pH of canned carrots during a six-month storage period at 70 F

Months/water hardness →	Control	$CaNa_2EDTA$ (800 ppm)				Na-HMP (800 ppm)			
	0	20	40	80	160	20	40	80	160
2	5.72	6.00	6.20	6.38	6.60	5.80	5.61	5.40	5.20
4	5.33	5.83	5.83	5.85	5.83	5.60	5.40	5.40	5.20
6	5.12	5.50	5.50	5.50	5.50	5.34	5.34	5.34	5.20

Table 6. Effect of $CaNa_2EDTA$ (800 ppm) and Na-HMP (800 ppm) at different water hardness on pH of canned carrots during a six-month storage period at 100 F

Months/water hardness →	Control	$CaNa_2EDTA$ (800 ppm)				Na-HMP (800 ppm)			
	0	20	40	80	160	20	40	80	160
2	5.30	5.61	5.70	5.81	5.70	5.52	5.40	5.31	5.10
4	5.28	5.29	5.29	5.38	5.24	5.20	5.21	5.22	5.10
6	5.08	5.28	5.28	5.25	5.15	5.15	5.15	5.15	5.08

Table 7. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on firmness (lbs/sq inches) of canned sweet cherries during a six-month storage period at 70 F

Water	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
hardness/months →	2	4	6	2	4	6	2	4	6
0	80	73	70	80	78	72	81	80	78
20	83	75	72	81	79	74	83	80	80
40	85	78	75	83	81	79	87	83	82
80	88	78	68	80	76	74	90	86	78
160	92	76	60	74	72	66	94	85	75

Table 8. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on pH of sweet cherries during a six-month storage period at 70 F

Water	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
hardness/months →	2	4	6	2	4	6	2	4	6
0	4.08	4.07	4.03	4.10	4.08	4.04	4.08	4.05	4.01
20	4.07	4.05	4.01	4.08	4.07	4.03	4.08	4.06	4.03
40	4.06	4.02	3.90	4.06	4.05	4.03	4.08	4.05	4.02
80	4.05	4.00	3.85	4.04	4.02	4.00	4.06	4.04	4.02
160	4.00	3.90	3.70	4.02	4.00	3.90	4.04	4.00	3.90

Table 9. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on color of canned sweet cherries during a six-month storage period at 70 F

Water hardness/months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	0.330	0.292	0.270	0.430	0.420	0.410	0.372	0.360	0.350
20	0.340	0.300	0.278	0.420	0.420	0.412	0.380	0.362	0.360
40	0.362	0.310	0.287	0.432	0.425	0.420	0.400	0.380	0.370
80	0.360	0.320	0.280	0.424	0.415	0.405	0.395	0.375	0.365
160	0.350	0.300	0.270	0.405	0.400	0.390	0.362	0.350	0.340

Table 10. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on volatile reducing substance of canned sweet cherries during a six-month storage period at 70 F

Water hardness/months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	163	154	141	174	168	154	172	158	148
20	168	148	134	178	169	160	174	160	150
40	165	144	130	180	171	163	176	162	156
80	158	138	124	176	170	158	170	154	147
160	151	124	116	170	164	150	164	146	139

Table 11. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on titratable acidity (%) of canned sweet cherries during a six-month storage period at 70 F

Water hardness/months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	0.2350	0.2430	0.2742	0.2490	0.2550	0.2600	0.2492	0.2600	0.2700
20	0.2490	0.2640	0.2800	0.2490	0.2560	0.2620	0.2492	0.2630	0.2654
40	0.2555	0.2750	0.2853	0.2500	0.2600	0.2680	0.2492	0.2650	0.2679
80	0.2600	0.2890	0.2966	0.2554	0.2679	0.2750	0.2510	0.2679	0.2742
160	0.2679	0.2928	0.3136	0.2650	0.2742	0.2803	0.2550	0.2742	0.2790

Table 12. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on organolyptic quality evaluation of canned sweet cherries after a six-month storage period at 70 F

Quality/water hardness →	Control					$CaNa_2EDTA$ (500 ppm)					Na-HMP (500 ppm)				
	0	20	40	80	160	0	20	40	80	160	0	20	40	80	160
Texture	4.2	6.2	7.0	5.0	3.3	7.0	7.2	9.0	8.2	7.2	6.0	7.0	8.5	8.0	8.0
Flavor	4.0	4.5	5.1	5.3	3.5	7.2	8.0	8.5	8.0	6.8	6.5	6.5	8.0	8.0	7.5
Color	4.5	5.0	5.3	5.2	3.0	7.0	7.5	9.0	8.2	6.5	7.0	6.3	8.2	7.2	7.5

Table 13. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on firmness of canned apricots during a six-month storage period at 70 F

Water hardness/Months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	38	34	30	70	65	60	63	50	46
20	44	42	36	72	66	62	70	58	52
40	64	52	45	74	68	64	80	62	58
80	73	60	48	76	70	58	68	60	55
160	80	60	40	80	65	53	63	55	49

Table 14. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on pH of canned apricots during a six-month storage period at 70 F

Water hardness/Months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	3.58	3.50	3.45	3.60	3.55	3.50	3.60	3.55	3.50
20	3.58	3.50	3.45	3.63	3.60	3.55	3.65	3.60	3.50
40	3.58	3.50	3.50	3.66	3.63	3.60	3.68	3.65	3.50
80	3.60	3.55	3.50	3.68	3.60	3.55	3.70	3.65	3.50
160	3.73	3.68	3.40	3.70	3.68	3.50	3.70	3.60	3.45

Table 15. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on titratable acidity (%) of canned apricots during a six-month storage period at 70 F

Water hardness/Months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	0.5358	0.5395	0.5450	0.4860	0.4990	0.5109	0.4860	0.4950	0.5050
20	0.5109	0.5234	0.5353	0.4984	0.5100	0.5200	0.5058	0.5410	0.5450
40	0.5234	0.5340	0.5460	0.5020	0.5109	0.5230	0.5407	0.5500	0.5510
80	0.5334	0.5450	0.5550	0.5109	0.5200	0.5280	0.5458	0.5580	0.5595
160	0.5500	0.5540	0.5700	0.5230	0.5285	0.5310	0.5460	0.5600	0.5680

Table 16. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on volatile reducing substance of canned apricots during a six-month storage period at 70 F

Water hardness/Months →	Control			$CaNa_2EDTA$ (500 ppm)			Na-HMP (500 ppm)		
	2	4	6	2	4	6	2	4	6
0	130	120	112	145	140	132	141	135	130
20	140	130	121	150	142	134	143	140	132
40	152	139	128	160	156	148	158	150	142
80	150	140	120	158	150	142	153	144	136
160	142	130	110	152	142	135	148	140	130

Table 17. Effect of $CaNa_2EDTA$ (500 ppm) and Na-HMP (500 ppm) at different water hardness on color of canned apricots during a six-month storage period at 70 F

Water hardness	Months					
	2		4		6	
	+a	+b	+a	+b	+a	+b
			Control			
0	26.5	23.1	27.3	23.0	27.5	22.5
20	26.8	23.5	27.2	23.3	27.3	22.3
40	26.1	23.6	27.0	23.8	27.4	23.5
80	26.0	23.2	26.5	22.7	27.8	22.3
160	26.8	22.7	27.2	22.0	28.5	21.5
			$CaNa_2EDTA$ (500 ppm)			
0	24.2	23.7	25.0	23.6	26.0	23.6
20	23.8	24.0	25.0	23.7	26.2	23.5
40	23.5	24.8	25.0	24.5	26.1	24.2
80	24.2	24.4	25.1	24.1	27.0	24.0
160	24.0	23.8	25.5	23.6	26.0	23.5
			Na-HMP (500 ppm)			
0	26.5	23.6	26.5	23.4	27.3	23.0
20	25.6	23.8	26.8	23.8	27.5	23.5
40	25.0	24.3	26.2	24.2	27.0	24.0
80	25.2	24.0	26.5	24.0	27.0	23.8
160	25.6	24.0	26.7	23.8	27.5	23.7

Table 18. Analysis of variance for cherries due to chemical treatment, storage, and water hardness

Treatment	df	Mean square			
		Color	VRS	TA	Firmness
Chemical	2	0.041**	2050**	0.0005**	184**
Hardness	4	0.0021**	289**	0.0007**	32 ns
Time	2	0.0052**	2282**	0.0022**	46**
Error	36	0.00003	22	0.000036	31

*Significant at 5% level
**Significant at 1% level, according to F-Distribution (Bernard, 1966).
ns = not significant
VRS = volatile reducing substances
TA = titratable acidity

Table 19. Analysis of variance for apricots due to chemical treatment, storage, and water hardness

Treatment	df	Mean square			
		Color	VRS	TA	Firmness
Chemical	2	5.0*	904**	0.0017**	1400**
Hardness	4	1.2 ns	383**	0.00065*	251**
Time	2	98**	1197**	0.0012*	1115**
Error	36	1.1	12	0.00025	50

*Significant at 5% level
**Significant at 1% level, according to F-Distribution (Bernard, 1966).
ns = not significant
VRS = volatile reducing substances
TA = titratable acidity

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