MINERAL CONTENT OF SWEET CORN AND BROCCOLI COOKED IN WATERS OF VARYING HARDNESS

by

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INTRODUCTION

Recent food consumption surveys have indicated that there may be problems with certain minerals in the North American diet. The 1977-78 Nationwide Food Consumption survey labeled calcium, iron, and magnesium as possible problem nutrients for certain groups (1). Calcium intake was especially low in the South and in non-Caucasians, possibly because of lactose intolerance in these populations (2). When data for diets analyzed by the FDA were adjusted to 1500 calories per day, the levels of calcium, iron, zinc, copper, and magnesium in all diets were approximately half of the United States Recommended Dietary Requirements (USRDA). This level of calorie intake is typical of many teenage girls and women (3).

Mineral intakes may be related to the finding that incidence of cardiovascular mortality is lower in areas with hard water. In fact, incidence of other diseases, such as nephritis, malignant neoplasms, congenital malformation of the central nervous system, bronchitis, as well as infant moralities (4), and mortalities from all causes (5) have been negatively correlated with hard water. Whereas the cause for this correlation could be spurious factors, there are other theories as to the relationship between hard water and heart disease. Some of these are 1) calcium and/or magnesium in hard drinking water help meet total dietary requirements for these nutrients and so protect against cardiotoxic agents (6); 2) soft water is chemically more active than hard water and increases the liberation from pipes of heavy toxic metals such as lead and cadmium (6); 3) soft water may extract more minerals from food (6); and 4) calcium may give protection against the hypertensive effect of sodium (7).

The estimated intake of calcium and magnesium from drinking water is less than 10-20% of the total daily intake and so does not seem large enough to cause a drastic effect in health (4). Perhaps the differences in mortality are affected or compounded by amounts of calcium and magnesium in food cooked in the hard water. Conclusive results showing the factor(s) in water that may affect cardiovascular health are complicated by uncertainties as to exact amounts of minerals in foods. Data in food composition tables are for vegetables cooked in distilled water and so do not reflect the amounts of minerals actually ingested. Under certain conditions, vegetables may lose undesirable elements, such as nitrates, to and gain valuable nutrients from cooking water. This fact makes necessary the need to reconsider the loss and/or gain of nutrients to water depending on the local water conditions, the vegetable, and its preparation (8).

The purpose of this study was to investigate how increasing the surface area of broccoli and corn affected mineral changes after cooking in hard and soft waters. Changes in calcium, magnesium, sodium, potassium, iron, and zinc were monitored by flame emission and atomic absorption spectrophotometry. This type of study was recommended by a World Health Organization Working Group on health effects of removing substances occurring naturally in drinking water (8). This group recommended seeking information about changes in the mineral and other nutrient content of foods during their preparation, especially when boiled in waters of different mineral content.

REVIEW OF LITERATURE

Water Constituents

The concentration of dissolved substances varies greatly in waters depending on geographic location and season of the year. Usually, the concentration of cations in order of abundance is calcium, then sodium, magnesium, potassium. For anions the order is bicarbonate, sulfate, then chloride. These usually are present in concentrations of from one to 250 mg./l. Other cations present, such as iron, zinc, manganese, aluminum, and strontium, are usually in lower concentrations (less than one mg./l. and many even less than one ug./l.) (8).

Hardness refers to the tendency of cations such as calcium, magnesium, iron, manganese, aluminum, and strontium to form insoluble compounds with soap. Although all of these minerals contribute, water hardness is expressed as the equivalent concentration of calcium carbonate (6). In the past, hardness was expressed as grains per gallon but now is expressed in ppm or mg./l. The conversion factor is one grain per gallon = 17.1 ppm or mg./l. (9). Drinking water with a hardness over 150 mg./l. is considered to be "hard" (6).

Calcium and magnesium are the main contributors (approximately 95%) to water hardness. There are two kinds of hardness, temporary and permanent. Temporary refers to the bicarbonate compounds formed with calcium and magnesium. This hardness can be eliminated by boiling the water and converting soluble bicarbonates to insoluble carbonates and removing them as sediment. Permanent hardness results when magnesium and calcium complex with sulfates. These complexes cannot be boiled out but must be removed chemically (10).

In addition to forming complexes with anions, calcium and magnesium can exist as simple ions, as complexes with organic matter, and in dispersion. Sodium and potassium usually are dissolved freely and ionized fully in water. Iron and other polyvalent ions form polymeric hydroxides that can adsorb lead, cadmium, or mercury (8).

In some areas, hard water is softened before being distributed to the community. In others, water may be softened at home to varying degrees.

There are several ways to soften water. If the water contains a high amount of bicarbonate ions, lime may be used to soften it. This action raises the pH and precipitates calcium carbonate; at a higher pH magnesium hydroxide also is precipated. No ions are added in this process, and the mineral content is reduced. If the principal anion is sulfate, the water still can be softened by using sodium carbonate to raise the pH. In this process sodium ions are added. Sodium is bound to an ion exchange resin in a third method of softening, the only procedure presently used for home water softeners. Calcium and magnesium ions in the water are replaced with twice as many sodium ions. In some areas this method also is used for municipal water treatment (8).

Factors influencing mineral losses in vegetables

Cooking losses in vegetables can occur by 1) the solvent action of water or dilute salt solutions; 2) chemical decomposition, which may be caused by heat or a reaction of the cooking water; 3) oxidation; 4) mechanical loss of solids to the cooking water; and 5) volatilization. Mechanical losses can occur by agitation, such as too rapid boiling, or overcooking, resulting in excessive disintegration of the vegetable. Volatile losses are mostly water, though some flavor compounds are lost to steam (11).

Since water is the cooking medium in the boiling method of vegetable preparation, water soluble nutrients are lost. Generally, the more water used for cooking, the greater the loss of soluble nutrients. Increased surface exposure or longer cooking time results in even greater loss of water soluble constituents (11). Krehl (12) concluded that leaching is the source of greatest nutrient loss during boiling. Mineral losses are not as great as vitamin losses and usually can be correlated with loss of dry matter. Dry matter is lost when vegetables degrade during long cooking, thus the length of the cooking period contributes to losses. Reports show that average loss of dry matter in vegetable cooking is 15% during steaming, 30% when boiling in a small amount of water, and 40% when twice the amount of water needed to cover the vegetable is used (11).

Some ions leach more readily than others. Salts of potassium, sodium, and iron are more soluble than magnesium and calcium (11). Perhaps the roles of magnesium and calcium in the plant cell contribute to the lesser amount of leaching. Calcium and magnesium can form salts with pectic acids in and between cell walls or in the middle lamella (10). This results in an increased firmness of the middle lamella and primary cell wall, helping the vegetable to resist degradation during heating (13). Magnesium's role of uniting the four pyrrole groups forming the porphyrin ring of chlorophyll also may help to limit this mineral's leaching.

Recommendations for boiling most vegetables include using as little water as possible and covering to speed cooking and reduce volatile losses (10). Exceptions to this are the strong flavored vegetables in the Brassica and Allium families which contain sulfur compounds. Charley (10) recommends cooking broccoli, a member of the Brassica family, with just enough water to cover, without a lid. The water dilutes the acids; and the uncovered pan allows unpleasant volatile acids to escape. This helps to keep green vegetables from becoming dull and olive-colored.

Noble and Halliday (14) cooked green beans, asparagus, spinach, peas, and carrots in two liquids with different calcium concentrations--Chicago city water (30-38 mg./l. Ca) and a solution of calcium chloride (76-158 mg./l. Ca) plus distilled water. All vegetables except carrots cooked in water with calcium contained more calcium than did the raw products. But when these vegetables were cooked in distilled water, they lost calcium. Carrots lost less calcium when cooked with calcium present in the liquid. Researchers noted that as the calcium concentration of the water increased, the quantity of calcium taken up by the vegetable became relatively smaller. Phosphorus losses were unaffected by the calcium concentration of the cooking liquid.

In another experiment, Noble and Halliday (15) cooked additional vegetables, including broccoli. Vegetables cooked in Chicago city water, distilled water, and steam were compared to raw vegetables. Changes in calcium content for all treatments were small compared to previous work, possibly because of the short cooking periods. Broccoli, along with carrots, califlower, and turnips lost the most calcium in distilled water but still retained 75-80% of the original amount. When broccoli and nine other vegetables were cooked in Chicago city water (approximately 30 mg./l. Ca), calcium retention was 83-95%. Six other vegetables cooked in Chicago city water gained calcium (6-27%).

Horner (16) used hard water to compare mineral losses during cooking and canning of vegetables. Calcium was the only constituent absorbed from the water. When the water used contained calcium but not magnesium, the magnesium content of peas decreased. Horner reasoned that the more soluble con= stituents in peas were replaced by less soluble calcium. In earlier work, Horner showed that if enough sodium chloride (NaCl) were added to the water, a greater amount of calcium leached into the water. Since potassium diffused so rapidly, its loss appeared to depend more on the proportion of solid to liquid than on the length of boiling time. In blanching, losses of potassium ranged from 10 to 40% though the time of blanching was only three to seven minutes.

Eheart and Sholes (17) tested four different methods of blanching green beans on phosphorus, calcium, and ascorbic acid content. Green beans were blanched in plain tap water, tap water plus sodium sulfate hydrogen ($NaHSO_3$), tap water plus $NaHSO_3$ and sodium sulfate (Na_2SO_4), and steam. Beans were blanched for 18 minutes in water and 30 minutes in steam. The amounts of $NaHSO_3$ and Na_2SO_4 were enough to lower the temporary hardness of the tap water from 200 to 105 mg./l. Beans blanched in all tap water, whether sodium compounds were added or not, contained significantly more calcium. Those beans steam-blanched did not contain more calcium than the raw. Beans took up calcium from all tap waters to about the same degree, even though hardness of plain water was almost twice that of the tap waters with sodium compounds added.

Lee et al. (18) substantiated the above results when they blanched peas and beans in distilled and two different hardnesses of water. The vegetables blanched in hard water gained more calcium than did the others.

Bryant and Jordan (19) cooked three varieties each of cabbage wedges, carrots, and snap beans in distilled, hard (92 mg./l. Ca), and soft (26 mg./l. Ca) waters and measured calcium contents. All vegetables lost calcium in distilled and soft waters to the same degree; therefore, the effect was attributed to leaching, not to the excess sodium ions. The cabbage lost the most calcium even though cooking time was shorter. Only the beans and one variety of carrots gained a significant amount of calcium in hard water. The more mature carrot variety was cooked longer (30 minutes) than was the young variety (20 minutes) and lost more calcium than did the young carrots.

Retention of minerals in frozen vegetables was observed during cooking for home use by Teply and Derse (20). All vegetables were cooked in distilled water. In most cases 10% or less of the minerals leached into the liquor. Sodium leached most readily with 10-25% appearing in the cooking water. Broccoli, both spears and chopped, and cut corn were observed for mineral retention. Chopped broccoli retained more iron, magnesium, potassium, and sodium than spears, even though spears were cooked for a total of eight minutes as opposed to 10 for cuts. No explanation was provided for the finding that the larger pieces leached more of these minerals.

Suarez and Pozuelo (21) studied the losses of manganese, iron, sodium, potassium, calcium, and magnesium in green beans, cabbage, beet greens, spinach, and artichokes using different cooking treatments. All were cooked in distilled water but the amount of water, length of cooking time, added salt and oil, size of pieces, and kind of cooking utensil used were varied. Cutting vegetables into smaller pieces resulted in a greater loss of all minerals except calcium. In general, calcium loss was the least, followed by iron. Except in green beans, the mineral lost to the greatest extent was potassium, followed by magnesium. Sodium loss was the most variable. Cabbage lost calcium more easily than did spinach. Researchers postulated that spinach lost calcium less easily than cabbage did because the calcium was in a less soluble form (as calcium oxalate) compared to the more soluble form in cabbage. The greatest percentage of loss of all minerals occurred in the first ten minutes of cooking.

Marston et al. (22) studied calcium and magnesium retention in cabbage, carrots, and broccoli cooked in water containing various levels of calcium and phosphorus. Portions were cooked in distilled water; tap water containing approximately 160 mg./l. Ca, 150 mg./l. Mg, and 0.8 mg./l. P; and distilled water with the addition of 60 mg./l. P in the form of sodium polyphosphate ($Na_5P_3O_{10}$). The vegetables cooked in distilled water or distilled water added $Na_5P_3O_{10}$ had lower ($p<0.01$) calcium content than those cooked in tap water. The vegetables cooked in tap water were not significantly different in calcium content from the raw. The magnesium content of cabbage cooked in tap water was equal to that of the raw vegetable. Both raw cabbage and that boiled in tap water were higher in magnesium than cabbage cooked either in distilled water or distilled water with added $Na_5P_3O_{10}$. Magnesium contents of carrots and broccoli cooked in tap water were lower ($p<0.01$) than raw and higher ($p<0.01$) than those cooked in distilled water with or without added $Na_5P_3O_{10}$. The investigators suggested that perhaps calcium and magnesium combined with the pectates or low-ester pectinates to form insoluble salts that prevented excessive leaching of those minerals, or perhaps an equilibrium existed on each side of the cell wall so that calcium and magnesium loss was limited.

Five different vegetables (potatoes, cabbage, califlower, peas, and carrots) were cooked in either hard or soft water in England by Dauncey and Widdowson (23). Vegetables cooked in hard water took up calcium from the water while those in soft Glasgow water lost calcium. In both cities vegetables lost magnesium to water; however, magnesium content of water was not very high in either city. The workers concluded that the contribution of calcium and magnesium in cooked vegetables to the total calcium and magnesium intake was small. Although the calcium and magnesium from vegetables did not make a large contribution, the researchers suggested that the increase in the calcium content of vegetables cooked in hard water would be more important for persons with diets low in total calcium. Similarly, the decrease in vegetable calcium could be important for those with low calcium intake living in soft water areas.

Zohm et al. (24) observed mineral losses in spinach cooked at different temperatures. At all temperatures sodium and potassium losses were higher than magnesium and calcium losses. Calcium contents increased because of the relatively hard water used for the experiments. The smaller magnesium loss was attributed to its being bound in the chlorophyll molecule. The calcium decrease in cooking water was much slower when water was heated with no vegetable. Researchers observed that the spinach attracted and absorbed the calcium in the water.

Haring and Van Delft (6) cooked vegetables in waters from six different Netherlands cities. Calcium contents of the waters varied from 17 to 114 mg. of calcium per liter; and magnesium contents, from 2.2 to 19 mg. per liter. One hundred fifty grams each of potatoes, califlower, carrots, and endive were cooked in 250 ml. of water and 12.5 gm. salt. The calcium content of the vegetables usually increased when cooked in hard water and decreased when cooked in soft water. Magnesium content of the vegetables decreased with all types of cooking water, but slightly more was lost with soft than with hard water. Iron, manganese, potassium, and zinc levels were lower after cooking regardless of water hardness. The investigators concluded that the relationship between cardiovascular mortalities and hardness of water might be attributed to deficiencies of calcium and magnesium in soft water and increased leaching of those minerals from vegetables cooked in soft water. They recommended further study on factors affecting changes in mineral content of food during cooking.

MATERIALS AND METHODS

"Merit" variety corn was obtained in August and "Green Comet" broccoli, in October from the Kansas State University Departments of Horticulture and Extension Horticulture, respectively. Six different waters were analyzed preliminarily for mineral content (Appendix, p. 51). The three waters chosen for the various treatments were distilled deionized, hard well water (hardness of approximately 326 mg./l.) and the same well water treated with a home water softener (hardness of approximately 75 mg./l.). Waters were measured for mineral content and pH (Appendix, p. 52). Enough water for cooking all six replications of one vegetable was obtained immediately before cooking and stored in gallon glass jars at 2°C (35°F) in a standard combination refrigerator.

All glassware were acid-rinsed; pans and other metalware used were stainless steel. One-quart pans were used for cooking all vegetables except corn on the cob, which required 1½-quart pans. All cooking was done on a Roper top unit gas range (Model 540).

Preparation of vegetables

For each type of water, a vegetable was cooked as follows: corn was cooked on the cob and cut off the cob; broccoli was cooked in stalks and in pieces. Samples of each raw vegetable were kept and analyzed as controls.

Broccoli. A separate head of broccoli was used for each treatment, including raw. Leaves and woody protrusions were removed. Stems were trimmed so that measurement from the tip of the floweret to the bottom of the stem equaled 15 cm. One hundred grams were taken from each head, which was split lengthwise so that each stalk consisted of the same amount of flower and stem. The diameter of each stalk was approximately 1.0-1.5 cm. thick. Chopped broccoli was cut into 1.5-2.0 cm. pieces from 100 gm. stalks so as to include the same parts as did broccoli stalks.

Corn. Large ears of corn (176-224 gm.) were used for cooking off the cob so as to obtain 100 gm. of corn from the ear. For whole corn the ear was weighed, trimmed to 15 cm. to fit in the pan, then weighed again. The ear was put into the pan and water poured over the ear to cover it. The corn was removed, and water was heated to boiling as described below.

For all vegetables, water was brought to a boil, the vegetable added and water allowed to return to a boil. Timing began at this point with a lid put on for corn and left off for cooking broccoli. The heat was turned down and water kept to a low boil for the specified time (Table 1).

Table 1. Timetable and quantities for cooking of vegetables.

variable	amount	water (ml.)	time (min.)
corn on the cob	1 ear	750-835	5
corn, cut off the cob	1 ear	110	5
broccoli, stalks	100 gm.	325	8
broccoli, chopped	100 gm.	250	7

Analysis

After cooking, the vegetable was drained and the cooking water poured through cheesecloth treated according to a method of Halliday and Noble (25) soaked in hot 1.0% HCl for 10 minutes, rinsed with distilled water, soaked in hot 1.0% NaOH for 10 minutes and then rinsed thoroughly in distilled, then deionized water. The volume then was measured. The pan was rinsed twice with distilled deionized water, and those contents were poured also through the cheesecloth. Cooking water was put into 1000 ml. beakers (corn), or pint jars (broccoli), covered tightly with plastic wrap, and frozen at -25°C (-13°F). Vegetables were weighed and then cut into or put directly into preweighed Petri dishes. These were weighed again and frozen. Corn cobs were not analyzed.

Both vegetables were freeze-dried (Virtis Model 10-100) and ground in a Waring blender (Model 91-203). The ground vegetables were stored in polyethylene bags at -25°C (-13°F) until analysis. For corn, 1.5 gm. samples, and for broccoli, 1.0 gm. samples were weighed out as needed.

Corn and broccoli cooking liquids were thawed at room temperature. Broccoli liquid was transferred to volumetric cylinders and the volume recorded. Aliquots of broccoli liquid were transferred to acid-rinsed 30 ml. Coors crucibles, evaporated, charred, and then ashed and digested as were vegetable samples. Total corn cooking liquids were evaporated partially in beakers and transferred to crucibles to be evaporated, charred, and ashed. Calcium, magnesium, iron, and zinc were analyzed by atomic absorption; and potassium and sodium, by flame emission according to a modified AOAC method (25, Appendix, pp. 51-54) at American Institute of Baking, Manhattan, Kansas, on an Instrumentation Laboratories atomic absorption spectrophotometer (Model 251) (27,28).

Before cooking of vegetables, both sets of cooking waters were analyzed for mineral content by atomic absorption spectrophotometry according to a modified method of Willis (29). Distilled deionized water was used to set the instrument to zero and as a blank. Waters were diluted with distilled deionized water for calcium, magnesium, sodium, and potassium determinations and analyzed directly for determination of iron and zinc. Hydrochloric acid was added to waters for iron and zinc determination so as to correspond with standards.

Statistical analysis

A randomized complete block design was used to examine the separate and interactive effects of water and size of vegetable. Significant differences were determined by a general linear models analysis of variance procedure (30).

RESULTS AND DISCUSSION

Calcium

Corn. The calcium content of corn was affected by type of water ($p<0.001$) but not by size or interaction of water and size (Table 2). Corn cooked in hard water contained more calcium than raw corn or corn cooked in either soft or distilled water (Table 3). The percentage retention of calcium in both corn on the cob and off the cob is illustrated in Figure 1a. This finding

Table 2. Analysis of variance for mineral content of cooked corn.[a]

		mean squares and significance					
source of variation	df	calcium	magnesium	iron	zinc	sodium	potassium
water	2	5128.41***	1338.70	0.47	0.26	1939.24*	228823.45
size	1	34.49	10060.28***	1.24	6.07**	26.06	1865051.91***
water x size	2	455.29	739.02	0.63	2.05*	487.87	19966.03
treatment	6	1962.74**	2776.70	0.63	1.87	784.67	514337.35*

[a]equivalent to 100 gm. raw

*$p<0.05$ **$p<0.01$ ***$p<0.001$

Table 3. Least square means* for mineral content of corn.

source of variation	calcium	magnesium	iron	zinc	sodium	potassium
water	--------------------------	----------------------mg./100	gm.------------------------			
distilled	[a]3.58±0.63	[a]27.07±0.74	[a]0.25±0.03	[a]0.75±0.02	[a]3.82±0.68	[a]243.43±10.38
soft	[a]4.32±0.60	[a]25.65±0.72	[a]0.29±0.03	[a]0.72±0.02	[b]6.32±0.68	[a]259.62±10.38
hard	[b]7.99±0.64	[a]27.84±0.68	[a]0.26±0.03	[a]0.74±0.02	[a]4.27±0.64	[a]231.20± 9.79
size						
off cob	[a]5.19±0.51	[a]25.10±0.60	[a]0.25±0.02	[a]0.69±0.02	[a]4.89±0.54	[a]221.24± 8.32
on cob	[a]5.40±0.50	[b]28.61±0.57	[a]0.29±0.02	[b]0.78±0.02	[a]4.72±0.54	[b]268.26± 8.32
treatment						
raw	[a]4.75±0.83	[a]28.66±1.82	[a]0.26±0.03	[a]0.74±0.05	[a]4.61±0.95	[cd]287.87±20.79
distilled off cob	[a]2.70±0.92	[a]25.99±2.02	[a]0.26±0.03	[a]0.76±0.05	[a]3.13±0.95	[ab]219.25±16.44
distilled on cob	[a]4.38±0.92	[a]27.89±2.03	[a]0.25±0.04	[a]0.74±0.06	[a]4.39±1.10	[acd]267.60±18.38
soft off cob	[a]4.62±0.92	[a]23.82±2.03	[a]0.25±0.04	[a]0.66±0.06	[a]6.68±1.10	[abc]232.31±18.38
soft on cob	[a]3.94±0.83	[a]27.31±1.82	[a]0.33±0.03	[a]0.77±0.05	[a]5.84±0.95	[d]286.93±16.44
hard off cob	[b]8.18±0.92	[a]25.22±1.82	[a]0.23±0.03	[a]0.66±0.05	[a]4.75±0.95	[b]212.16±16.44
hard on cob	[b]7.80±0.92	[a]30.47±1.82	[a]0.28±0.03	[a]0.82±0.05	[a]3.80±0.95	[abd]250.24±16.44

*Means of six replications.

[abcd]Values bearing different letters within the same column differ significantly ($p < 0.05$) as separated by least square means.

Figure 1a - Percentage retention of calcium in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 1b - Percentage rention of calcium in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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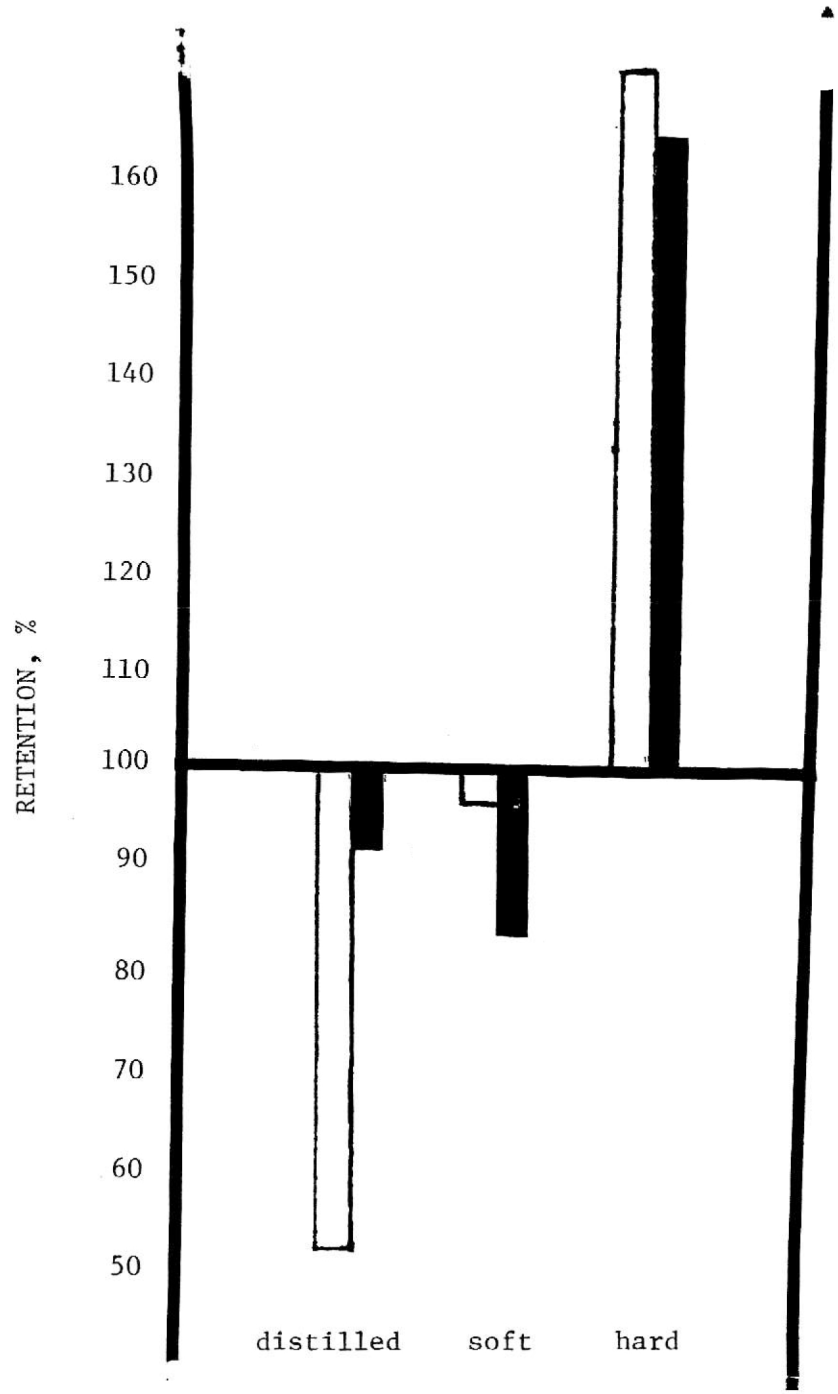
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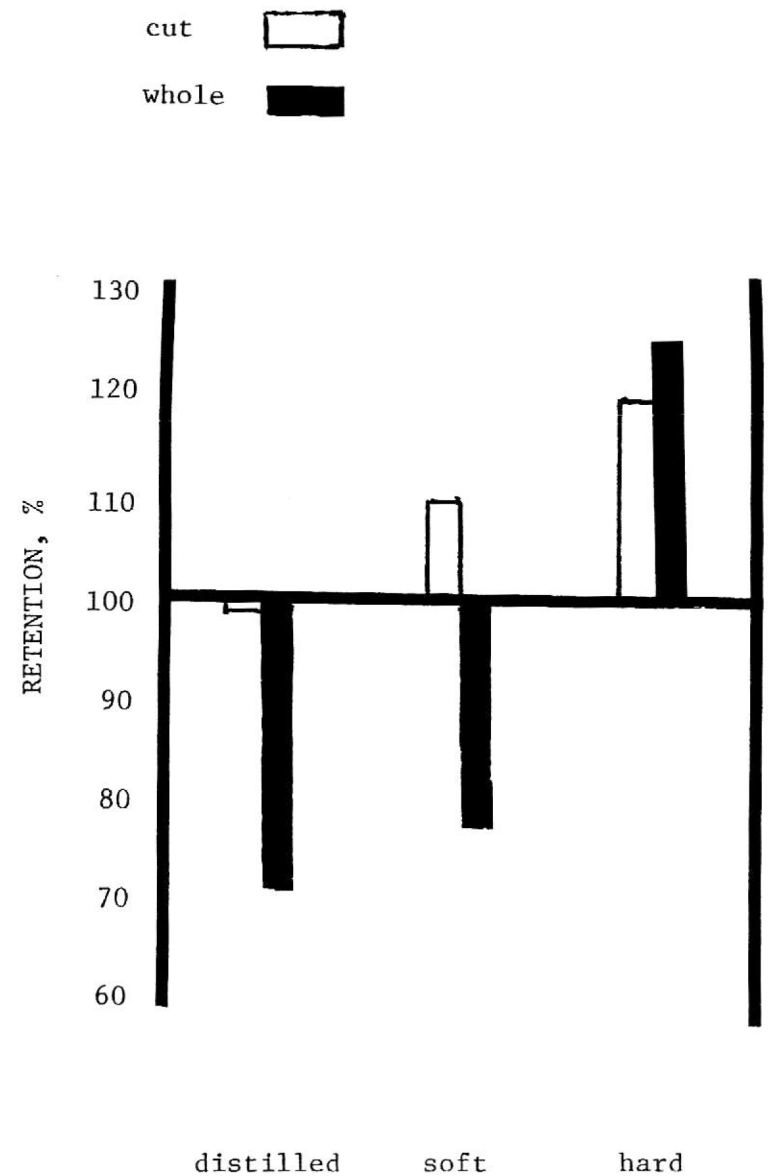
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agrees with many researchers (6,14,16,17,18,19,23,24) who have found vegetables to gain calcium when cooked in hard water. Calcium leached out to the same extent from corn cooked in soft and distilled waters. Bryant and Jordan (19) also found vegetables to lose calcium to the same degree in soft and distilled waters.

Monitoring of the calcium content of corn liquid after cooking showed a difference ($p<0.001$) resulting from type of water (Table 4). Corresponding losses and gains in the water indicated that hard water lost more calcium to the vegetable than did soft and distilled, which gained calcium (Table 5). Suarez and Pozuelo (21) showed similar results regarding the effect of size to calcium loss. They found five vegetables cooked in distilled water to lose more potassium, manganese, sodium, and magnesium, but not calcium when cut into smaller pieces.

Broccoli. Water, size, and interaction of the two did not affect significantly calcium retention of the broccoli itself (Table 6). However, the vegetables cooked in hard water did gain some calcium, and those cooked in soft and distilled waters lost calcium except for chopped broccoli cooked in soft water (Table 7). Figure 1b illustrates how broccoli follows the same trend of percentage calcium retention regarding water type as corn except for chopped broccoli in soft water. This could be attributed to increased calcium absorption because of broccoli's greater surface area or to possible contamination of calcium from other sources such as glassware. Whole broccoli lost slightly more calcium in distilled and soft waters, possibly as a result of the greater amount of water used for cooking stalks and the slightly longer cooking time. Noble and Halliday (15) also found broccoli to lose calcium in a 30 mg./l. solution, though not as much as when cooked in distilled water. In that study some other vegetables gained calcium.

Table 4. Analysis of variance for mean change in mineral content of corn cooking liquid (mg/l.)

		mean squares and significance					
Source of variation	df	calcium	magnesium	iron	zinc	sodium	potassium
water	2	5534.72***	371.97***	0.00	0.00	2527.93**	4653.67
size	1	30.37	12807.93***	2.60***	11.42***	17697.63***	3131415.38***
water size	2	664.25	147.60**	0.01	0.00	2026.25**	2612.24

*$p<0.05$ **$p<0.01$ ***$p<0.001$

Table 5. Least square means* for mineral change in corn cooking liquid.

source of variation	calcium	magnesium	iron	zinc	sodium	potassium
water	←mg./l.→					
distilled	^{a}3.82±5.22	^{a}26.74±1.69	^{a}0.35±0.06	^{a}0.70±0.03	^{a}15.05±5.88	^{a}368.44±10.06
soft	^{a}2.15±6.43	^{a}29.14±2.01	^{a}0.40±0.07	^{a}0.68±0.04	^{b}-15.81±6.11	^{a}416.13±25.98
hard	^{b}-41.12±5.60	^{b}15.55±2.08	^{a}0.37±0.06	^{a}0.69±0.03	^{a}20.46±5.62	^{a}404.29±17.65
size						
off cob	^{a}-12.84±4.80	^{a}48.33±1.55	^{a}0.70±0.04	^{a}1.37±0.03	^{a}35.45±6.11	^{a}777.04±19.21
on cob	^{a}-10.59±4.65	^{b}-0.71±1.65	^{b}0.05±0.05	^{b}0.02±0.03	^{b}-23.26±4.52	^{b} 15.54±15.19
water x size						
distilled off cob	^{a} 7.11±7.38	^{a}53.22±2.38	^{a}0.68±0.08	^{a}1.38±0.05	^{a}31.69±9.47	^{a}529.90±28.82
distilled on cob	^{a} 0.53±7.38	^{b} 0.26±2.38	^{a}0.39±0.08	^{a}0.02±0.05	^{b}-1.40±6.97	^{a} 6.98±25.96
soft off cob	^{a} 6.87±9.93	^{a}45.79±3.22	^{a}0.69±0.11	^{a}1.35±0.06	^{a}34.29±9.44	^{a}798.74±42.01
soft on cob	^{a}-2.56±8.42	^{b} 1.59±2.73	^{a}0.12±0.09	^{a}1.01±0.05	^{c}-65.90±8.01	^{a} 9.84±28.82
hard off cob	^{a}-52.50±7.38	^{c}34.98±2.38	^{a}0.73±0.08	^{a}1.36±0.05	^{a}43.50±8.00	^{a}802.48±25.96
hard on cob	^{a}-29.73±8.42	^{b}-3.89±3.22	^{a}0.01±0.08	^{a}0.01±0.05	^{b}-2.48±8.01	^{a} 29.79±24.96

*Means of 6 replications.

^{abcd}Values bearing different letters within the column differ significantly ($p<0.05$) as separated by least square means.

Table 6. Analysis of variance for mineral content of cooked broccoli.[a]

		mean squares and significance					
source of variation	df	calcium	magnesium	iron	zinc	sodium	potassium
water	2	23509.40	1998.74	1.47	0.12	59066.92**	29903.13
size	1	25206.81	1553.16	11.71	1.16	265.63	29736.49
water x size	2	9913.90	113.30	2.31	0.48	185.32	105645.58
treatment	6	20108.94	4336.54**	3.38	1.70	20048.12***	1243198.27***

[a]equivalent to 100 gm. raw

* $p<0.05$ **$p<0.01$ *** $p<0.001$

Table 7. Least square means* for mineral content of broccoli.

source of variation	calcium	magnesium	iron	zinc	sodium	potassium
	mg./100 gm.					
water						
distilled	^{a}29.49±4.82	^{a}12.50±0.99	^{a}0.59±0.07	^{a}0.25±0.03	^{a}10.31±0.79	^{a}226.84±16.01
soft	^{a}32.70±5.22	^{a}11.70±0.86	^{a}0.60±0.07	^{a}0.27±0.03	^{b}25.40±0.89	^{a}217.73±16.01
hard	^{a}42.51±4.22	^{a}14.01±1.07	^{a}0.65±0.06	^{a}0.24±0.03	^{a}10.28±0.69	^{a}214.78±14.00
size						
chopped	^{a}38.20±3.99	^{a}13.89±0.82	^{a}0.69±0.05	^{a}0.27±0.03	^{a}15.00±0.62	^{a}223.25±12.55
stalks	^{a}31.61±3.71	^{a}12.25±0.76	^{a}0.55±0.05	^{a}0.23±0.03	^{a}15.66±0.61	^{a}216.31±12.32
treatment						
raw	^{a}34.86±4.57	^{a}20.25±1.10	^{a}0.73±0.06	^{a}0.40±0.04	^{b}14.24±0.75	^{a}352.55±15.45
distilled/ chopped	^{a}34.73±6.14	^{bc}13.63±1.48	^{a}0.74±0.09	^{a}0.28±0.05	^{a}10.69±1.00	^{b}243.22±20.74
distilled/ stalks	^{a}24.66±6.14	^{bc}11.27±1.48	^{a}0.53±0.09	^{a}0.24±0.05	^{a}11.59±1.00	^{b}212.23±20.74
soft/chopped	^{a}38.62±7.07	^{bc}12.33±1.71	^{a}0.74±0.09	^{a}0.32±0.05	^{c}26.42±1.00	^{b}211.22±20.74
soft/stalks	^{a}27.30±6.14	^{c}10.83±1.48	^{a}0.56±0.09	^{a}0.23±0.05	^{c}26.03±1.00	^{b}226.02±20.74
hard/chopped	^{a}42.11±6.06	^{b}15.35±1.46	^{a}0.73±0.08	^{a}0.25±0.05	^{a}10.45±0.99	^{b}218.06±20.46
hard/stalks	^{a}43.84±5.41	^{bc}14.59±1.31	^{a}0.71±0.08	^{a}0.25±0.04	^{ab}11.89±0.89	^{b}213.42±18.28

*Means of 6 replications.

^{abc}Values bearing different letters within the column differ significantly ($p<0.05$) as separated by least square means.

Although the size of the broccoli or interaction of size with water caused no difference in the gain or loss of calcium in the cooking liquid, the type of water used resulted in significant differences ($p<0.001$) (Table 8). Hard water lost more calcium than did soft and distilled waters, which increased in calcium content (Table 9). If experimental error was introduced in the analysis of broccoli itself, then liquid calcium contents may be a better indicator of what actually occurred. Also, the calcium in the hard water could have formed complexes that adhered to the sides of the pan, appearing to be lost into the vegetable. Guthrie (25) states that in the human body, the availability of calcium from broccoli may be reduced because calcium is contained within the cell whose cellulose wall is digested with difficulty. If this cell wall also contains lignin which is even less affected by cooking, calcium will remain in the intact cell. Thus, less mineral may be released or absorbed even if the vegetable is cut into pieces.

Magnesium

Corn. The hardness of water had no significant effect on the amount of magnesium lost or absorbed by the corn (Table 2). Except for corn on the cob cooked in hard water, all cooked corn lost small amounts of magnesium (Table 3). The percentage retention of magnesium can be seen in Figure 2a. Mineral content of water appeared to be a more sensitive indicator of change ($p<0.001$) (Table 4). Soft and distilled waters gained more magnesium from the vegetable than did hard water (Table 5).

The amount of surface area of the corn affected the magnesium content of both the vegetable itself ($p<0.001$) and the cooking liquid ($p<0.001$) (Tables 2 and 4). Corn on the cob retained more magnesium than did corn cut off the cob (Table 3). Figure 2a graphically depicts percentages. Perhaps the greater magnesium content of hard water caused whole corn on the cob to gain magnesium,

Table 8. Analysis of variance for mean change in mineral content of broccoli cooking liquid (mg./l.)

		mean squares and significance					
source of variation	df	calcium	magnesium	iron	zinc	sodium	potassium
water	2	13755.40***	1315.82***	0.54**	0.03	3439.35	40534.49
size	1	1152.93	1166.41***	0.63**	0.83***	1674.16	591840.32***
water x size	2	610.54	63.46	0.07	0.08*	868.65	3729.22

*$p<0.05$ **$p<0.01$ ***$p<0.001$

Table 9. Least square means* for mineral changes in broccoli cooking liquid.

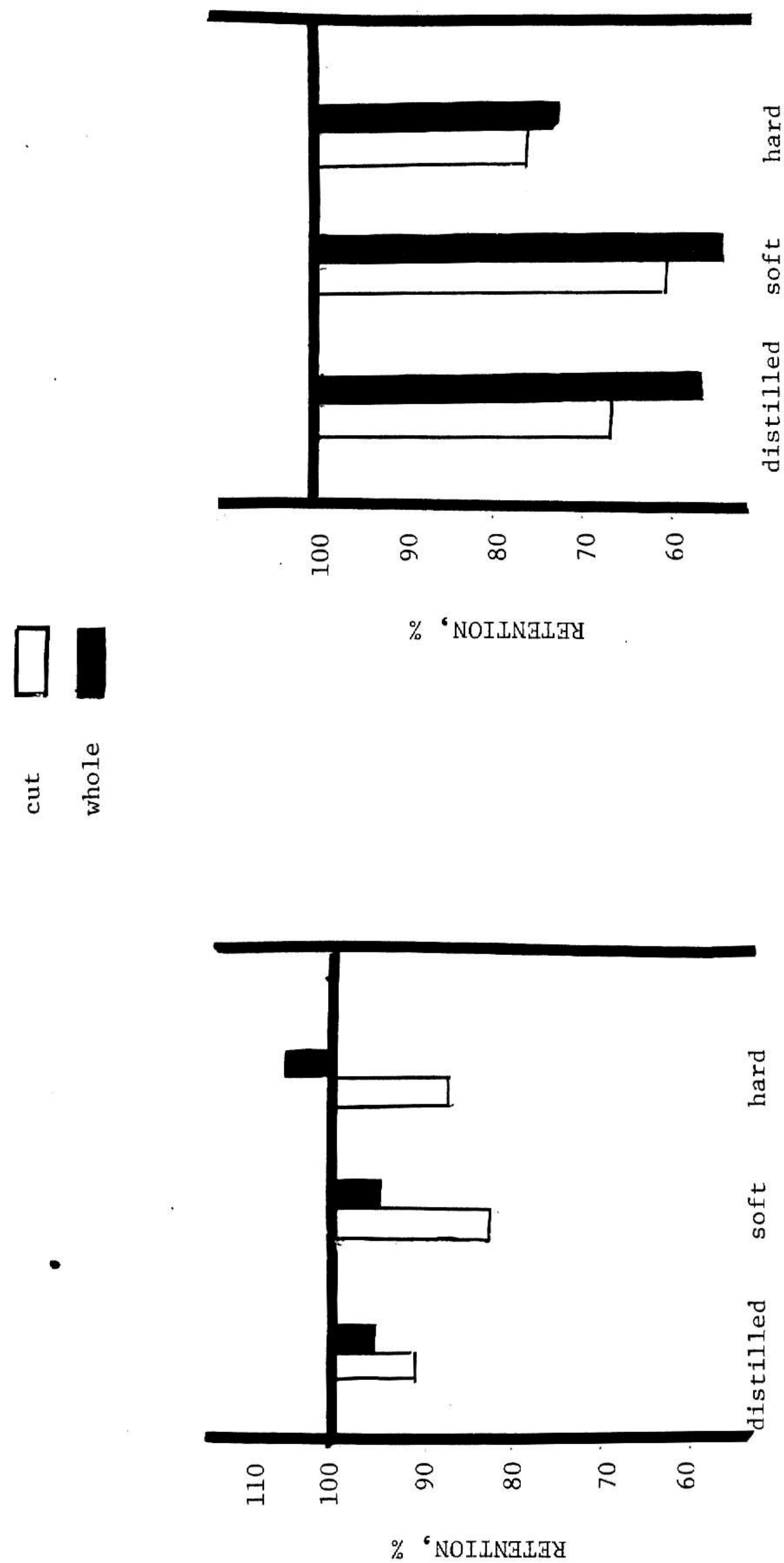
source of variation	calcium	magnesium	iron	zinc	sodium	potassium
water						
distilled	[a] 44.42±5.97	[a] 41.46±2.04	[a] 1.05±0.08	[a] 0.80±0.04	[a] 74.82±12.91	[a] 764.96±32.01
soft	[a] 42.72±5.63	[a] 37.77±1.92	[a] 1.13±0.08	[a] 0.86±0.04	[a] 69.52±12.91	[a] 728.25±32.01
hard	[b] -19.69±6.25	[b] 20.27±2.13	[b] 0.70±0.09	[a] 0.74±0.04	[a] 54.21±12.91	[a] 651.09±32.01
size						
chopped	[a] 28.44±4.94	[a] 39.15±1.69	[a] 1.10±0.07	[a] 0.96±0.03	[a] 65.29±10.54	[a] 842.99±26.14
stalks	[a] 16.53±4.78	[b] 27.18±1.63	[b] 0.82±0.07	[b] 0.64±0.03	[a] 55.74±10.54	[b] 586.55±26.14
water x size						
distilled/ chopped	[a] 51.16±8.90	[a] 47.71±3.04	[a] 1.20±0.12	[a] 0.97±0.06	[a] 77.61±18.26	[a] 909.96±45.27
distilled/ stalks	[a] 37.69±7.96	[a] 35.21±2.72	[a] 0.91±0.11	[b] 0.62±0.15	[a] 73.04±18.26	[a] 616.96±45.27
soft/chopped	[a] 55.86±7.96	[a] 46.07±2.72	[a] 1.34±0.11	[ad] 1.10±0.05	[a] 86.12±18.26	[a] 858.06±45.27
soft/stalks	[a] 29.58±7.96	[a] 29.47±2.72	[a] 0.91±0.11	[b] 0.62±0.05	[a] 52.91±18.26	[a] 598.45±45.27
hard/chopped	[a] -21.71±8.87	[a] 23.68±3.03	[a] 0.76±0.12	[ac] 0.81±0.06	[a] 45.16±18.26	[a] 760.94±45.27
hard/whole	[a] -17.67±8.90	[a] 16.85±3.04	[a] 0.65±0.12	[bc] 0.68±0.06	[a] 41.26±18.26	[a] 541.24±45.27

*Means of six replications.

[abcd] Values bearing different letters within the column differ significantly ($p<0.05$) as separated by least square means.

Figure 2a - Percentage retention of magnesium in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 2b - Percentage retention of magnesium in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.


RETENTION, %
100
90
80
70
60
distilled
soft
hard
cut
whole
RETENTION, %
110
100
90
80
70
60
distilled
soft
hard

but the increased cut surfaces of corn off the cob overruled this effect so that magnesium was lost even in hard water. Water used for cooking the cut corn gained more magnesium than did waters used to cook corn on the cob (Table 5). The interaction of hard water with cut corn had an effect ($p<0.01$) on mineral content of cooking liquid (Table 4). The higher magnesium content of the hard water seemed to prevent the liquid from pulling out as much magnesium as those cooked in soft and distilled waters (Table 5).

Broccoli. Neither water type nor size of broccoli significantly affected magnesium losses (Table 6); however, all broccoli lost magnesium with cooking (Table 7). Broccoli cooked in distilled and soft waters lost slightly more magnesium than did broccoli cooked in hard water (Figure 2b). Marston et al. (22) also found that carrots and broccoli cooked in hard water lost magnesium but not as much as those vegetables cooked in distilled water with and without added $Na_5P_3O_{10}$. These researchers also found the magnesium content of cabbage cooked in tap water to be equal to that of raw, but higher than that cooked in distilled water or in the phosphate solution. Dauncey and Widdowson (23) and Haring and van Delft (6) found that vegetables lost magnesium in all types of water. Haring and van Delft found that slightly more magnesium was lost in soft water than in hard water.

Analysis of variance for mineral changes in liquid (Table 8) shows a difference ($p<0.001$) in water type, with soft and distilled waters gaining more magnesium than hard (Table 9). The size of the vegetable pieces also resulted in differences ($p<0.001$) in mineral changes of liquids (Table 8). Liquid gained more magnesium from chopped broccoli than from broccoli stalks (Table 9). Teply and Derse (20) noticed a similar effect in chopped broccoli and broccoli spears. The chopped broccoli retained a greater percentage of magnesium than did spears, but the liquid containing chopped broccoli gained a greater percentage of magnesium than did the liquid containing the spears.

The results regarding magnesium losses in the vegetables in this study agree with those of Suarez and Pozuelo (21) who found that magnesium losses were the second highest of several mineral losses investigated. However, they used distilled water for cooking the vegetables. Their finding differs from Horner (16) and Zohm et al. (24) who found that sodium leached out more easily than magnesium. The latter two researchers used hard but not soft cooking waters. The increase in the sodium content of vegetables in the present study could be attributed to the soft water.

Iron

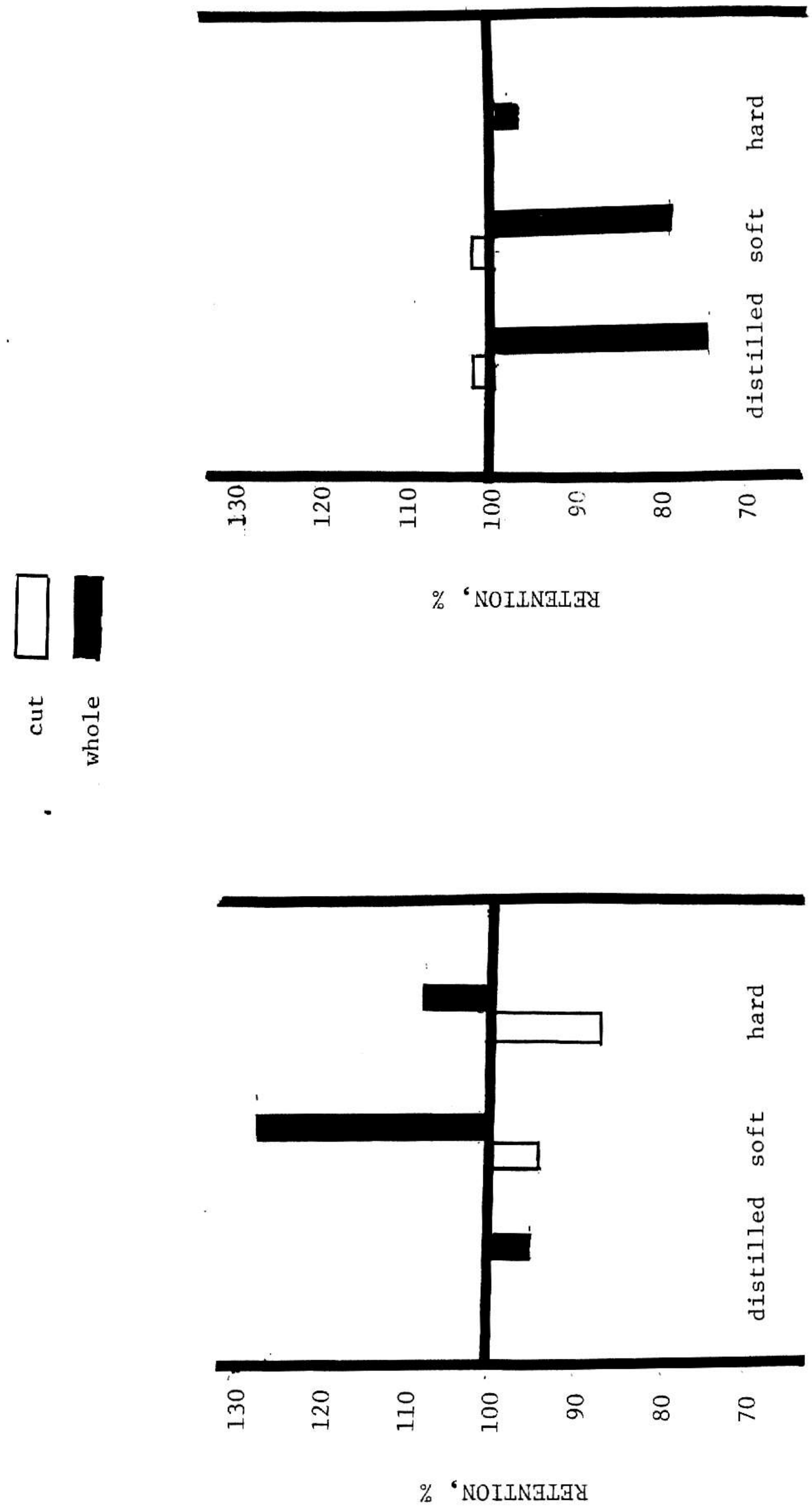
Corn. The iron content of corn was not affected significantly by the type of cooking water, surface area of the vegetable, or interaction of the two (Table 2). Whole corn retained slightly more iron than did cut corn (Table 3). Figure 3a illustrates the differences attributed to cooking waters and size of pieces. Surface area did have an effect ($p<0.001$) on the mineral content of the cooking water (Table 4). Water used to cook cut corn gained more iron than did water used to cook corn on the cob (Table 5). More iron leached out through the greater surface area. The amount of leaching appeared to be large enough to affect the mineral content of the liquid but not of the corn itself.

Broccoli. The type of cooking water had no significant effect on iron retention in broccoli (Table 6). Figure 3b illustrates small differences attributable to types of cooking water; slightly more iron was retained in hard water than in soft or distilled waters.

Size of pieces had no significant effect on iron retention in broccoli (Table 6); however, chopped broccoli retained slightly more iron than did stalks (Table 7). Percentage retention is illustrated in Figure 3b. Perhaps in this case, the greater amount of water and time used for cooking stalks

Figure 3a - Percentage retention of iron in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 3b - Percentage retention of iron in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.


cut
whole
RETENTION, %
130
120
110
100
90
80
70
distilled
soft
hard
RETENTION, %
130
120
110
100
90
80
70
distilled
soft
hard

caused more leaching and was not accounted for by using mg./l. as units of measure.

Type of cooking water did have an effect ($p<0.01$) on iron changes in broccoli liquid (Table 8) but not in the broccoli itself. Soft and distilled waters gained more iron than did hard water (Table 9). Hard water often forms calcium complexes which can adhere to containers used for cooking. Perhaps iron also became bound in these and adhered to the pan or evaporating dishes and, thus, appeared to be lower in hard water.

Size of vegetable pieces also had an effect ($p<0.01$) on iron changes in broccoli liquid (Table 8), but the gains in liquid did not correspond to the changes in the mineral content of the vegetable. Liquid from cooked chopped broccoli gained more iron than did that from cooked whole broccoli (Table 9). Teply and Derse (20) found that chopped broccoli retained 7% more of the original iron value than did stalks after cooking (62% compared to 69%).

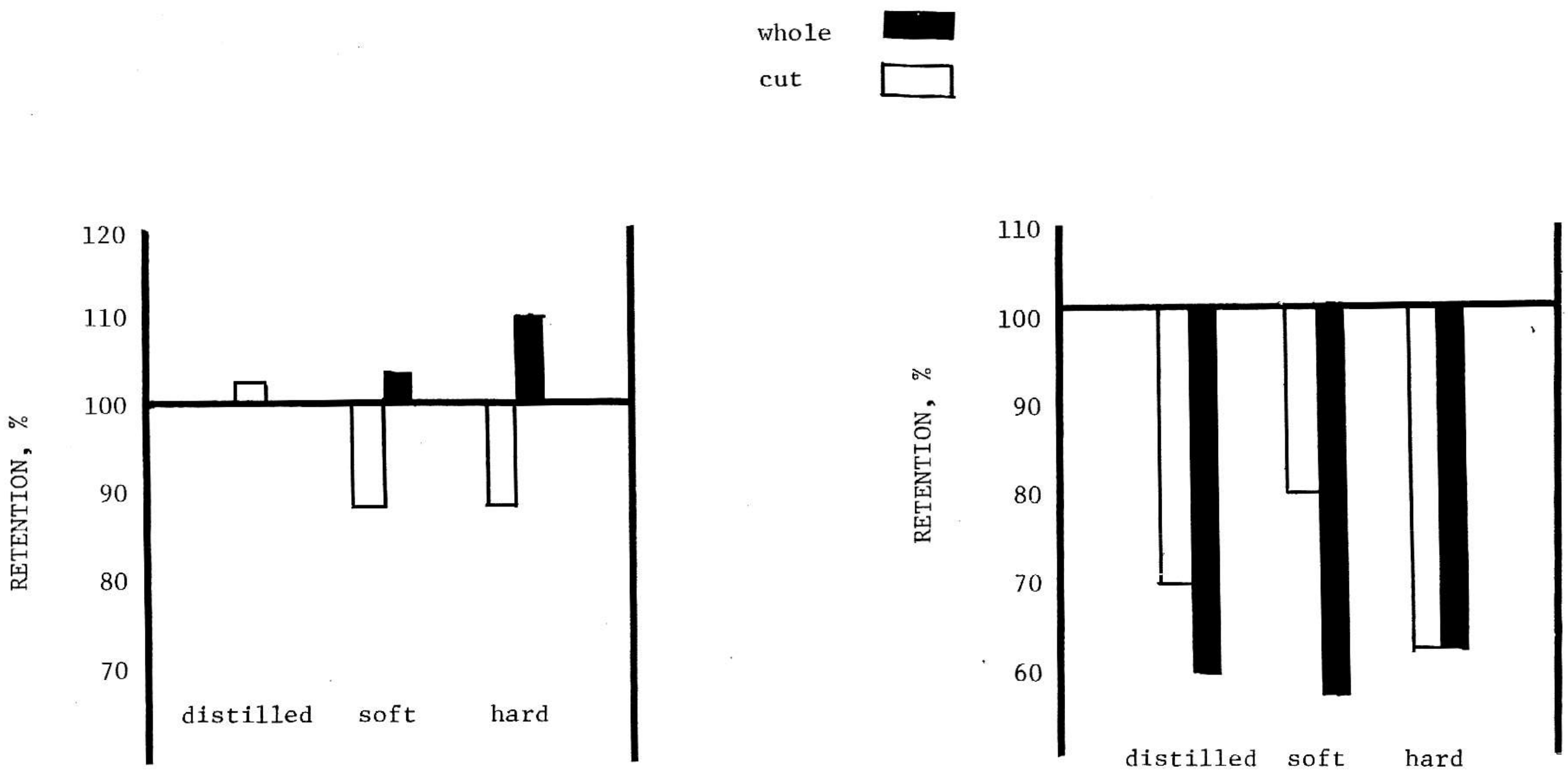
Zinc

Corn. Cooking water type had no effect on zinc content of cooked corn (Table 2) or the liquid in which the corn was cooked (Table 4). Zinc content was affected ($p<0.01$) by size of pieces (Table 2); cut corn lost more zinc than whole corn (Table 3). Figure 4a illustrates the percentage retention of zinc in corn. Size had an effect ($p<0.001$) in the zinc content of cooking waters (Table 4). Water used for cooking cut corn, regardless of water type, gained more zinc than that used for cooking corn on the cob. (Table 5).

Broccoli. All variations of broccoli lost zinc. Although type of cooking water, size or interaction between the two did not affect significantly zinc losses in the cooked vegetable (Table 6), all variations of broccoli lost some zinc (Fig. 4b). This finding agrees with Haring and van Delft (6) who found that zinc, potassium, and iron levels in four different vegetables

Figure 4a - Percentage retention of zinc in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 4b - Percentage retention of zinc in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.


whole
cut
RETENTION, %
120
110
100
90
80
70
distilled
soft
hard
RETENTION, %
110
100
90
80
70
60
distilled
soft
hard

were lower after cooking regardless of water hardness. Table 7 shows that broccoli pieces retained slightly more zinc than did the stalks. There were differences in zinc content of liquids attributed to size of the vegetable ($p<0.001$) and to interaction ($p<0.05$) (Table 8). The cooking waters containing chopped broccoli gained more zinc than did those containing stalks (Table 9). The water again may be a more sensitive indicator of mineral changes. Because of the low zinc content of these waters, a small change will appear significant. Interaction showed that chopped broccoli cooked in soft water gained the most zinc, followed by chopped cooked in distilled, then chopped cooked in hard water.

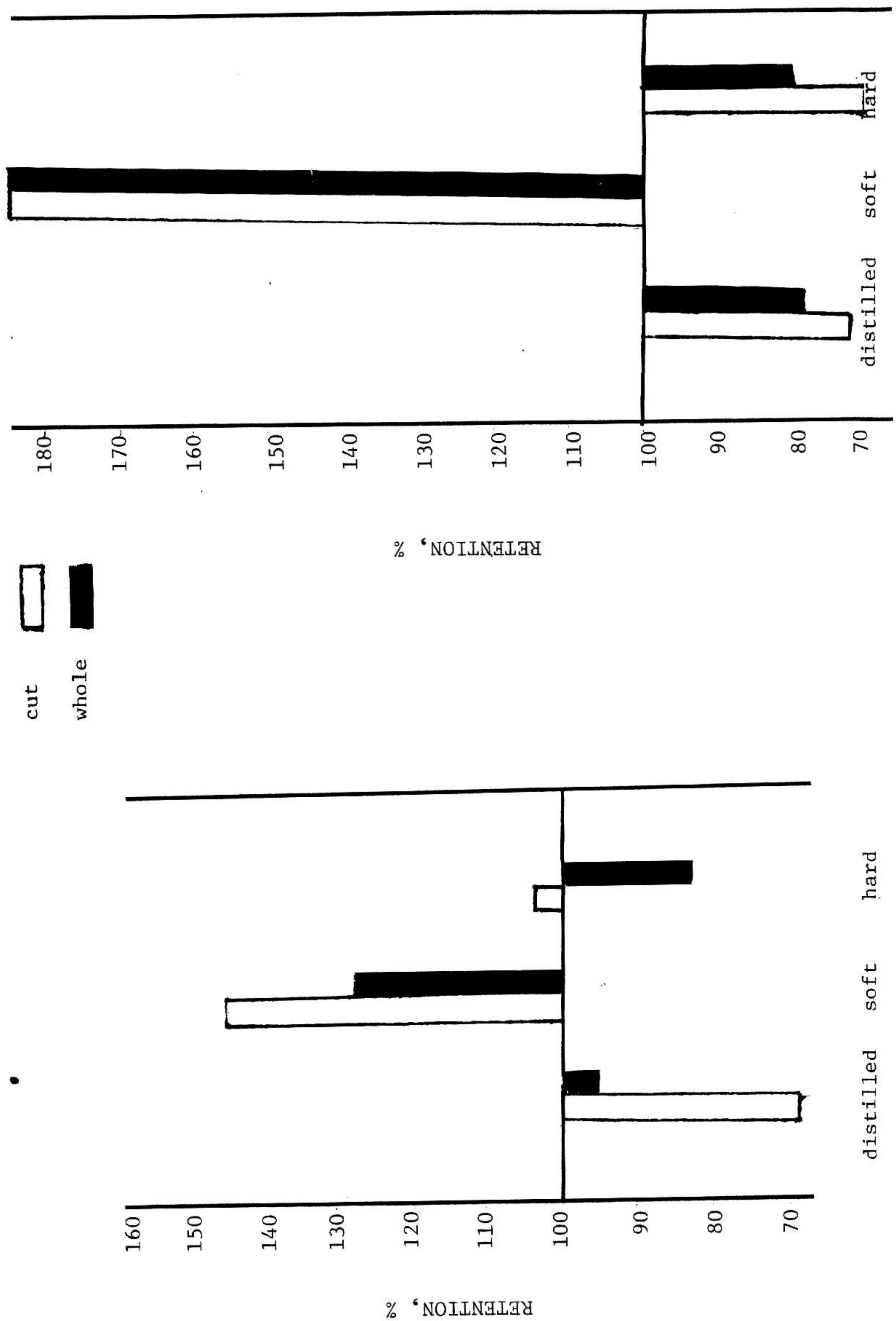
Sodium

Corn. The type of water used for cooking had an effect ($p<0.05$) on the sodium content of corn (Table 2). Corn cooked in soft water absorbed more sodium than that cooked in hard and distilled waters (Table 3). Figure 5a illustrates how corn cooked in soft water gained sodium. Except for cut corn in hard water, all samples cooked in hard and distilled waters lost sodium. Neither surface area nor interaction affected sodium retention in the vegetable (Table 2).

Water type made a difference ($p<0.01$) in mineral content of liquids also (Table 4). Soft water cooking liquids lost while hard and distilled water cooking liquids gained (Table 5). Although surface area did not affect sodium content of the corn itself, it did affect the sodium content of the cooking liquid ($p<0.001$) (Table 4). Water containing cut corn gained sodium while water used for whole corn lost sodium (Table 5). The sodium appeared to leach out of the cut vegetable enough to affect the mineral content of the liquid but not the vegetable itself. Because of extremes in sodium gains or

Figure 5a - Percentage retention of sodium in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 5b - Percentage retention of sodium in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.



RETENTION, %
180
170
160
150
140
130
120
110
100
90
80
70
distilled
soft
hard
cut
whole
RETENTION, %
160
150
140
130
120
110
100
90
80
70
distilled
soft
hard

losses in cut corn cooked in different waters, the sodium loss of all cut corn averaged together is negligible.

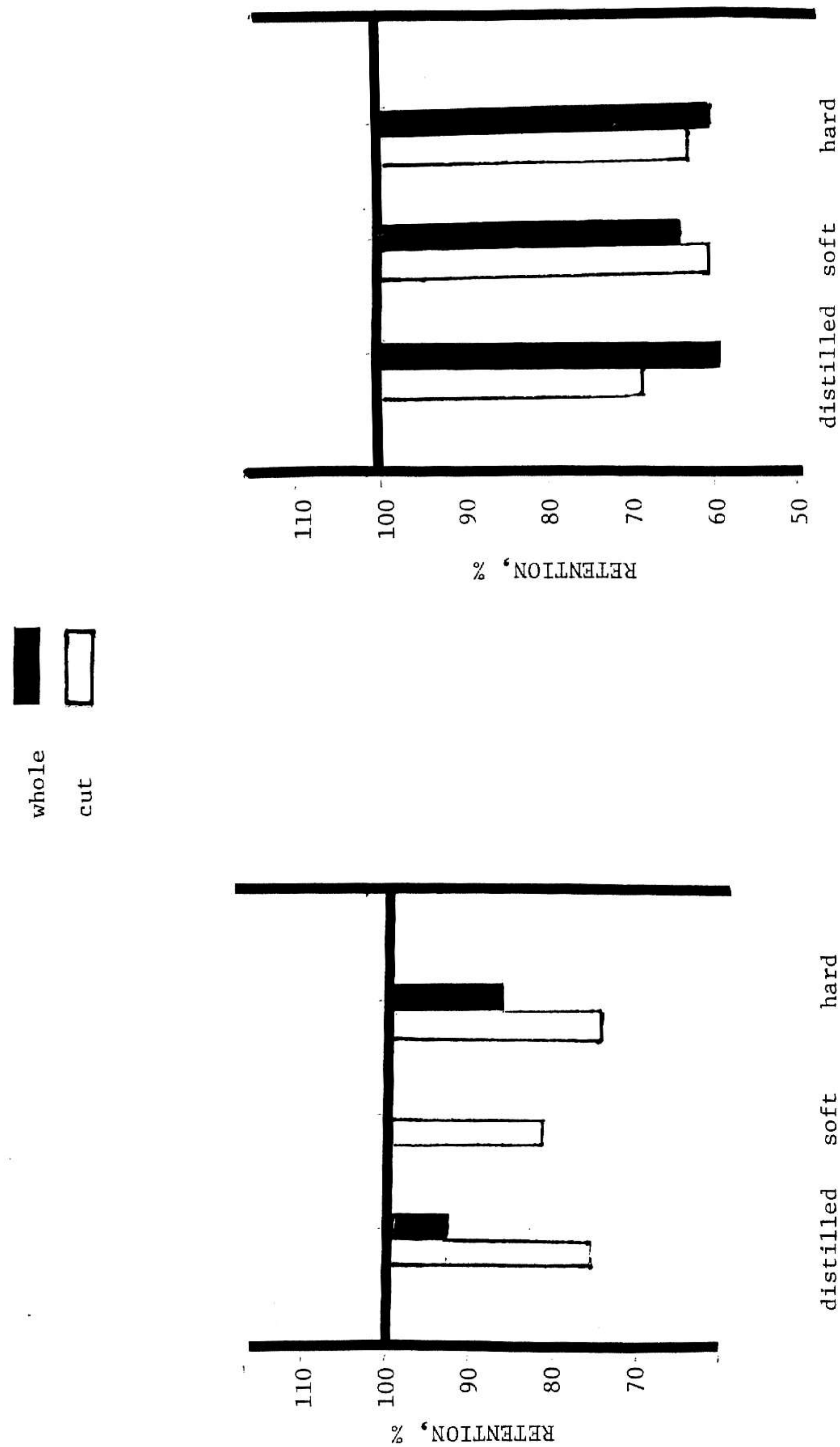
Broccoli. Water type also affected sodium retention in broccoli ($p<0.01$) (Table 6). Broccoli cooked in soft water increased in sodium content more than did broccoli cooked in hard and distilled waters (Table 7). Figure 5b illustrates the marked difference in sodium retentions attributed to water type. Increasing the surface area of broccoli did not appear to affect the sodium content of solids (Table 6) or liquids (Table 8). Liquid used to cook cut broccoli gained slightly more sodium in all cases (Table 9). Water type did not result in a change in the sodium content of cooking liquids (Table 8). Apparently, sodium was absorbed into the vegetable to some degree but not enough to cause significant losses of sodium content of water. Teply and Derse (20) found that frozen vegetables lost from 10-25% sodium when cooked in distilled water. In this study, vegetables cooked in distilled water lost from 5-32% of their sodium content.

Potassium

Corn. Water type did not affect losses or gains of potassium in corn itself (Table 2) or in cooking water (Table 4). The surface area of corn affected potassium content in the vegetable ($p<0.001$) (Table 2) and in the cooking liquid ($p<0.001$) (Table 4). Cut corn lost more potassium than did corn on the cob (Table 3), and the cut corn cooking liquid gained more potassium than did corn on the cob cooking liquid (Table 5). Greatest losses of potassium were from cut corn cooked in hard and distilled waters (Figure 6a). This does not agree with the suggestion made by Dauncey and Widdowson (23) that soft water may extract more minerals than other waters from vegetables.

Figure 6a - Percentage retention of potassium in corn (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.

Figure 6b - Percentage retention of potassium in broccoli (equivalent to 100 gm. raw) cooked in distilled, soft, or hard water.


RETENTION, %
110
100
90
80
70
60
50
distilled
soft
hard
whole
cut
RETENTION, %
110
100
90
80
70
distilled
soft
hard

Broccoli. Potassium content changes in cooked broccoli were not affected by water type, surface area, or interaction (Table 6). When compared to the raw vegetable, all cooking treatments caused a significant ($p<0.001$) potassium loss (Table 7). The percentage loss can be seen in Figure 6b.

The potassium content of cooking liquid was effected ($p<0.001$) by the surface area (Table 8). The chopped broccoli appeared to leach out more potassium into the liquid than did the stalks (Table 9). Again the water appeared to be a more sensitive indicator of losses.

All Minerals

Corn cooked in hard water increased in calcium content, and broccoli increased in calcium content to a small extent but not enough to be statistically significant. This finding supports the suggestion of Dauncey and Widdowson (23) that the increase of this mineral in foods cooked in hard water may be important for people on marginal diets and living in soft-water areas. Vegetables cooked in soft water absorbed more sodium than those cooked in hard and distilled waters. Individuals on low-sodium diets should take these gains into account or avoid cooking in soft water. Since calcium and sodium were in greatest concentration of any minerals in hard and soft waters, respectively, their greater absorption into vegetables likely was attributed to a balancing of equilibrium, rather than to the nature of these minerals. Increasing the surface area of the vegetables did not increase calcium absorption of the vegetable in hard water or sodium absorption of the vegetable in soft water.

Broccoli lost more minerals, especially magnesium, zinc, and potassium, than did corn. The edible portion of broccoli consists of a stem and flowers, while the edible part of corn is the seed. The larger mineral losses from broccoli in total might be attributed to the large surface area of the flower buds of broccoli. Cooking the broccoli in smaller pieces did not significantly affect mineral losses. Except for sodium, broccoli stalks lost slightly more of all minerals than did chopped broccoli. This might be attributed to the larger amount of water used for stalks and/or to the longer cooking time.

Compared to mineral losses in broccoli stalks and pieces, corn was more variable in mineral losses between cut corn and corn on the cob. This might be attributed to the greater difference in size between an ear of corn and individual kernels as compared to the difference between broccoli stalks and pieces. Also, when the corn is cut off the cob, the kernel is cut through parts of the germ, endosperm, and pericarp, making it susceptible to further loss. Overall, mineral losses from corn were less than those from broccoli.

SUMMARY

Corn and broccoli were each cooked in distilled deionized, soft, and hard waters. For each type of water a vegetable was cooked as follows: corn was cooked on and off the cob; broccoli was cooked in stalks and in pieces. Raw and cooked vegetables were compared for calcium, magnesium, iron, zinc, sodium, and potassium content. Minerals in the vegetable and in cooking waters were analyzed by flame emission spectrometry for sodium and potassium, and atomic absorption spectrophotometry for the other minerals.

Data were analyzed by a general linear models analysis of variance procedure. Least square means were compared to determine treatment effects.

Type of water affected calcium and sodium contents of corn and sodium content of broccoli. Cooking in hard water increased the calcium content of the vegetable. Cooking corn and broccoli in soft water increased the sodium content of the vegetables. The hardness of water did not affect the retention of iron, zinc, magnesium or potassium in these vegetables.

Increasing the surface area of corn resulted in greater leaching of magnesium, zinc, and potassium. Corn cut off the cob lost more of these minerals than did corn on the cob, regardless of water type. Cutting broccoli from stalks into pieces did not result in increased gains or losses of minerals, but in general broccoli tended to lose more minerals than did corn.

The mineral contents of cooking waters were affected by type of water and size of vegetable. Cutting vegetables into smaller pieces increased magnesium, iron, and potassium contents of corn and broccoli cooking waters and sodium content of corn cooking water. Magnesium content of soft and distilled waters after cooking of all vegetables increased more than did that of hard water. For broccoli waters, iron content of soft and distilled increased more than did that of hard.

CONCLUSIONS

Under the conditions of this study, it was concluded that:

1. Corn cooked in hard water contained more calcium than raw corn or corn cooked in soft or distilled waters. Hard water did not affect the calcium content of broccoli. Cooking either vegetable in smaller pieces did not increase calcium content.

2. Corn and broccoli cooked in soft water gained more sodium than those vegetables cooked in hard or distilled water.

3. Increasing the surface area of corn by cutting it off the cob resulted in greater leaching of magnesium, zinc, and potassium. Cutting broccoli from stalks into pieces did not result in increased losses of minerals.

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VITA

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APPENDIX

Table 10. Preliminary analysis of water samples.[a]

water	hardness	Ca	Mg	Fe	Zn	Na	K	P
		minerals						
		←mg./l.→						
[b]distilled deionized	<20	0.047	0.062	0.005	--	1.350	--	0.115
city tap	95	42.300	8.390	0.020	0.142	46.420	6.220	0.140
[b]soft 1	75	22.900	7.970	--	0.034	64.130	4.530	0.180
soft 2	54	14.300	8.370	--	--	80.190	3.370	0.153
[b]hard 1	326	83.100	27.700	0.007	0.128	8.420	3.890	0.074
hard 2	333	122.000	17.200	0.044	--	13.600	13.600	0.250

[a]Waters were analyzed by Keltner Laboratories, Inc., Manhattan, KS.

[b]Waters chosen for use in final study.

Table 11. Mineral content and pH of waters before cooking.

water	calcium	magnesium	iron	zinc	sodium	potassium	pH
for corn	←------------	------------	------------	mg./l.	------------	------------→	
distilled	0.064	0.048	0.003	--	3.574	--	5.16
soft	0.511	0.041	0.003	--	178.995	0.571	7.13
hard	90.545	30.812	0.071	0.057	7.936	1.710	7.07
for broccoli							
distilled	0.103	0.004	0.073	0.023	0.059	--	5.16
soft	0.678	0.211	0.104	0.014	156.946	0.775	7.13
hard	102.149	33.032	0.136	0.066	8.354	1.658	7.07

ANALYSIS OF ELEMENTS BY FLAME EMISSION AND ATOMIC ABSORPTION SPECTROPHOTOMETRY

Reagents

1. Prepare calcium, magnesium, zinc, iron, sodium, potassium, and lanthanum stock solutions according to AOAC Methods of Analysis (26). Before diluting lanthanum solution to volume, add 0.15 ml. Triton-X 100 (Fisher Chemical Co.) as a wetting agent.

2. Prepare 0.1% cesium solution as follows: Dissolve 6.335 gm. CsCl (Fisher Chemical Co.) in a little water. Add 41.3 ml. HCl and 0.15 ml. Triton-X 100. Dilute to 1 liter.

3. Dilute aliquots of calcium, magnesium, sodium, and potassium with distilled deionized water, and iron and zinc with 0.5 N HCl to make 5 standard solutions of each element within the appropriate ranges (Table 3; may differ with another model spectrophotometer).

Table 12. Operating Parameters

Element	Linear to: ug./l.
Calcium	3.0
Magnesium	0.5
Iron	5.0
Zinc	1.0
Potassium	2.0
Sodium	1.0

Make up fresh dilutions of standards for every run. Dilutions are stable for 4-8 hours.

4. To prevent phosphorus interference for calcium and magnesium determinations, add 5.0% solution of lanthanum to calcium and magnesium standards and zero before fully diluting to make a final concentration of 1.0% lanthanum.

5. To prevent ionization in sodium and potassium determinations during flame emission, add 0.5% cesium solution to sodium and potassium standards and zero before fully diluting to make final concentration of 0.1% cesium.

6. Prepare a zero for each set of standards using appropriate dilution liquid and addition such as cesium or lanthanum but without aliquot of stock solution.

Sample Preparation

1. Freeze-dry samples (Virtis Model 10-100) for approximately 16 hours at -40°C (-40°F.) and grind in Waring blender.

2. Weigh out 1.0 gm. (broccoli) or 1.5 gm. (corn) dried sample into 30 ml. Coors crucibles.

3. Ash samples overnight in muffle furnace (Type 2000 Thermolyne Furnace) at 560°C (1040°F). Samples may be kept in a dessicator for a few days at this stage.

4. Under hood, add 10 ml. HCl (1+1) to each sample and to an empty crucible as a blank. Cover each crucible with a watchglass. Heat on hot plate at 450°C (840°F). until liquid starts to bubble.

5. Filter solutions through Whatman #40 filter paper into 100 ml. volumetric flasks, washing paper and residue thoroughly with water. Dilute to 100 ml. and mix.

6. Depending on vegetable and mineral being analyzed, may dilute samples into 25 ml. flasks to fit within above parameters (Table 3).

7. Add cesium solution to sodium and potassium standards and lanthanum solution to calcium and magnesium standards for final concentration of 0.1% or 1.0% respectively.

8. Determine absorption (calcium, magnesium, iron, zinc) following instrument procedure manual (27) for settings.

9. Determine emission (sodium potassium) following instrument procedure manual (28).

10. Prepare a regression line plotting absorption against concentration. Obtain concentration of samples from plot of absorption against concentration.

Calculations

1. Samples:

If final volume diluted:

$$\text{Element (ug./gm. dry weight)} = \frac{\left(\frac{\text{conc. from regression}}{\text{line}}\right)\left(\frac{\text{dil.vol.}}{\text{aliquot}}\right)(\text{mls.orig.vol.})}{\text{gm. weight of sample}}$$

Final volume, no dilution:

$$\text{Element (ug./gm. dry weight)} = \frac{(\text{conc. from regression})(\text{mls. orig. vol.})}{\text{gm. weight of sample}}$$

2. Liquids:

$$\text{Element (ug./ml.)} = \frac{\left(\frac{\text{conc. from regression}}{\text{line}}\right)\left(\frac{\text{dil. vol.}}{\text{aliquot}}\right)(\text{mls. orig. vol.})}{\text{ml. liquid}}$$

MINERAL CONTENT OF SWEET CORN AND BROCCOLI COOKED IN WATERS OF VARYING HARDNESS

by

LORRAINE KAY BOHN

B.A., Bluffton College, 1981

AN ABSTRACT OF A MASTER'S THESIS

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Local water, the vegetable itself, and method of preparation all contribute to mineral composition of vegetables. Under certain conditions, vegetables may lose undesirable elements to and gain valuable nutrients from cooking water. Calcium, iron, and magnesium may be possible problem nutrients in the North American diet and sodium is of concern in hypertension. These minerals, plus zinc and potassium, were analyzed in two vegetables cooked in varying hardnesses of water.

Corn and broccoli were each cooked in distilled deionized, soft, and hard waters. For each type of water a vegetable was cooked as follows: corn was cooked on and off the cob; broccoli was cooked in stalks and in pieces. Raw and cooked vegetables were compared for calcium, magnesium, iron, zinc, sodium, and potassium content. Minerals in the vegetable and in cooking waters were analyzed by flame emission spectrometry for sodium and potassium, and atomic absorption spectrophotometry for the other minerals.

Data were analyzed by a general linear models analysis of variance procedure. Least square means were compared to determine treatment effects.

Type of water affected calcium and sodium contents of corn and sodium content of broccoli. Cooking corn in hard water increased the calcium content of the vegetable. Cooking corn and broccoli in soft water increased the sodium content of the vegetables. The hardness of water did not affect the retention of iron, zinc, magnesium, or potassium in these vegetables.

Increasing the surface area of corn resulted in greater leaching of magnesium, zinc, and potassium. Corn cut off the cob lost more of these minerals than did corn on the cob, regardless of water type. Cutting broccoli from stalks into pieces did not result in increased gains or losses of minerals, but in general broccoli tended to lose a greater percentage of minerals than did corn.

The mineral contents of cooking waters were affected by type of water and size of vegetable. Cutting vegetables into smaller pieces increased magnesium,iron, and potassium contents of corn and broccoli cooking waters and sodium content of corn cooking water. Magnesium content of soft and distilled waters after cooking of all vegetables increased more than did that of hard water. For broccoli waters, iron content of soft and distilled increased more than did that of hard.