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Hsi Hsuan Yu for the M.S. in H. Ec.
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(Major Professor)

The importance of an adequate supply of calcium and phosphorus in the diet has been emphasized by investigators in the field of nutrition.

Milk is our best and most constant source of calcium; where milk is not commonly used, green vegetables must carry the major share of supplying it. It has been found that the calcium of vegetable sources ~~are~~ is quite well utilized by adults.

A review of the literature on the loss of minerals in the cooking of vegetables shows that the best method of cooking in order to retain most of the mineral constituents is cooking without using water, such as baking, steaming or cooking in a waterless cooker. Mineral losses are increased with time of cooking and with the volume of water used.

In China, one common way of cooking vegetables is sautéing in a little fat or oil. Vegetables cooked in this way usually retain most of their original color and flavor and have a tender but firm texture. It is, therefore of great practical importance to find out whether this method of cooking will conserve the food value as well as flavor and texture.

The present study was initiated to investigate the conservation of calcium and phosphorus of vegetables cooked by sautéing. Peas, asparagus and celery cabbage were chosen to represent the three classes of vegetables: green leaves, stems and seeds. Duplicate samples were analyzed for calcium and phosphorus both raw and after cooking.

The average calcium contents of the raw asparagus, celery cabbage and peas were 0.026%, 0.032% and 0.022% respectively, and the average calcium contents of the three vegetables after cooking were 0.026%, 0.034% and 0.022% respectively. The average phosphorus contents were 0.074% for raw and 0.073% for cooked asparagus, and 0.115% for raw and 0.119% for cooked peas. The average calcium and phosphorus contents of the cooked vegetables were therefore practically the same as the raw, so under the conditions of this investigation, cooking these vegetables by sauteing caused no loss in calcium and phosphorus. Sauteing is, therefore, to be recommended in the preparation of vegetables for the best conservation of these minerals.

THE CALCIUM AND PHOSPHORUS LOSSES OF COOKING VEGETABLES IN FAT

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HSI HSUAN YU

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APPROVED:

[redacted]

Associate Professor of Foods and Nutrition

In Charge of Major

[redacted]

Head of Department of Foods and Nutrition

[redacted]

Chairman of School Graduate Committee

[redacted]

Chairman of State College Graduate Council

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THE CALCIUM AND PHOSPHORUS LOSSES OF COOKING VEGETABLES IN FAT

INTRODUCTION

The importance of an adequate supply of minerals in the diet is always of interest to investigators in the field of nutrition. Calcium and phosphorus are of particular importance because they are essential both to the structure and the functioning of the body. The bones and teeth owe their needed degrees of permanence of form, of rigidity and hardness, to the relatively insoluble calcium and phosphorus compound which they contain. Both calcium and phosphorus likewise have essential parts to play in the soft tissues and the body fluids as well. The characteristic properties of the body fluids, such as solvent power and osmotic pressure, upon which the life processes depend is due largely to the interactions between calcium and other mineral elements. Muscles and nerves must be constantly bathed and nourished by fluids containing the right proportions of salts of sodium, potassium and calcium. The rhythmic contraction and relaxation of heart muscle which constitutes the beating of the heart and the preservation of the normal response of nerves to stimuli are dependent upon the presence of the right proportions of these salts in the blood plasma; calcium is especially essential in assisting in the coagulation of the blood. In addition to these very important functions calcium is a kind of coordinator among the mineral elements, being capable of correcting the disturbance of other minerals which they might make, whether it be in the direction of increased or decreased irritability.

In metabolism, there is some evidence to show that calcium is a sparer of iron and that the organism has a more favorable utilization of even a small quantity of iron if calcium is abundant.

Phosphorus also has other functions besides those in which it participates in combination with calcium. Phosphorus is indispensable for all active tissues of the body, being concerned in cell multiplication and cell movement and the maintenance of the proper liquid content of the tissues. It also plays an important part in regulating the neutrality of the blood and is essential at that stage of the chemical change through which carbohydrates are oxidized and their energy liberated. Sjollema (85) found that proper amount of calcium and phosphorus in the diet increases the reproductive power of human beings.

At least ninety-nine per cent of calcium and over two-thirds of the phosphorus which the body contains are found in chemical combination with each other in true mineral form in the bones and teeth. The remainder of the small amount of calcium and the larger amounts of phosphorus are distributed in the soft tissues and body fluids.

As the growing body must increase not only the amounts but also the percentages of calcium and phosphorus which it contains, it needs these two elements--and particularly calcium--in relatively greater abundance in its food than any of the other body building materials which the food supplies. Sherman (82) says, "To be normal and healthy the full-grown human body must be richer in calcium than in any other mineral elements; yet every human being is born calcium poor".

Food is the natural source of calcium in the body, although a small amount may be ingested as an inorganic constituent of some drinking waters. (61) (44)

To keep the body in calcium and phosphorus equilibrium the intake must exceed or at least equal the output. Since the same food may vary in calcium and phosphorus content, since these minerals may be lost in preparing food for the table, and since absorption is not 100 per cent efficient, Sherman (84) advocates an allowance of at least fifty per cent above the minimum requirement as a margin of safety in estimating the calcium and phosphorus requirements. Hitherto, 0.68 gm. of calcium a day has been considered sufficient for an adult (84), but more recent practice favors 0.75 to 1.0 gm. as optimal. (80) (51) Sherman (81) (83) has shown that the rapid calcification in the growing animal hastens maturity and delays senescence, and that to secure this storage, the factor of prime importance is a liberal allowance of calcium in the diet. "For best permanent results the level of intake of calcium should be perhaps three times as high as the minimal adequate level." (84)

Sherman (84) has suggested 1.32 gm. of phosphorus per adult per day as the standard allowance. Studies of calcium and phosphorus metabolism in children have indicated a requirement of about 1 gm. each of calcium and phosphorus per day for the growing child.

Calcium is by no means evenly distributed in foods. Milk is our best and most constant source; where milk is not commonly used, green vegetables must carry the major share of supplying calcium. And vegetables may vary widely in calcium and phosphorus contents.

In calculating the mineral content of vegetables from published tables of analyses of raw materials, consideration should be given to the losses incurred in the preparation of the food, and the difference in efficiency of the vegetables as source of calcium and phosphorus in the dietary; and the variations in the mineral content of the vegetables grown in different localities with different fertilizers.

As suggested by the Council on Foods (13) and by Davidson (18) the composition of vegetables might well be thought of as a range of values rather than as any fixed value.

Variations in Calcium and Phosphorus Contents of Vegetables

Variations in the mineral content of plant material were early noted by Beal (4) Wheeler and Hartwell (89), Forbes, Whittier and Collison (29) and Hoagland (38). It was found that calcium and phosphorus varied with the type of soil and with the fertilizer used on the soil. Wheeler and Hartwell reported that the unlimed white radish averaged 1.14 per cent CaO; the once-limed, 1.21 per cent; and the thrice-limed 1.70 per cent. Forbes found that some samples of blue grass contained more than three times as much calcium as other samples. He also reported a considerable increase of both calcium and phosphorus in the grass when the soil was fertilized with lime and phosphorus. Gile and Ageton (31) showed that while the calcium content of some plants was greatly increased by application of lime to the soil, that of others was not appreciably affected. Emmert (22) and Sewell and Latshaw (77) found that the phosphorus content of tomatoes, lettuce and alfalfa was decreased by liming.

A study of Frank and Wang (30) has shown very significant differences in the calcium content of different samples of certain foods. Peterson, Elvehjem and Jamison (68) analyzed eighteen samples of cabbage of five varieties grown in four different states, in which the percentages of calcium varied from 0.029 to 0.056. The phosphorus content of one sample was more than double that of another. But there is no seasonal variation apparent in the analysis. Storms (87) found that although New Zealand milk has the same calcium content as that of other countries, the vegetables showed a lower calcium content. The work of Greave and Hirst (32) has shown very great differences in the calcium and phosphorus content of certain grains as influenced by variety, soil type and irrigation, and more recently Greaves and Greaves (33) report that wheats vary in their nutritive value. Holmes and Tripp (40) found it advisable to analyze each lot of corn used in rachitogenic diets, because the calcium and phosphorus content of corn from different areas varied materially. Bishop (6) has demonstrated that a particular variety of plant cannot be expected to have a constant calcium and phosphorus content. There was a wide variation in the calcium and phosphorus content of a given vegetable. The greenhouse plants showed a regular increase in phosphorus with increased rates of application of superphosphate. Type of seed also is a very important factor in the variation of mineral content of a certain plant. Bishop found that the Japanese varieties of turnips consistently gave a lower calcium content than American varieties grown under the same conditions. Coleman and Ruprecht (12) have conducted very complete mineral analyses of the edible portion of lettuce, tomatoes and celery grown under widely different fertilizer treatment on the same soil. They found that the fertilization had little effect on the mineral content of the crop with the exception of potash in the case of celery. But Davidson (17) (1933) reported that leafy vegetables theoretically are more subject to variation than fruits and seeds. Recently Davidson and LeClerc (18) studied five kinds of leafy vegetables in regard to the mineral content and the condition of growth. They found that the mineral composition of the vegetables is correlated with the fertilizer treatment or with the chemical composition of the irrigation water. Each vegetable studied had its own range of variation. Different varieties of plants grown under the same conditions may also vary widely.

Cowell (15) first noted that there was a five fold variation in the calcium contents of leaves from the same plant which were indistinguishable in appearance while the calcium content of the outermost leaves of the cabbage in summer might be from twenty to thirty times as great as that of the inner leaves. Loughlin (48) also found differences in calcium and phosphorus content of leaves and stems of spinach, beet greens and chard.

Hsii and Adolph (41) determined the calcium contents of the inner and the outer leaves of ten leafy vegetables commonly used for food in China. The dry material of the outer or green leaves contained from two to twenty times as much calcium as the inner leaves. Recently a more thorough and extensive investigation was made by Wang (88) on some commonly used Chinese leafy vegetables. He found that the calcium content is highest in the lamina of the outer leaves, medium in the stalks and lowest in the central portion. But the distribution of phosphorus and iron is quite different from that of calcium. The phosphorus content is much higher in the central portion than in either the lamina or the stalks. The distribution of iron shows less variation in the different parts than either the calcium or the phosphorus. It would appear that only calcium is related to the photosynthetic function and to the green color of the leaf.

A survey of the above data indicates that the mineral content of vegetables or plants is not a constant factor. But equally important is the effect of different conditions on the utilization of calcium and phosphorus by the individual organism and the effect of various cooking methods concerned with the preparation of the dish that is eaten.

In the countries where milk and milk products are widely used as staple foods there is less danger of calcium deficiency than in those countries where the milk is unknown to the average housewife, and where the vegetables and legumes are the chief sources of calcium and phosphorus in the human body and the losses of these two important elements in cooking vegetables are of utmost importance.

<u>Utilization of Calcium and Phosphorus from Vegetable Sources</u>

A number of studies have been made on man to test the efficiency of different vegetables as sources of calcium and phosphorus. In a calcium retention study on carrots with four adult women on an average intake of approximately five to nine mg. of calcium per kg. of body weight, Rose (73) reported positive calcium balances in all subjects except one, who had found the carrot diet slightly less satisfactory for calcium retention on account of digestive disturbances. One subject had nearly the same calcium retention when approximately fifty-five per cent of the total calcium intake was furnished by the carrots as when milk furnished seventy per cent of the total calcium intake. Blatherwick and Long (7) in a study including a mixture of vegetables--raw lettuce, canned asparagus, cooked celery and spinach, steamed summer squash and boiled cabbage--found positive calcium and phosphorus balance on two adult women. They concluded that calcium and phosphorus derived from vegetables are capable of meeting the maintenance needs of man. In a study of the availability of the calcium of spinach, McLaughlin (58) found it to be a satisfactory source of calcium for seven adult women when spinach furnished seventy per cent of the total calcium intake. Six subjects were in positive calcium balance and one was in equilibrium. This seems surprising because of the high oxalic acid content of the spinach. Both diets furnished considerably more calcium than the average requirement for maintenance, so that there was always equilibrium or calcium retention. The availability of calcium in spinach is receiving great attention recently. Most of the work shows that calcium of the spinach is utilized very poorly if at all. (26) (23) (2)

Mallon, Johnson and Darby (53) found that calcium of the fresh green leafy vegetable--lettuce, which furnished ninety-three per cent of the total calcium, was superior in its utilization to that of pasteurized whole milk when these foods were fed on an approximately equal calcium intake to two healthy young women.

The results of the studies seem to show that the calcium and phosphorus of vegetables except spinach are quite well utilized by adults.

Sherman and Hawley (79), studying the calcium balances of growing children, found that the retention of calcium was more variable but always less favorable when half of the milk of the diet was replaced by a carefully prepared mixture of vegetables (carrots and spinach with or without celery or string beans) which provided the same amount of calcium, i.e., the same total calcium intake.

The calcium of this mixture of vegetables was clearly less well utilized than that of milk in these experiments with three to thirteen year old children. The phosphorus balance seemed also unfavorably affected when vegetables were substituted for half of the milk in the diet. Edelstein (21) studying mineral balances during the feeding of vegetables to children found that the addition of spinach and carrots to a milk diet almost regularly led to a decreased retention of both calcium and phosphorus. Schultz (76) fed infants celluflour, dried spinach, pureed spinach, and raw spinach. He concluded that mineral retention from vegetable matter is negligible in infants.

Utilization of Calcium and Phosphorus from Nuts and Legumes Sources

Rose and MacLeod (74) in an experiment with adult women on a diet in which seventy-three per cent of the calcium was derived from almonds, found that calcium equilibrium could be secured about as efficiently as when milk or carrots furnished the same amount. When eighty-five per cent of calcium was furnished by almonds the utilization was lower and more variable.

Soy bean products are quite extensively used in the place of milk and cheese in Chinese diets. Bean curd is one of the commonest soy bean products which supplies most of the protein for the vegetarian diet. According to Adolph and Chen (1), in the presence of adequate protein in the diet, the bean curd is as efficient as cow's milk as a source of calcium in the Chinese diet when the intake of calcium is above 0.45 gm. per day.

Another soy bean product which is quite commonly used for both infants and invalids is the soy bean milk. With the addition of certain supplementary foods, it has proved quite successful as an infant's food. (71) (86) (11)

Since calcium from the soy bean is quite well utilized, it would seem that other beans might also prove a good source of calcium. The results of a study on five healthy women reported by Pittman (69) in which navy beans furnished eighty to eighty-five per cent of the total calcium intake showed that they were unable to maintain the calcium balance of the body. Their phosphorus was utilized somewhat better than calcium. When baked and pureed beans were fed at two protein levels, calcium assimilation did not improve with increased nitrogen retention; although the negative balances were slightly more favorable with the pureed beans.

In a metabolism experiment conducted by Burton (10) to determine the retention of calcium and phosphorus by six children and two adults on cereal diets containing rolled oats or refined wheat, she found that the retention of both calcium and phosphorus was higher on the wheat diet than on the oat diet for children. Both adults were in negative calcium balance, while the loss was greater on the oat than on wheat diet. However, the total amount of calcium ingested was considerably greater in the wheat than on the oat diet.

Losses of Minerals in Cooking

The effect of cooking on the nutritive value of vegetables has been studied by a number of workers and it is well known that the effects vary somewhat depending upon the method of cooking and handling. There is general agreement among investigators that mineral losses increase with time of cooking and with the volume of water used; and that there is also an increasing loss of minerals as the food surface exposed to the cooking water is increased. The preferred methods of cooking in order to retain mineral constituents are: baking, steaming, and cooking in a small amount of water.

Maurel and Carcassagne in 1909 found that blanching by boiling (56) for twenty minutes in distilled water removed forty to eighty per cent of the total salts from cauliflower, brussels sprouts, green cabbage, celery stalks, celery leaves, lentils, asparagus, green beans, white beans, and potatoes.

Poppe in 1911 (70) cooked (or soaked) fresh green peas for varying lengths of time at different temperatures in distilled water, salt solutions or sugar solutions of different concentration. He found greater losses (especially of phosphorus) in distilled water than in salt solution, and all losses were as a rule, greater at the higher temperatures because these kill the protoplasm and convert it from a semi-permeable membrane to a permeable one.

Masoni and Savini in 1918 (55) first suggested the use of vegetable cooking water for soups or similar foods, because they found great phosphorus losses in the cooking water.

Early in 1912, Berry (5) found that spinach boiled in water lost more than half of its phosphorus in the cooking water (fifty-two per cent) while steaming caused a loss of five per cent only. Both boiling and steaming saved most of its calcium. There was no difference between the percentage of calcium lost in the two methods (only two per cent loss). But this is not true in other vegetables. Boiled cabbage lost thirty-four per cent of phosphorus and twenty-eight per cent of calcium, while steamed cabbage only two per cent and nine per cent respectively.

Morgan (63) reports a smaller loss of salts in peas canned by the commercial process than in those canned by the three-day sterilization home process. The blanching of peas caused twenty-five per cent loss of its phosphorus.

Courtney, Fales and Bartlett in 1917 (14) cooked seven varieties of vegetables in the manner usual when preparing them for children; i.e.--by a "thorough boiling" for thirty to one hundred and fifty minutes, and analyzed cooked vegetables and cooking water for calcium, magnesium, phosphorus, chlorine, potassium, sodium, sulphur, iron and nitrogen. Both ordinary spinach and New Zealand spinach lost very little of their calcium while young carrots, asparagus and string beans lost twenty to thirty per cent. New Zealand spinach was an especially heavy loser of all the other minerals (seventy per cent of phosphorus and fifty-one per cent of iron). Ordinary spinach lost about half of its phosphorus and a quarter of its iron. Both asparagus and young carrots lost thirty-five per cent of their phosphorus but only traces of iron. Reducing the time of cooking made little difference in the losses. Steaming, however, reduced the losses materially; in spinach the loss being about half as much as when boiled. In asparagus and carrots, the losses when steamed were only a fourth to a third as great as when boiled. No difference was noticed in mineral losses in steaming and double boiler cooking.

Denton (20) concluded that the extraction of the soluble constituents depends largely upon the length of the period of cooking and upon relative proportion of water and vegetable. These two factors are widely variable and exceedingly uncertain, as is also the relative surface exposed when the vegetable is cut or pared. Also the loss varies in different vegetables owing to the different proportions of readily soluble constituents which they contain; therefore there can be no possible universal factor applied in dietary calculation to show losses of values of foods incurred in cooking.

A carefully and scientifically conducted investigation on the loss of minerals from vegetables by various methods of cooking was carried out by Peterson and Hoppert (67). Sixteen vegetables (asparagus, string beans, beet greens, cabbage, cauliflower, celery, celery cabbage, spinach, beets, carrots, kohlrabi, onions, parsnips, potatoes, sweet potatoes, and rutabagas) were studied by four methods of cooking: steaming, pressure cooking, boiling in a moderate quantity of water, and boiling in double this volume of water. The losses increased in general for the different methods in the order named; the least occurring when the vegetable was steamed and the greatest when it was boiled in an excess of water. Losses varied considerably ranging from no loss for calcium in steamed spinach to seventy-six per cent of magnesium lost in boiled cabbage. Celery, beet greens, and onions suffered great loss of mineral elements. Average losses for calcium were ten per cent for steaming and pressure cooking; twenty per cent and thirty per cent respectively for the two methods of boiling. Magnesium was more soluble, there being twenty per cent loss by the first two methods of cooking and thirty and forty-five per cent by boiling. The average losses for phosphorus and iron were the same as for magnesium excepting by the two methods of boiling where the figures were from five to ten per cent higher.

Peterson, Elvehjem and Jamison (68) reported that eight and six tenths per cent of the calcium and nineteen and eight tenths per cent of the phosphorus of cabbage were lost in the making of sauerkraut.

McLaughlin (59) found that cooking New Zealand spinach for thirty-five minutes in a double boiler caused loss of only a little of its calcium and phosphorus, but most of the brilliancy of the green color had gone too, while cooking spinach for ten minutes in excess tap water gave an attractive, tender, green product; the draining off of the cooking liquid took with it little calcium but more than sixty per cent of the phosphorus.

Brookover and Pittman (9) compared the losses of calcium and phosphorus of vegetables with two cooking methods commonly used in the home: boiling in a small amount of water and cooking in a waterless cooker. Although home economists do not generally recommend that cabbage and other green vegetables be cooked in a tight container, yet they found that both cabbage and carrots lost less calcium and phosphorus in waterless cooking than in boiling. The saving of phosphorus in waterless cooking was even greater than that of calcium. But in the case of spinach, there was no difference in mineral loss between the two methods. It is unfortunate, that they did not mention anything about the color and flavor or the palatability of the products prepared by the waterless cooking method.

Halliday and Noble (37) cooked different kinds of vegetables according to the directions in their "Hows and Whys of Cooking" (36). These directions are designed especially to preserve color and flavor with the saving of nutrients as a secondary consideration. In boiled cabbage which was cut into small pieces and cooked in a fairly large proportion of water, the losses for calcium and phosphorus were twenty-one and twenty-eight per cent respectively. For sweet potatoes which can be cooked successfully in a small portion of water, the losses for calcium and phosphorus were five and twelve per cent respectively. In comparison with the results of Peterson and Hoppert (67) Halliday and Noble gave much smaller losses; they attribute this to the fact that they dropped the vegetable into boiling water and cooked it only until tender.

The loss of iron in boiling vegetables in a minimum amount of water and the minimum cooking time was about fifty per cent reported in many independent investigations.

(28) (8) Field (25) reported that in cooking mustard and turnip greens in tap water, the loss was twice as great as in distilled water.

Sheets, Frazier and Dickins (78) found that the greatest loss of iron resulted when more than enough water was used for cooking vegetables. Both steaming and pressure cooking caused only slight losses of iron. The same fact was true in case of copper and manganese as reported by Culp and Copenhaver (16).

The above reports all seem to show the losses of calcium and phosphorus during cooking but it is obvious that exchange must go on in either direction with the surrounding medium and therefore, vegetables may actually be richer in some constituents after they have been cooked than they were before. Thus Ziegelmayer in 1931 (90) reported that potatoes lost twenty-five per cent of their calcium when they were cooked in distilled water but that in very hard water their calcium might be increased four times. Kohman and Sanborn (45) made this remark regarding the use of hard water in the canning industry: "Raw peas absorb appreciable amounts of calcium from water within a few seconds. Calcium from hard water used in canning peas is absorbed by the skins and thus causes toughening to the extent of lowering the quality."

Fisher (27) found the extraction of calcium by cooking vegetables in hard water was less than that by soft water.

Recently Noble and Halliday (65) (66) in determining the calcium and phosphorus content of a number of green and root vegetables before and after cooking showed that when vegetables were cooked in Chicago city water containing thirty parts per million of calcium the losses were very small and there was even a gain in the case of peas, spinach and other greens. The type of cooking liquid did not affect the phosphorus loss.

Then they again cooked asparagus, beans, peas or spinach in water containing varying amounts of calcium. All the vegetables contained more calcium than when cooked in distilled water or than they did in the raw state. But all vegetables suffered equal losses of phosphorus on boiling whether the water contained calcium or not.

Miller and Robbins (62) in Hawaii found that cooking green immature soy beans in their pods in salted tap water for twenty to twenty-five minutes showed a higher percentage of calcium, phosphorus and iron than the raw beans. This may be due to the lowered moisture content of cooked beans or the tap water used in cooking might have been hard. They did not mention it.

The literature regarding the effect of salt on the calcium and phosphorus losses of cooking vegetables are contradictory. Jordan (42) Fisher (27) did not find any significant difference in calcium loss by the addition of salt to the cooking water. Kohman, Sanborn and Eddy (45), Nagai (64), Lanman and Minton (47) all reported that the addition of salt increased the losses of calcium and phosphorus; while Griebel and Miermeister (35) and Lang (46) found that salt would prevent the loss of calcium and phosphorus.

THE PROBLEM

In China the problem of an adequate supply of calcium is a very urgent one. Cow's milk, upon which the people of some countries depend for a large part for their calcium intake, is not accepted as a common food in the dietary of China, except for invalids and babies. But a majority of the babies still are on breast feeding. They get the maximum protection from the mother's milk by an extension of the nursing period until the children are two or three years old, but for the remainder of the growth period and for the entire period of adult maintenance the individual is dependent upon calcium derived from vegetable sources.

A very considerable amount of this calcium is supplied by the soy bean and its various products, which would seem to have filled, in part, the place which milk has occupied in the Occident. Vegetables also are the chief source of calcium supply in Chinese diet.

As mentioned above, information which is available from the various investigations indicates that the loss of calcium and phosphorus in cooking vegetables depends upon the amount of water used and the time of cooking. It seems as if the larger the quantity of cooking water and the longer the cooking time, the greater is the loss of these two elements. Steaming which involves practically no water induces the smallest amount of loss, sometimes even no loss.

The same is true in regard to waterless cooker.

Although steaming and cooking in waterless cooker do conserve the minerals, King (1935) (43) does not recommend cooking leafy green vegetable in such ways because of the unpalatable products obtained. She thinks the smaller loss of minerals in cooking would be more than counterbalanced by their loss in palatability. According to Loughlin (49), Holliday and Noble (36) and Lowe (50) the vegetables should be so prepared as to maintain both food value and palatability. The characteristic flavors and color should be retained as far as possible. The texture should be tender but still firm.

In China, one common way of cooking vegetables is sautéing in a little fat or oil. Vegetables cooked in this way usually retain most of their original flavor and color, and develop a tender but still firm texture. It is, therefore, of great practical importance to find out whether this method will conserve the food value as well as flavor and texture. Especially the calcium and phosphorus contents of the vegetables need special attention, as they are the chief ~~and~~ available sources of calcium and phosphorus in the Chinese dietary. So every possible way to conserve the calcium and phosphorus to the utmost possible degree should be investigated.

The present study was initiated therefore, to investigate the calcium and phosphorus content of vegetables cooked by the common Chinese household method, i.e., sauté-ing in a small amount of fat or oil.

EXPERIMENTAL

1. Preparation of the Vegetables

Peas, asparagus and cabbage were chosen to represent the three classes of commonly used vegetables, namely: green leafy vegetables, stems and seeds. Because the different classes of vegetables differ so much from one another both structurally and functionally, perhaps they would not behave in the same way under the influence of heat; so it was more desirable to have representives from different types of vegetables.

All the vegetables were purchased from a grocery store near the campus in Corvallis. The first lot of peas was purchased in May, while the second lot was in September. The autumn peas were somewhat more mature and larger in size than the Spring peas. The asparagus was grown in Harrisburg, Oregon. The celery cabbage was grown on a farm near Salem, Oregon. This vegetable originated in China where it is a winter vegetable.

The preparation of vegetables was undertaken as soon as the day's supplies had been received and the exact procedure necessarily varied with the type of vegetable.

In the case of peas, after shelling, all the seeds were well mixed in a bowl; it was thought unnecessary to wash them since the pods protected them from coming into contact with outside. Individual portions were weighed and wrapped up in wax paper and thick paper envelope and were stored in refrigerator until the time for cooking or analysis.

The asparagus was washed very quickly in tap water first, then it was rinsed in distilled water, and dried very carefully with clean towels. Then let it stand at room temperature for several minutes until all noticeable surface water had evaporated. The tough parts of the butts were broken off, the tips and the remainder of the butts being chopped with a big knife and well mixed on a piece of rubber cloth, and samples carefully taken. These were wrapped in double layers of wax paper and were put into thick paper bag and stored in refrigerator until used. Special precaution was taken to have the samples thoroughly mixed because Noble and Halliday (66) found that the tips of asparagus were richer in calcium than the butts.

Of the celery cabbage the coarse green outer leaves were removed. The inside head was then washed in distilled water twice, and cut into quarters, two alternate fractions of each quarter were used for cooking, the other two fractions for raw analysis. Then they were spread on clean towels and allowed to stand at room temperature until all noticeable surface water had evaporated. Care had been taken not to have the cabbage stand longer than was necessary to accomplish the drying, to avoid wilting. The cabbage was then cut into small pieces about one half inch squares with stainless knife and was thoroughly mixed by hand in a large bowl. Individual portions of desired weight were weighed out and were wrapped in wax paper as the other two vegetables.

2. Method of Cooking

In order to standardize the method of cooking each vegetable to be studied preliminary tests were made. The following points were considered:

a. Amount of vegetable by weight to use in each series.

b. The proportion of fat used.

c. The proportion of water.

d. Length of the cooking period for each vegetable studied.

e. The size and shape of the cooking vessels.

Standardized Method of Cooking Vegetable by Fat

A small amount of lard was melted first in a preheated skillet; when the fat was about at smoking temperature, the vegetable was added and the electric stove was turned to moderate heat in order to prevent burning. The vegetable was stirred for a few minutes, then a little distilled water was added to prevent drying. The vegetable was cooked until "tender" as tested by piercing. The time of cooking, the amount of lard and distilled water used all were determined by the amount of vegetables and the character of the vegetables used. Table I shows the proportions of ingredients and time of cooking of each vegetable.

TABLE I

AMOUNT OF INGREDIENTS USED AND TIME OF COOKING OF DIFFERENT VEGETABLES

Vegetables	Wt. of Sample gm.	Total Length of Time of Cooking min.	Amount of Fat Used	Amount of Water Added
Peas				
P analysis	50	6	1 tsp.	1 T
Ca analysis	100	6	2 tsp.	1 T
P analysis	150	6	2 tsp.	1 T
Ca analysis	250	6	1 T	1½T
Asparagus	150	9	1 T	2 T
	200	9	4 tsp.	2 T
Cabbage	250	8	4 tsp.	1 T

Swift Brand of pure lard and distilled water were used in cooking the vegetables in order to eliminate any other possible source of calcium and phosphorus. All the cooking utensils used were rinsed with distilled water. The same electric stove was used for all the cooking.

3. Preparation of Samples for Analysis

a. For Calcium Analysis

The individual portion of the weighed samples was put in porcelain evaporating dishes and was heated by low flame until the samples ceased to smoke and then were ashed in a muffle furnace at the temperature of red heat.

When the greyish white ash was cooled it was dissolved by hydrochloric acid and boiled gently for five minutes; the solution filtered through ashless filter paper(Whatman #44) and washed with hot water, cooled, transferred to a 250 c.c. volumetric flask and made up to volume with distilled water. Aliquots of 100 c.c. were used for analysis, the determinations being made in duplicate.

b. For Phosphorus Analysis

The samples were completely covered with a thin layer of $MgNO_3$ before ashing (19), because if uncovered, on heating at ashing temperature, the phosphorus content of the samples which was in the form of mono-potassium phosphate or dipotassium phosphate will be converted into potassium metaphosphate and pyrophosphate respectively. According to (1) $KH_2 PO_4 = KPO_3 + H_2O$

(2) $2K_2H PO_4 = K_4P_2O_7 + H_2O$

neither of these is precipitated with ammonia molyledate or "magnesia mixture".

The samples were first cautiously heated over a low flame; when the brown fumes and smoke were driven off, the dish was placed in the furnace and heated to a gray ash.

When the ash was cold, it was dissolved in nitric acid, the solution heated gently to boiling, then filtered through ashless paper. Both the washings and filtrates were transferred to a 250 c.c. volumetric flask and made up to volume, 100 c.c. aliquots being taken for analyses, and analyses being made in duplicate as with the calcium determinations.

4. Method of Analysis

a. Method of Calcium Determination

Calcium was determined by the method of McCrudden (60) as modified by MacLeod (52).

Aliquots of 100 c.c. were withdrawn from the solution by a pipette and were placed in 400 c.c. beaker. This solution was made just alkaline using 2.5 M NH_4OH as shown by the appearance of white precipitates and then just acid with molar HCl and 5 c.c. of 2.5 per cent oxalic acid were then added. The solution was boiled and an excess of 3 per cent ammonium oxalate was slowly added to the boiling solution and the boiling continued until the precipitate was coarsely crystalline. When the mixture was cold, 8 c.c. of 20 per cent sodium acetate were added slowly with vigorous stirring.

The precipitate of calcium oxalate was allowed to stand over night at room temperature and then filtered on Whatman #44 ashless filter paper and washed free from chloride with 0.5 per cent ammonium oxalate solution. Then the precipitate was washed three times with cold distilled water filling the filter about two-thirds full and allowing it to drain completely before adding more. A hole was made in the paper and the calcium oxalate was washed into the flask. The volume of the fluid was brought up to about 50 c.c. and 10 c.c. of concentrated H_2SO_4 were added, then the solution was heated to boiling and titrated immediately with standard potassium permanganate solution. The excess of permanganate used to cause the end point color was estimated by matching the color with a blank. Since the solution should not be below 60^o by the time the end point is reached, more rapid cooling was prevented by allowing the beaker to stand on a small asbestos board during the titration.

The reaction of the permanganate with the oxalates is as follows:

$$2KMnO_4 + 5CaC_2O_4 + 8H_2SO_4 \longrightarrow 2MnSO_4 + K_2SO_4 + 5CaSO_4 + 10CO_2 + 8H_2O$$

The potassium permanganate was standardized against Baker's special sodium oxalate for standardizing.

b. Method of Phosphorus Determination

The method used in this study was a modification of the directions given by the Association of Official Agricultural Chemists (3); some of the solutions were made according to the directions given in Fales' Quantitative Analysis (24).

The following is a detailed description of the procedure followed in this laboratory.

Aliquots of 100 c.c. were drawn with a pipette to a 400 c.c. beaker, concentrated NH_4OH was added in slight excess until a white precipitate was formed, then the precipitate barely dissolved with a few drops of HNO_3, stirring vigorously. The solution was heated on a steam bath at about 80^oC. To the hot solution, 84 c.c. ammonium molybdate reagent were added rapidly with constant stirring for every decigram P_2O_5 present. After which the solution was put on steam bath to digest at about 65^o for one hour; a few more c.c. of molybdate reagent were added to the clear supernatent liquid in order to determine whether the phosphorus had been completely precipitated. The precipitate of ammonium phospho-molybdate was then set aside for a few hours before filtering. The clear supernatent fluid was decanted off into a filter; the precipitate in the original beaker was washed four or five times with NH_4NO_3 solution, each time the precipitate being stirred up and let to settle again, then the clear fluid decanted off. Then the beaker was placed under the filter paper, and 30 c.c. of hot half-concentrated NH_4OH were poured over the latter in 10 c.c. portions to dissolve the adhering precipitate; after which the filter was washed several times with hot water. The filtrate and washings, whose combined volume should not exceed 100 c.c., were caught in the beaker and were used to dissolve the precipitate which it contained. After the ammonium phospho-molybdate had been dissolved, the solution was made slightly acid to litmus with 3 M HCl, cooled to room temperature, and then 19.5 c.c. of "magnesia mixture" for each decigram P_2O_5 present were added slowly dropwise from burette with constant stirring. After fifteen minutes, 12 c.c. concentrated NH_4OH were added. The solution was then allowed to stand at room temperature for at least four hours, until the precipitate of $MgNH_4PO_4 \cdot 6H_2O$, which was characterized by its crystalline form, had completely settled.

The precipitate of $MgNH_4PO_4 \cdot 6H_2O$ was filtered off into a weighed Gooch crucible and washed several times with dilute ammonium hydroxide until the washings were practically free from chloride. Then it was dried over a low flame, transferred to the muffle furnace and ignited to red heat for at least one hour. It was cooled in a desiccator for half of an hour, and weighed as $Mg_2P_2O_7$. The heating was repeated several times until constant weight was obtained.

The results reported were averages of two aliquot portions of each sample, each determination checked with the other within 0.1 per cent.

$$2MgNH_4PO_4 + 6H_2O \longrightarrow Mg_2P_2O_7 + 2NH_3 + 7H_2O$$

RESULTS AND DISCUSSION

The calcium contents of raw and cooked asparagus, celery cabbage and peas are given in Tables II, III and IV.

The percentage composition of calcium in the individual determinations from the same lot of vegetables did not vary very much. In the case of celery cabbage, all the four determinations show 0.032 to 0.033 per cent calcium; in raw peas the individual determinations all checked very closely with each other from 0.020 to 0.025 per cent calcium; raw asparagus, 0.021 to 0.028 per cent calcium.

The percentage composition of cooked celery cabbage and cooked peas did not vary very much from each individual determination, being 0.033 to 0.034 per cent calcium for the cooked celery cabbage and 0.020 to 0.024 per cent for the cooked peas. But the calcium determination of each individual sample of cooked asparagus varied somewhat more, being from 0.017 to 0.030 per cent. This may be due to the difficulty of sampling the asparagus, Noble and Halliday (65) having reported that the calcium content of asparagus butts was only about two thirds as much as that of the tips. It was very difficult to have the tips and the butts equally distributed among each individual sample.

The four determinations of two samples of cooked fall peas and two samples of raw fall peas resulted in a uniform figure of 0.020 per cent of calcium. The three determinations of the raw spring peas varied only little from 0.023 to 0.024 per cent of calcium. The fact that these results check more closely than the analyses of asparagus may be due to the fact that peas are more uniform in composition, so it was easier to obtain a representative sample.

Other investigators have reported that variety, fertilizer, soil and water all can effect the calcium and phosphorus content of vegetables. In the present investigation, in one determination (Table II) the Emerald Brand of asparagus which was grown in Harrisburg, Oregon showed a somewhat lower calcium content than the Shamrock Brand of asparagus grown in Salem; but the differences were small.

The peas which had been purchased in May seemed to have a little higher calcium content than those purchased in September, being 0.024 per cent and 0.020 per cent respectively. The Autumn peas were somewhat larger in size and more mature than the Spring peas. Although Brookover and Pittman (9) did not find any differences in the calcium content of vegetables purchased in February or in April, they found that the phosphorus content of carrots purchased in April was twice as high as that of those purchased in February, and the losses of calcium in cooking were consistently higher in the February cabbage and spinach.

In the present study, the average percentage composition of calcium of the raw asparagus is 0.026 per cent, while the figure for the cooked asparagus also is 0.026 per cent, so there is no difference in calcium content between raw and cooked asparagus. The average calcium content of raw celery cabbage is 0.032 per cent, while the average figure for cooked celery cabbage is 0.034 per cent, a difference which probably has no significance. The calcium contents of both raw and cooked peas were 0.022 per cent; so there is no loss of calcium in cooking peas.

The phosphorus content of raw and cooked asparagus and peas are shown in Tables V and VI. The phosphorus contents of raw asparagus range from 0.071 to 0.076 per cent and 0.069 to 0.075 per cent for the cooked asparagus. As in the case of calcium content of asparagus this range of variation which is wider than that for peas, may be due to uneven distribution of tips and butts in sampling. The average phosphorus contents of raw and cooked asparagus are 0.074 per cent and 0.073 per cent respectively; this small difference cannot be considered significant.

The spring peas seemed also to have a little higher phosphorus content than the fall peas, being 0.104 per cent and 0.122 per cent respectively. The average phosphorus content of the raw peas is 0.115 per cent and that of the cooked peas is 0.119 per cent. The slightly higher value of the cooked is inexplainable.

Comparing the data of the average calcium and phosphorus contents of raw and of cooked vegetables as shown in Table VII, no differences are to be observed between cooked and raw vegetables for both calcium and phosphorus.

Since recent research indicates that the calcium and phosphorus content of vegetables may vary greatly, it seemed interesting to compare the analyses made in this study with those of other investigations. (See Table VIII) The average calcium contents of asparagus and peas here analyzed are found to agree quite well with Sherman's figures, but they are definitely higher than the other two investigations. Few analyses of celery cabbage are available. Peterson and Hoppert (67) report a higher calcium content than found here. The average phosphorus contents of asparagus are much higher in the present experiment than those given by Sherman (84). The phosphorus content of peas agrees fairly well with both Sherman and Noble and Halliday.

Few studies have been made on the effect of frying of nutritive content. McCance, Widdowson and Shackleton (57) showed that the frying of potato chips in deep fat resulted in great loss of water, but no loss of chloride whatever, and presumably therefore no loss of any other salts. They remark, "These results are of practical interest because potatoes are so often cooked in this way".

Richardson, Davis and Mayfield (72) found that German fried potatoes (fried raw potatoes) lose much less vitamin C than the American fried potatoes (potatoes boiled then fried). More recently Wellington and Tressler (88a) in comparing the different methods of cooking cabbage with special regard to the total destruction of ascorbic acid and its extraction by the cooking water reported that in panned cabbage, the ten minutes heating in fat resulted in a greater total destruction of vitamin C, but as none of the ascorbic acid was extracted by the cooking water, the cabbage itself retained a greater amount of ascorbic acid.

Thus, this method of cooking vegetables--sautéing--is a very good practice in those countries where the calcium and phosphorus supplies are dependent on vegetable sources to a large extent. In China, in ordinary household practice, soy bean sauce is used to flavor the vegetables instead of salt. According to Hoh's (39) analysis, 10 c.c. of soy bean sauce contain 0.022 gm. of calcium and 0.008 gm. of phosphorus. So the liberal use of soy bean sauce may add a little to the total intake of calcium. In addition to vegetables, the common Chinese diet includes eggs, fowl, fish, pork (sometimes with bones) which also may help to meet the demand of calcium and phosphorus to a certain extent. When it is difficult to obtain enough calcium in the diet losses in cooking may mean the difference between adequacy and inadequacy. Therefore, the method used in this investigation is to be recommended, as all of the calcium and phosphorus is retained.

CONCLUSION AND SUMMARY

Asparagus, celery cabbage and peas were analyzed for calcium and phosphorus both in the raw state and after cooking by sautéing, a common Chinese method of preparing vegetables. The average calcium contents of the raw asparagus, celery cabbage and peas were 0.026 per cent, 0.032 per cent and 0.022 per cent respectively, and the average calcium contents of the three vegetables after cooking were 0.026 per cent, 0.034 per cent and 0.022 per cent respectively.

The average phosphorus contents were 0.074 per cent for raw and 0.073 per cent for cooked asparagus, and 0.115 per cent for raw and 0.119 per cent for cooked peas. The average calcium and phosphorus contents of the cooked vegetables were, therefore, practically the same as the raw ones. So under the conditionsof this investigation cooking these vegetables by sautéing caused no loss in calcium or phosphorus.

TABLE II

CALCIUM CONTENTS OF RAW AND COOKED ASPARAGUS

Size of Sample gm.	Brand of Asparagus	Wt. Ca in Sample gm.	% Ca in Sample
		Raw	
150	Shamrock	0.0427	0.028
150	Shamrock	0.0393	0.026
150	Shamrock	0.0423	0.028
200	Emerald	0.0423	0.021
Average			0.026
		Cooked	
150	Shamrock	0.0422	0.028
150	Shamrock	0.0446	0.030
150	Shamrock	0.0414	0.028
200	Emerald	0.0348	0.017
Average			0.026

TABLE III

CALCIUM CONTENTS OF RAW AND COOKED CELERY CABBAGE

Size of Sample gm.	Wt. of Ca in Sample gm.	% of Ca in Sample
	Raw	
250	0.0812	0.033
250	0.0794	0.032
250	0.0794	0.032
250	0.0808	0.032
Average		0.032
	Cooked	
250	0.0840	0.034
250	0.0846	0.034
250	0.0835	0.033
250	0.0830	0.033
Average		0.034

TABLE IV

CALCIUM CONTENTS OF RAW AND COOKED PEAS

Size of Sample gm.	Month of Purchase	Wt. Ca in Sample gm.	% Ca in Sample
		Raw	
100	May	0.0238	0.024
100	May	0.0234	0.023
100	May	0.0247	0.025
250	Sept.	0.0491	0.020
250	Sept.	0.0495	0.020
Average			0.022
		Cooked	
100	May	0.0240	0.024
100	May	0.0240	0.024
100	May	0.0244	0.024
250	Sept.	0.0500	0.020
250	Sept.	0.0500	0.020
Average			0.022

TABLE V

PHOSPHORUS CONTENTS OF RAW AND COOKED ASPARAGUS

Size of Sample gm.	Brand of Asparagus	Wt. P. in Sample gm.	% P. in Sample
		Raw	
150	Shamrock	0.1059	0.071
200	Emerald	0.1598	0.076
200	Emerald	0.1437	0.072
200	Emerald	0.1522	0.076
Average			0.074
		Cooked	
150	Shamrock	0.1122	0.075
200	Emerald	0.1427	0.071
200	Emerald	0.1478	0.074
200	Emerald	0.1388	0.069
Average			0.073

TABLE VI

PHOSPHORUS CONTENTS OF RAW AND COOKED PEAS

Size of Sample gm.	Month of Purchase	Wt. P. in Sample gm.	% P. in Sample
		Raw	
50	May	0.0569	0.114
50	May	0.0657	0.131
50	May	0.0612	0.123
150	Sept.	0.1528	0.102
150	Sept.	0.1610	0.107
Average			0.115
		Cooked	
50	May	0.0640	0.128
50	May	0.0695	0.136
50	May	0.0676	0.124
150	Sept.	0.1579	0.105
150	Sept.	0.1581	0.105
Average			0.119

TABLE VII

AVERAGE CALCIUM AND PHOSPHORUS CONTENTS OF RAW AND COOKED ASPARAGUS, CELERY CABBAGE AND PEAS

Vegetables	Calcium Raw	Calcium Cooked	Phosphorus Raw	Phosphorus Cooked
Asparagus	0.026%	0.026%	0.074%	0.073%
Celery Cabbage	0.032%	0.034%		
Peas	0.022%	0.022%	0.115%	0.119%

TABLE VIII

AVERAGE CALCIUM AND PHOSPHORUS CONTENT OF VEGETABLES AS DETERMINED BY VARIOUS INVESTIGATORS

(In quantity equivalent to 100 gm. raw)

	Calcium			Phosphorus		
	Asparagus gm.	Celery Cabbage gm.	Peas gm.	Asparagus gm.	Celery Cabbage gm.	Peas gm.
Peterson and Hoppert (67)	0.016	0.045		0.049	0.041	
Sherman (84)	0.021		0.023	0.040		0.127
Noble and Halliday (65)	0.019		0.020 to 0.028	0.068		0.099
Yu	0.026	0.032	0.022	0.074		0.115

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