

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given **Jean Muir Dorsey** final oral examination for the degree of Master of Science . We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

May 26 1921

Alice Biester
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R. Adams Butcher

THE UNIVERSITY OF MINNESOTA

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Report
of
Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by **Jean Muir Dotsey** for the degree of **Master of Science**. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of

Alice Biester

Chairman

Clarence A. Morrow

R. Adams Dutcher

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STUDIES ON THE LOSSES OF IRON
IN THE
COOKING OF VEGETABLES

A Thesis Submitted to the
Faculty of the Graduate School of the
University of Minnesota

by

Jean Muir Dorsey

in partial fulfillment of the requirements
for the degree of
Master of Science

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INTRODUCTION

Many of the methods of cooking vegetables have been developed primarily from the standpoint of the appearance and palatability of the cooked product, instead of from the effect upon the composition. The addition of salt to the cooking water for the purpose of retaining color and of improving the flavor is a common household practice. The effect of this method of cooking upon the composition has been given little consideration. Recent investigations indicate that there is a decrease in the loss of total minerals in vegetables cooked in salted water. While this knowledge is valuable from one standpoint, it gives no definite information on the effect of the salted water upon the loss of some of the most significant mineral elements such as iron, calcium and phosphorus. For this reason, a study of the losses of iron in vegetables cooked in salted water and of the losses of iron in vegetables cooked in distilled water was undertaken.

In a study of the effect of salted cooking water upon the loss of the total mineral salts, Bodinus (1915) found that potatoes lost 10 percent of their mineral salts in contrast to 33 percent in the check in which no salt was added. Denton (1919) reports similar results in the blanching of vegetables. In blanching peas in distilled water there was a loss of 15 percent of the total minerals while in a 1.5 percent salt solution, the loss was only 8 percent.

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In blanching string beans in distilled water the mineral loss was 15 percent in contrast to a loss of 13 percent in a 0.25 percent salt solution. In all of these experiments cooking in the salt solution decreased the loss of mineral salts. It should be noted, however, that this method of attack gives no indication of the effect upon any single mineral.

The literature dealing with the loss of iron in cooking vegetables is meagre. In cooking 100 grams of fresh spinach in distilled water, Haensel (1908) reported a loss of approximately 0.08 grams of iron, estimated as iron oxide. Courtney, Fales and Bartlett (1917) determined the mineral salts lost in the cooking of seven different vegetables. They determined the iron in the cooked vegetables and in the cooking water. They found that carrots, onions and asparagus lost but a trace of iron, while spinach lost 28 percent of the total iron present, and New Zealand spinach, 51 percent. They also found that reducing the time of cooking made little difference in the loss of mineral salts. Blunt and Otis (1917) worked with spinach, string beans, navy beans, peas and potatoes. These were cooked in 25 - 75 c.c. distilled water in a covered beaker 20 to 40 minutes, except the navy beans, which were cooked two hours. Seven potatoes were scraped, washed in distilled water, grated and mixed. Four samples of this pulp were then taken for analysis. The cooked potatoes were treated in much the same way, seven being

scraped and cooked together, riced and well mixed, and four samples being taken. Both the raw and cooked vegetables and the cooking water were analyzed for iron. The loss of iron from each was found to be as follows: spinach, 43 to 50 percent; string beans, 39 to 43 percent; navy beans, 32 to 39 percent and potatoes 15 to 22 percent.

It will be seen, that the investigations reported above, have dealt with the effect of cooking upon the loss of the total salts and upon iron. In the case of the total mineral salts the loss was determined in both salted and unsalted water. In the case of iron, however, the loss was determined only in unsalted water. Since the practice of cooking vegetables in salted water is so general this investigation was undertaken with the object of obtaining information upon the loss of iron in vegetables cooked in salted water.

EXPERIMENTAL

Method: The colorimetric methods are the most satisfactory for determining small quantities of iron. Both the ferrocyanide method and the thiocyanate method are used. In a method involving the quantitative estimation of iron by means of colorimetry, it is evident that a given quantity of iron should always produce a given density of color in a given volume of solution. In matching colors it is also necessary that the shade of color should be the same. For these reasons the reaction must be relatively stable, that is, not affected by such acids and salts as may be used in the experiment, or as may be contained in the material analyzed.

Before selecting a method, a survey of the literature was made. The thiocyanate method was first studied. This reaction takes place when a ferric salt interacts with a soluble thiocyanate. The red ferric thiocyanate formed is a most suitable color for matching in the colorimeter, even in dilute solutions.

Curtman and Harris (1916) state that the equilibrium of the thiocyanate reaction is so easily disturbed by the addition of ferric chloride intensifying the color, or by the addition of other salts diminishing the color, that it is difficult to adjust conditions so as to obtain constant results. They also state that many acids interfere with this reaction. Arsenates, phosphates, oxalates, tartrates, fluorides and borates hinder the free course of the reaction; ferrocyanides mask the red color; while iodides, acetates and nitrates

offer the most serious interferences by forming colorations with ferric salts similar to the color of ferric thiocyanate. In order to produce the maximum color, Kruss and Moraht (1899) found that there must be at least twelve times as many grams of potassium thiocyanate as ferric chloride. This condition, however, is not reproducible when unknown quantities of iron are present. Prescott and Johnson (1903) found that borates, tartrates and oxalates and salts of mercury render the reactions with thiocyanates unreliable. Nottbohm and Weiszwange (1912) working with milk ash observed that the phosphates affected the red color. Moore (1886) also notes that the presence of phosphates renders the reaction with thiocyanates unreliable. This observation is confirmed by Marriot and Wolf (1905). They state that the difficulty may be avoided by increasing the concentration of the hydrochloric acid used in acidifying the solution. Blunt and Otis (1917) in experiments with vegetables report that the phosphates do not affect the color if an excess of thiocyanate is used. In some preliminary experiments in which the feasibility of using the thiocyanate method for determining iron with salted and unsalted vegetables was being tested, by the writer, it was found that the color faded after a short time although an excess of thiocyanate was added. It is obvious from these reports that the thiocyanate reaction, although a very sensitive test for iron is affected by many acids and salts and is consequently unreliable. Therefore, the ferrocyanide method was investigated.

Potassium ferrocyanide, $K_4 Fe (Cn)_6$, produces in neutral or acid solutions of ferric salts an intense blue pre-

precipitation of Prussian blue or ferric ferrocyanide. This clear blue solution can easily be matched in the colorimeter. Bell (1889) and Sutton (1911) suggest this method for the determination of small quantities of iron in water. The material containing minute quantities of iron is dissolved in dilute hydrochloric acid and small amounts of nitric acid and potassium ferrocyanide added thus producing a clear blue color. Vorländer (1913) found that very dilute solutions of ferric chloride and weak hydrochloric acid on the whole form no blue color, or only an indefinite greenish color. In such solutions the reaction continues for hours and the Prussian blue forms gradually and separates out in flakes. He also states that the formation of Prussian blue may be retarded or even prevented by acids and salts.

Viehoever and Johns (1915) in the determination of hydrocyanic acid found that sodium chloride and potassium fluoride hastened the formation of Prussian blue. They also found that an excess of hydrochloric acid tended to make the color of the suspension green because of the formation of ferric chloride. The mixture of the yellow ferric chloride solution with the Prussian blue produced the green shade. They obtained good results with sulphuric and nitric acids of different concentrations. It should be noted that in these experiments only ferrous sulphate was used and sufficient ferrous salt oxidized during the operation to furnish the ferric ions needed.

Claudius (1918) reported the Prussian blue method for the micro-determination of iron in blood. He experienced

no difficulty if fresh solutions were used in making up the standard.

Since the reports above do not agree, the conditions under which a satisfactory standard could be prepared were first studied. Iron wire (99.9% pure) was used for a standard. One tenth of a gram was dissolved in 5 c. c. each of concentrated sulphuric and nitric acids, and made up to 2 litres. One cubic centimeter of this solution contained 0.05 milligram of iron or 0.00005 gram. The purity of the iron wire was determined as follows. A sample of sodium oxalate was purified according to the method given by the Bureau of Standards in Circular No. 40. Potassium permanganate was then titrated against the sodium oxalate solution. Following the method of Mahin (1919) a known amount of iron wire was dissolved in 10 c. c. of concentrated hydrochloric acid. Four cubic centimeters of concentrated sulphuric acid were added to the iron solution and the whole evaporated until the characteristic white fumes of sulphuric acid appeared, this being the point at which all water and hydrochloric acid have been expelled. This solution was cooled and diluted and 0.05 of a gram of granular zinc was used for reducing the iron. After the zinc was dissolved, the liquid was cooled and titrated at once with the standard potassium permanganate solution and the percentage of iron in the wire calculated. A blank determination was made upon the zinc to ascertain the amount of iron present and the necessary corrections were made in the above determinations.

The standard described by Claudius was found to be the most satisfactory for studying the effects of different compounds and different conditions upon the ferrocyanide reaction. In these experiments two cubic centimeters of the standard iron solution were measured into a 50 c. c. volumetric flask. One drop of 10% nitric acid and 2 drops of a freshly prepared 5% potassium ferrocyanide solution were added, and the whole, made up to the mark with distilled water. This resulted in a clear blue solution which could easily be compared with the standard in the colorimeter. The potassium ferrocyanide was made up fresh each time, because dilute solutions decompose if allowed to stand for a few hours. Claudius reports that the standard solution must be freshly prepared - not older than two hours - since the potassium ferrocyanide itself will become blue in dilute solutions. Observations were made on the length of time that the standard used in matching could be allowed to stand before using, and no change was noted over a period of twelve hours, when the solution was matched against a fresh standard.

Vorländer as noted above reported that the formation of Prussian blue may be retarded or even prevented by acids. Since the iron in the vegetables is obtained in a ferric state which might involve the use of acids other than those used in preparing the standard, it seemed advisable to test out the effect of different amounts of acid which might be used for oxidation or in obtaining

satisfactory solutions, upon the formation of "Prussian blue".

Accordingly duplicate "standard" solutions were prepared with varying amounts of acid. Two drops. 0.5 c.c., 1 c.c., 2 c. c. and 3 c. c. of 10% nitric 10% sulphuric and 10% hydrochloric acids and 1 c.c. and 4 c.c. of the concentrated acids were substituted for a part of the water used by Claudius in making the standard for comparison with the unknowns.

The standards made up with the acids were matched against a standard solution made according to the directions of Claudius, as well as against each other. The results of the experiments in which the effect of varying amounts of different acids were tested are given in Table 1.

The results as given in Table 1 show that 2 cubic centimeters or lesser amounts of 10% nitric acid or 10% hydrochloric acid or 10% sulphuric acid do not interfere with the color formation in the ferrocyanide reaction, but with 1 c.c. or more of the concentrated nitric, hydrochloric or sulphuric acids or with larger amounts of 10% acids, blue green or yellow green colors are formed. A mixture of yellow ferric salts and Prussian blue form different colors. When the blue color predominates the solution is blue green, and when the yellow salts predominates the solution is yellow green. According to Vorländer (1913) and Treadwell and Hall (1913), concentrated hydrochloric acid dissolves the Prussian blue giving a yellow color.

Table 1. The Effect of Acid on the Ferrocyanide Reaction.

| Amount of Standard solution | Amount and Kind of acid | Color of resulting solution |
|-----------------------------|--|-----------------------------|
| 2 c. c. | 2 drops 10% HNO_3 | Blue |
| 2 | 0.5 c. c. " " | Blue |
| 2 | 1.0 c. c. " " | Blue |
| 2 | 2.0 c. c. " " | Blue |
| 2 | 3.0 c. c. " " | Blue green |
| 2 | 1.0 c. c. con. HNO_3 | Blue green |
| 2 | 4.0 c. c. " " | Yellow green |
| 2 | 2 drops 10% HCL | Blue |
| 2 | 0.5 c. c. " " | Blue |
| 2 | 1.0 c. c. " " | Blue |
| 2 | 2.0 c. c. " " | Blue |
| 2 | 3.0 c. c. " " | Blue green |
| 2 | 1.0 c. c. con. HCL | Blue green |
| 2 | 4.0 c. c. " " | Yellow green |
| 2 | 2 drops 10% H_2SO_4 | Blue |
| 2 | 0.5 c. c. " " | Blue |
| 2 | 1.0 c. c. " " | Blue |
| 2 | 2.0 c. c. " " | Blue |
| 2 | 3.0 c. c. " " | Blue green |
| 2 | 1.0 c. c. con. H_2SO_4 | Blue green |
| 2 | 4.0 c. c. " " | Yellow green |

Vörlander also states that salts retard or prevent the formation of Prussian blue. Therefore, a series of experiments were tried to test the effect of the various salts upon the ferrocyanide reaction. Salts comparable in kind and amount to those found in vegetables were weighed and dissolved in distilled water and made up with 1 c.c. of 10% hydrochloric acid, 1 drop 10% nitric acid and 2 drops potassium ferrocyanide and matched against the standard. The salts used were as follows: .150 grams sodium chloride, .200 grams monobasic sodium phosphate, .200 grams tribasic sodium phosphate, .050 grams sodium sulphate, .050 grams potassium nitrate, 2 drops 10% potassium fluoride and .200 grams potassium chloride. The results of these experiments have been compiled in Table 2.

Satisfactory blue colors which could be matched accurately against the standard solution were formed with all of the salts. The results set forth in Table 2 do not confirm Vorländer's statement. They agree more closely with the findings of Viehoveer and Johns (1918). The potassium fluoride hastened the formation of Prussian blue and gave a brilliant color. The addition of sodium chloride also gave a clearer blue color. The action of sodium chloride made this method particularly desirable for the determination of iron in vegetables cooked in salted water.

Table 2. The Effect of Salts on the Ferrocyanide Reaction

| Amount of Standard Solution | Amount and Kind of salt | Color of resulting solution | Matching against standard |
|-----------------------------|--|-----------------------------|---------------------------|
| 2 c.c. | .150 grams sodium chloride. | Blue | Accurate |
| 2 c.c. | .200 grams mono-basic sodium phosphate | Blue | Accurate |
| 2 c.c. | .200 grams Tri basic sodium phosphate | Blue | Accurate |
| 2 c.c. | .050 grams sodium sulphate | Blue | Accurate |
| 2 c.c. | .050 grams potassium nitrate | Blue | Accurate |
| 2 c.c. | 2 drops 10% potassium fluoride | Blue | Accurate |
| 2 c.c. | .200 grams potassium chloride | Blue | Accurate |

In order to carry out the ferrocyanide reaction, it was necessary to destroy the organic matter in the vegetables and to obtain the iron in the ferric state. The wet oxidation method was first tried. Blunt and Otis (1917) used this method in making their iron determinations on vegetables. They used concentrated sulphuric and nitric acids and then treated the acid solution with potassium thiocyanate. It was impossible to use sulphuric acid in the oxidation of vegetables with the ferrocyanide method, because the acid could not be evaporated. Neutralization of the sulphuric acid with sodium hydroxide and with potassium hydroxide was tried. This resulted in too great an error, because such large quantities of these bases were necessary to neutralize the acid. Moreover, the resulting solution gave only a faint color test.

Following the method of Halverson (1919) fuming nitric acid 1:4, was used for oxidation because the nitric acid used could be evaporated on the steam bath. Approximately ten grams of potatoes were digested in this manner until the solution was clear. This required 5 - 6 days.

The fuming nitric acid gave a sticky residue which prevented complete evaporation of the acid. Apparently the amount of unremoved concentrated acid interfered with the ferrocyanide reaction. This led to another series of experiments to determine if possible, the effect of fuming nitric acid, of the 1.5 percent salt solution used for cooking the vegetables, and of the starch and of the cellulose found in most vegetables, upon the color formation. Two cubic centi-

meters of the standard iron solution and different amounts of fuming nitric acid were first tried. These experiments were repeated with the addition of a 1.5 percent salt solution. Triplicate samples of 2 c.c. of the standard solution and a quantity of cellulose or starch comparable to that found in 10 grams of potato were digested in 20 c.c. of fuming nitric acid. Duplicates using 2 c.c. of the standard solution with both cellulose and starch added were digested in 20 c.c. of fuming nitric acid. Duplicate experiments using 2 c.c. of the standard solution with 15 c.c. of a 1.5 percent salt solution, starch, cellulose and 20 c.c. fuming nitric acid were tried. Digestion was carried on in Kjeldahl flasks over the steam bath 5 - 6 days, at which time the solutions appeared to be clear. These solutions were then transferred into evaporating dishes and evaporated over the steam bath. The residue was dissolved in water and washed into a 50 c.c. volumetric flask. One drop of 10% nitric acid and 2 drops of fresh potassium ferrocyanide were added. The solution was made up to volume and compared with the standard. The results of this series of experiments are given in Table 3.

Table 3. The Effect of Fuming Nitric Acid, NaCl, Starch and Cellulose upon the Ferrocyanide Reaction.

| Amount of standard solution or vegetable | Amount of fuming nitric Acid | Amount of 1.5% NaCl solution | Amount of soluble starch | Amount of cellulose | Color of resulting solution | Matching against Standard |
|--|------------------------------|------------------------------|--------------------------|---------------------|-----------------------------|---------------------------|
| c.c. | c.c. | c.c. | grams | grams | | |
| 2 | 5 | | | | Blue | Accurate |
| 2 | 10 | | | | " | " |
| 2 | 15 | | | | " | " |
| 2 | 20 | | | | " | " |
| 2 | 5 | 15 | | | Blue | Accurate |
| 2 | 10 | 15 | | | " | " |
| 2 | 15 | 15 | | | " | " |
| 2 | 20 | 15 | | | " | " |
| 2 | 20 | | 1.739 | | Blue | Accurate |
| 2 | 20 | | 1.666 | | " | " |
| 2 | 20 | | 1.756 | | " | " |
| 2 | 20 | | | .040 | Blue | Accurate |
| 2 | 20 | | | .040 | " | " |
| 2 | 20 | | 2.000 | .040 | Yellow Green | Accurate |
| 2 | 20 | | 2.000 | .040 | " | " |
| 2 | 20 | 15 | 2.000 | .040 | Yellow green | - |
| 2 | 20 | 15 | 2.000 | .040 | " | - |
| 9.905 gm. raw potato | 20 | | | | Yellow green | - |
| 10.02 gm raw potato | 20 | | | | " | - |

The results summarized in Table 3 show that from 5-20 c.c. of fuming nitric acid or 15 c.c. of 1.5 percent sodium chloride do not interfere with the formation of the Prussian blue color. When starch and cellulose were digested separately in 20 c.c. of fuming nitric acid and evaporated, no difficulty was experienced in carrying out the color test, but a combination of starch and cellulose digested in 20 c.c. of fuming nitric acid gave a sticky residue similar to the one with potatoes. When the residue was dissolved and tested, a yellow color was formed which according to Vorlander is due to the fact that the acid dissolves the Prussian Blue. Neutralization of the acid, with sodium hydroxide gave no better results. Consequently, this method was abandoned and the method suggested by Claudius (1918) with a few minor variations was adopted in this investigation.

In using the Prussian blue method for the micro-determination of iron in blood Claudius first oxidized the blood over a flame at a low temperature. He found that when ignition took place at a dark red heat the iron compounds were easily soluble in hydrochloric acid. When the ignition was completed the dish was cooled and 10 drops of concentrated hydrochloric acid (40%) were added and the dish placed upon a water bath. In this manner the temperature of the dish did not reach 100°. This was desirable because iron compounds dissolve in hydrochloric acid more easily at a temperature below boiling. The hydrochloric acid was evaporated and the iron remained in the form of ferric chloride. One drop of 10% nitric acid was added, and the contents of the dish were washed.

into a volumetric flask; 2 drops of fresh 5% potassium ferrocyanide were added and the whole made up to volume with distilled water. This solution was matched in a colorimeter against a known standard.

This method as described was tried out with samples of raw potato. The potato was sliced and weighed in a covered beaker to prevent as much evaporation as possible. These samples were ignited in an electric muffle furnace at a temperature which did not exceed 500° C. A rheostat and a pyrometer were used in controlling the temperature. The ash from each of two samples was dissolved in 1/2 c.c. of 10% hydrochloric acid over the steam bath, evaporated, treated with 1 drop 10% nitric acid and washed into a 50 c.c. volumetric flask. Two drops of freshly prepared potassium ferrocyanide were added and the solutions were made up to volume and matched against the standard in a Kober colorimeter. These solutions had a greenish shade, which according to Vorländer was due to the dilute solution of ferric chloride and hydrochloric acid. The ash from each of two similar samples of potatoes was dissolved in 1 c.c. of 10% hydrochloric acid, treated with 1 drop 10% nitric acid, made up and matched against the standard. Satisfactory blue colors of varying shades were formed. Accordingly 1 c.c. of 10% hydrochloric acid and 1 drop of 10% nitric acid were used in dissolving the ash in the succeeding experiments, described, and the standard for comparison was made up in a similar manner.

In order to be certain that none of the iron was lost in ignition, 2 c.c. of the standard solution were added to a

sample of potatoes and the whole was evaporated and ignited. The resulting ash was made up in the usual manner and matched against a standard. The reading showed an amount of iron comparable to that found in the other samples of potatoes plus that in 2 c.c. of the standard solution added. It appeared from this that little if any iron was lost by ignition.

The ferrocyanide method seemed to present fewer difficulties than did the thiocyanate method. Consequently this was the method used in these experiments.

Spinach, potatoes, peas, carrots and string beans, vegetables commonly used and relatively high in their iron content were available on the market and consequently these were selected for this study. All were cooked in Kjeldahl flasks. The evaporation of cooking water was prevented by means of a modified Hopkins condenser. The condensers were made from large test tubes which were inserted in the flasks. These were fitted with two holed rubber stoppers, glass tubes and rubber hose to provide inlets and outlets for the cold water. In this way a constant amount of cooking water as well as a fairly constant concentration of salt solution were maintained.

The vegetables were always plunged into boiling water and the cooking was continued at the boiling point. According to Snyder (1897) less of the nitrogenous matter and slightly less of the mineral salts are lost when vegetables are put immediately into boiling water. Triplicate samples of the raw vegetables were weighed and cooked in both salted and unsalted water for the same length of time. After cooking, the vege-

tables were drained in a glass funnel one or two minutes. The raw and the cooked vegetables and the cooking water were analyzed according to the method described.

Preliminary trials were made in the cooking of different vegetables to determine the proportion of liquid to vegetable and the time of cooking. The common methods of preparation were used. The aim was to prepare a cooked product which would retain its shape and still be tender. The proportion of approximately one tablespoon of sodium chloride to a quart of water or a 1.5 percent salt solution was selected as the concentration used in these experiments, because it gave the most palatable product.

Experiments with Potatoes: The variety of potato used in making these analyses was the Rural New Yorker, grown on a rich sandy loam. In the preparation of the potatoes nine were peeled, washed in distilled water, drained, cut into one-half inch cubes and thoroughly mixed. From 7 - 10 grams were then cooked in 15 c.c. of distilled water for 10 minutes, at the end of which time the pieces were thoroughly cooked, but unbroken. From the general appearance and texture of the cubes when cooked, the product seemed comparable to properly cooked whole potatoes. The analyses of the raw potatoes were made from cubes from the same potatoes.

As a basis for comparison the iron was first determined in the raw potato as shown in Table 4.

Table 4. Amount of Iron in Raw Potato

| Weight of raw potato | Quantity of Standard matched | Iron in Standard matched | Iron in raw potato | Iron in 100 grams raw potato |
|----------------------|------------------------------|--------------------------|--------------------|------------------------------|
| gm | cc | mg | mg | mg |
| 10.1220 | 2 | 0.1 | 0.0990 | 0.978 |
| 8.8745 | 2 | 0.1 | 0.0890 | 1.000 |
| 9.7415 | 2 | 0.1 | 0.0946 | 0.993 |
| Av. 9.5790 | | | 0.0946 | 0.990 |

It will be seen from the table that the potato contains a relatively high percent of iron which is apparently well distributed throughout the tuber. This indicates that potato is a good source of iron provided that the iron is retained in cooking. These analyses show 0.99 milligram of iron in 100 grams of raw potato. Sherman (1919) obtained 1.3 mg by the gravimetric method, Blunt and Otis (1917) an average of 1.1 mg. by the thiocyanate colorimetric method. The variety of potatoes used in these analyses was not given and may account for the differences in results.

Table 5 gives the amount of iron in the cooked potato and the amount lost in the cooking water. The loss of iron in the cooking water was also calculated by subtracting the iron in the cooked potato from the iron in the raw potato used (as calculated). The percentage of total iron of the potato, lost

in cooking in distilled water, is 30 percent by determination and 37 percent by calculation. In cooking whole potatoes in distilled water Blunt and Otis (1917) report a loss of 15-22 percent of the total iron, while the potatoes used in this experiment which were cut in one-half inch cubes and cooked in distilled water show a loss of 30 - 37 percent, almost twice as much. Berry (1912) found a greater loss of total minerals when carrots were cut in pieces and cooked, than when whole carrots were cooked. It would seem from these comparisons that the size of the pieces of the potato cooked may be an important factor in the amount of iron lost in cooking.

A similar set of analyses for potato cooked in a 1.5 percent salt solution (see table 6) shows the total loss of iron by determination to be 54.2 percent and by calculation 53.7 percent, about one half of the total iron. This shows an increase of 17 - 24 percent in the loss of iron in potatoes cooked in salted water over the loss of 30 - 37 percent observed in potatoes cooked in distilled water. These results indicate that cooking potatoes in salted water and discarding the water is more wasteful of iron than cooking in unsalted water. The practice of many housewives, of using potato water in making bread saves much of the iron lost by this method of cooking.

Table 5. Amounts of Iron Lost in Potatoes Cooked in Distilled Water.

| Weight of raw potato used | Quantity of the Standard matched | Iron in Stand- ard matched | Iron in raw potato matched | Iron in cooked potato (Deter- mined) | Iron in cooked water (deter- mined) | Iron in cooking water (calcu- lated) | Percentage of total iron lost | |
|------------------------------------|---|-------------------------------------|-------------------------------------|--|---|--|----------------------------------|------------|
| | | | | | | | determin- ed | calculated |
| gm. | cc | mg | mg | mg | mg | mg | % | % |
| 7.461 | 1 | 0.05 | 0.0738 | 0.0495 | 0.0244 | 0.0243 | 33.0 | 32.9 |
| 8.337 | 1 | 0.05 | 0.0825 | 0.0494 | 0.0242 | 0.0330 | 29.3 | 40.0 |
| 8.427 | 1 | 0.05 | 0.8340 | 0.0496 | 0.0240 | 0.0338 | 28.7 | 40.5 |
| Avg. 8.074 | | | 0.0799 | 0.0495 | 0.0242 | 0.0301 | 30.3 | 37.0 |

Table 6. Amounts of Iron Lost in Potatoes Cooked in a 1.5 percent Salt Solution.

| Weight of raw potato used | Quantity of the Standard matched | Iron in Standard matched | Iron in raw potato matched | Iron in cooked potato (determined) | Iron in cooked water (determined) | Iron in cooking water (calculated) | Percentage of total iron lost | |
|---------------------------|----------------------------------|--------------------------|----------------------------|------------------------------------|-----------------------------------|------------------------------------|-------------------------------|------------|
| | | | | | | | determined | calculated |
| gm | cc | mg | mg | mg | mg | mg | % | % |
| 7.992 | 1 | 0.05 | 0.0891 | 0.0402 | 0.0503 | 0.0489 | 56.4 | 54.8 |
| 9.162 | 1 | 0.05 | 0.0907 | 0.0415 | 0.0490 | 0.0492 | 54.0 | 54.2 |
| 8.912 | 1 | 0.05 | 0.0882 | 0.0460 | 0.0460 | 0.0460 | 52.2 | 52.2 |
| AV. 8.689 | | | 0.0892 | 0.0411 | 0.0487 | 0.0483 | 54.2 | 53.7 |

Experiments with Peas: Fresh peas were secured on the market, The variety could not be determined. Approximately 10 grams of peas of uniform size were used for the iron determinations. These were cooked for 15 minutes in 15 c.c. of cooking water until they were soft, but the skins unbroken. As in the potato the iron analyses were made from the same lot.

The data from the determinations are presented in tables 7, 8, and 9

Table 7. Amount of Iron in Raw Peas.

| Weight of peas | Quantity of the Standard matched | Iron in the Standard matched | Iron in raw peas | Iron in 100 gm raw peas |
|----------------|----------------------------------|------------------------------|------------------|-------------------------|
| gm | cc | mg | mg | mg |
| 9.769 | 2 | 0.1 | 0.093 | 0.95 |
| 9.553 | 2 | 0.1 | 0.094 | 0.98 |
| 11.225 | 4 | 0.2 | 0.148 | 1.32 |
| Av. 10.15 | | | 0.112 | 1.10 |

Table 8. Amounts of Iron in Peas Cooked in Distilled Water.

| Weight of raw peas used | Quantity of the Standard matched | Iron in the Standard matched | Iron in raw peas (calculated) | Iron in cooked peas (determined) | Iron in cooking water (determined) | Iron in cooking water (calculated) | Percentage of total iron lost | |
|-------------------------|----------------------------------|------------------------------|-------------------------------|----------------------------------|------------------------------------|------------------------------------|-------------------------------|------------|
| | | | | | | | determined | calculated |
| mg | cc | mg | mg | mg | mg | mg | % | % |
| 9.793 | 2 | 0.1 | 0.107 | 0.0688 | 0.0251 | 0.0382 | 23.4 | 35.7 |
| 9.802 | 2 | 0.1 | 0.107 | 0.0699 | 0.0302 | 0.0371 | 28.2 | 34.6 |
| 10.046 | 2 | 0.1 | 0.1105 | 0.0711 | 0.0304 | 0.0407 | 30.9 | 35.9 |
| Av. 9.881 | | | 0.1081 | 0.0699 | 0.0315 | 0.0386 | 27.5 | 35.4 |

Table 9. Amounts of Iron Lost in Peas Cooked in a 1.5 percent Salt Solution

| Weight of raw peas used | Quantity of the Standard Matched | Iron in the Standard matched | Iron in raw peas (calculated) | Iron in cooked peas (determined) | Iron in cooking water (determined) | Iron in cooking water (calculated) | Percentage of total Iron lost | |
|-------------------------|----------------------------------|------------------------------|-------------------------------|----------------------------------|------------------------------------|------------------------------------|-------------------------------|------------|
| | | | | | | | determined | calculated |
| gm | cc | mg | mg | mg | mg | mg | % | % |
| 9.920 | 1 | 0.05 | 0.1090 | 0.0535 | 0.0529 | 0.0555 | 48.5 | 50.9 |
| 12.010 | 1 | 0.05 | 0.1320 | 0.0666 | 0.0489 | 0.0654 | 37.0 | 49.5 |
| 12.890 | 1 | 0.05 | 0.1410 | 0.0686 | 0.0520 | 0.0720 | 36.8 | 51.3 |
| Av. 11.680 | | | 0.1276 | 0.0629 | 0.0512 | 0.0644 | 40.7 | 50.5 |

One and one tenth milligrams of iron were found in 100 grams of raw peas (Table 7). Sherman (1914) reported 1.6 mg. of iron in the same amount of material. Blunt and Otis (1917) obtained 2.7 mg. which is even larger. The difference in iron content of different varieties may account for the wide variation in results. The loss of iron in peas cooked in distilled water (Table 8) is 27.5 - 33 percent or about one third of the total iron. Blunt and Otis found a loss of 36 percent of the total iron. The data in Table 9 show^s a loss of about 50 percent of the iron when peas are cooked in salted water, an increase of 13 - 18 percent over the iron lost when peas are cooked in distilled water.

Since boiling peas in salted or unsalted water is the common method of cooking, it will readily be seen that one third to one half of the total iron will be lost if the cooking water is discarded. Cooking in a small amount of water and serving the liquid with the peas, would from these results appear to be the most economical method of cooking and serving this vegetable..

Experiments with Spinach: The spinach used was one of the common spring varieties. The leaves were young, tender and short stemmed. The analyses of both the raw and cooked spinach were made on the same material. The leaves were washed and dried on a wire screen by means of an electric fan until the water was evaporated, but the spinach was not allowed to wilt. From 7 - 9 grams were cooked in 15 c.c. of cooking water for 15 minutes. An attempt was made to secure an even distribution of leaves and stems in each portion weighed.

The results of the analyses are shown in Tables 10, 11 and 12.

Table 10. Amounts of Iron in Raw Spinach

| Weight of raw spinach | Quantity of the Standard matched | Iron in the Standard matched | Iron in raw spinach | Iron in 100 gm. raw spinach |
|-----------------------|----------------------------------|------------------------------|---------------------|-----------------------------|
| gm. | cc | mg | mg | mg |
| 7.015 | 4 | 0.2 | 0.199 | 2.82 |
| 4.800 | 4 | 0.2 | 0.130 | 2.70 |
| 4.848 | 4 | 0.2 | 0.154 | 3.12 |
| Av. 5.387 | | | 0.161 | 2.90 |

By referring to (Tables 11 and 12) it will be seen that the loss of the iron from the cooking in distilled water was 39.5 percent as compared to 41-45 percent when cooked in the salt solution. This represents a difference of only 3-6 percent, which is small when compared to the losses in potatoes and peas. This may be explained on the basis of the proportion of cooking water to spinach. The other vegetables were covered with water when cooked, while the spinach was started in a small amount of water which is the method advocated for cooking this vegetable. The fact that all of the leaves did not come in contact with the salted water and that the juice extracted diluted the salt solution may partly account for the small loss of iron. Blunt and Otis (1917) report a loss of 43 - 50 percent of iron

Table 11. Amounts of Iron Lost in Spinach cooked in Distilled Water.

| Weight of raw spinach used | Quantity of the Standard matched | Iron in the Standard matched | Iron in raw spin- ach (calcula- ted) | Iron in cooked spinach (deter- mined) | Iron in cooking water (deter- mined) | Iron in cooking water (calcu- lated) | Percentage of total iron lost | |
|-------------------------------------|---|---------------------------------------|--|---|--|--|----------------------------------|-----------------|
| | | | | | | | Determin- ed | Calcula- ted |
| gm. | c.c. | mg | mg | mg | mg | mg | % | % |
| 6.68 | 2 | 0.1 | 0.1930 | 0.11 | 0.089 | 0.0840 | 46.1 | 43.5 |
| 7.82 | 2 | 0.1 | 0.2267 | 0.14 | 0.083 | 0.0867 | 36.6 | 33.2 |
| 7.73 | 2 | 0.1 | 0.2254 | 0.14 | 0.081 | 0.0854 | 35.9 | 37.9 |
| Av. 7.04 | | | 0.2160 | 0.13 | 0.084 | 0.085 | 39.5 | 39.8 |

Table 12 Amounts of Iron lost in Spinach Cooked in a 1.5 percent salt Solution.

| Weight of raw spinach used | Quantity of the Standard matched | Iron in the Standard matched | Iron in raw spinach (calculated) | Iron in cooked spinach (determined) | Iron in cooking water (determined) | Iron in cooking water (calculated) | Percentage of total iron lost | |
|----------------------------|----------------------------------|------------------------------|----------------------------------|-------------------------------------|------------------------------------|------------------------------------|-------------------------------|------------|
| | | | | | | | Determined | Calculated |
| gm | c.c. | mg | mg | mg | mg | mg | % | % |
| 6.85 | 2 | 0.1 | 0.1986 | 0.115 | 0.0920 | 0.0836 | 45.5 | 42.0 |
| 7.75 | 2 | 0.1 | 0.2247 | 0.138 | 0.0951 | 0.0867 | 42.3 | 38.5 |
| 9.04 | 4 | 0.2 | 0.2620 | 0.145 | 0.1250 | 0.1170 | 47.7 | 44.6 |
| Av. 7.88 | | | 0.2300 | 0.132 | 0.104 | 0.0980 | 45.5 | 41.3 |

in cooking spinach in distilled water, but they do not state the amount of water used so that it is difficult to compare results. Courtney, Fales and Bartlett (1917) found that spinach lost only 28 percent of its total iron.

It is obvious from these results that any method of saving the water in which spinach is cooked is highly desirable. Berry (1912) reported a loss of about 50 percent of the total salts in boiling spinach. Consequently, it would appear that a conservation method is important from the standpoint of the other mineral salts. Berry also reports a loss of about 10 percent of the total salts when spinach is steamed. According to the work done by Masters (1920), spinach has a tendency to turn brown when steamed in a covered dish which to many people, may be an objection to this method. Spinach may be cooked largely in its own juice, and both the spinach and juice may be served, thus avoiding the loss of iron.

Experiments with Carrots: The carrots selected for the analyses were small, being about one inch in diameter. As was the case with some of the other vegetables bought on the market, the name of the variety could not be ascertained. In preparing the carrots for the analyses, nine were scraped and cut into wedge shaped pieces one inch long. Denton (1919) reported that cooking losses were decreased when vegetables were cut lengthwise instead of crosswise. Consequently these samples were cut lengthwise.

The results of these analyses are given in Tables 13, 14 and 15.

Table 13, Amount of Iron in Raw Carrots

| Weight of carrots | Quantity of the Standard matched | Iron in the Standard and matched | Iron in raw carrots | Iron in 100 gm raw carrots |
|-------------------|----------------------------------|----------------------------------|---------------------|----------------------------|
| gm | cc | mg | mg | mg |
| 9.915 | 1 | 0.05 | 0.043 | 0.43 |
| 9.136 | 1 | 0.05 | 0.042 | 0.45 |
| Av. 9.525 | | | 0.0425 | 0.44 |

The raw carrots (Table 13) contain 0.44 mg. of iron in 100 grams of raw material. This is less than the 0.6mg given by Sherman (1919). The losses of iron in the carrots in distilled water are relatively high (see Table 14). These losses do not agree with the findings of Courtney, Fales and Bartlett (1917) who report only small traces of iron in the cooking water. They do not state whether the carrots were cooked whole or cut into pieces. The percentage of error in the determination of iron in carrots is greater than in the other vegetables due to the smaller amounts of iron present and to the matching of lighter shades of blue. It would undoubtedly be advisable to use larger portions for analyses in working with vegetables containing small quantities of iron. It is difficult to com-

pare solutions containing amounts of iron less than 0.025 mg. Berry (1912) reported a great decrease in the loss of total mineral salts when carrots were steamed. Although steaming may be the most economical method of cooking this vegetable it is not a common household practice. As stated previously Berry also found less loss of mineral salts when carrots were cooked whole, than when cut into pieces. It is obvious that of the three methods mentioned, steaming, cooking whole, or cooking after cutting into pieces, the second method is the best to advocate.

Table 14. Amounts of Iron Lost in Carrots Cooked in Distilled Water.

| Weight of raw carrot used | Quantity of the Standard matched | Iron in Stand- ard matched | Iron in raw carrot (calcu- lated) | Iron in cooked carrot (deter- mined) | Iron in cooking water (deter- mined) | Iron in cooking water (calcu- lated) | Percentage of Total Iron Lost | |
|------------------------------------|---|-------------------------------------|---|--|--|--|----------------------------------|-----------------|
| | | | | | | | Determin- ed | Calcula- ted |
| gm | cc | mg | mg | mg | mg | mg | % | % |
| 9.668 | 0.5 | 0.025 | 0.040 | 0.025 | 0.0122 | 0.015 | 30.5 | 37.5 |
| 10.018 | 0.5 | 0.025 | 0.044 | 0.024 | 0.0122 | 0.020 | 27.7 | 45.4 |
| AV.9.84 | | | 0.042 | 0.0245 | 0.0122 | 0.0175 | 29.1 | 41.4 |

Table 15. Amounts of Iron Lost in Carrots Cooked in a 1.5 percent Salt Solution

| Weight of raw carrot used | Quantity of the Standard matched | Iron in Standard matched | Iron in raw carrot (calculated) | Iron in cooked carrot (determined) | Iron in cooking water (determined) | Iron in cooking water (calculated) | Percentage of Total Iron Lost | |
|---------------------------|----------------------------------|--------------------------|---------------------------------|------------------------------------|------------------------------------|------------------------------------|-------------------------------|------------|
| | | | | | | | Determined | Calculated |
| gm 9.481 | cc 0.5 | mg 0.025 | mg 0.0406 | mg 0.0167 | mg 0.0228 | mg 0.0238 | % 56.2 | % 56.6 |
| 9.899 | 0.5 | 0.025 | 0.0425 | 0.0172 | 0.0220 | 0.0253 | 51.7 | 59.5 |
| AV. 9.690 | | | 0.0415 | 0.0169 | 0.0224 | 0.0245 | 53.9 | 58.0 |

Discussion of Results: For the purpose of comparison the foregoing analyses have been assembled in Table 16 and calculated on the basis of the losses of iron in the cooking of 100 grams of raw vegetable, both in distilled and in salted water. It will be seen that without exception there is a greater loss of iron in vegetables cooked in salted water. Although previous investigations indicate a decrease in the loss of the total mineral salts when vegetables are cooked in salted water, it is apparent from these results that this does not hold true for iron. The increase in the loss of iron in the vegetables cooked in salted water is small, averaging only 0.15 milligrams. This additional loss of 0.15 milligrams of iron due to using salted cooking water seems insignificant, but the fact that from 27 - 50 percent of the total iron is lost when these vegetables are cooked in distilled water, and from 40 -60 percent when the vegetables are cooked in salted water is significant. Sherman estimates an allowance of 15 milligrams of "food iron" or organic iron for a man per day. According to Sherman (1919) we are dependent upon "food iron" for the body's supply. Since these analyses as well as those of others show that the amounts of iron found in vegetables and other foods are very small, the saving of every milligram of iron becomes a necessary economy.

The analyses given above show that spinach is the best source of iron, peas and potatoes contain similar amounts but less than the spinach, while carrots contain the smallest quantities of any of the four vegetables analyzed.

Table 16. Losses of Iron in Cooking 100 grams of Raw Vegetables

| Vegetable | Weight of raw vegetable | Iron in raw vegetables | Iron in cooked vegetable obtained | Iron in cooking water | | Percentage of total Iron lost | | Difference in loss in cooking in salted water | |
|-----------------------------------|-------------------------|------------------------|-----------------------------------|-----------------------|------------|-------------------------------|------------|---|------------|
| | | | | determined | calculated | determined | calculated | determined | calculated |
| | gram | mg | mg | mg | mg | % | % | % | % |
| Potato cooked in salted water | 100 | 1.00 | 0.474 | 0.54 | 0.536 | 54.2 | 53.7 | | |
| Potato cooked in distilled water | 100 | 0.99 | 0.617 | 0.30 | 0.370 | 30.3 | 37.0 | 24 | 17 |
| Peas cooked in salted water | 100 | 1.10 | 0.541 | 0.437 | 0.555 | 40.7 | 50.5 | | |
| Peas cooked in distilled water | 100 | 1.09 | 0.708 | 0.29 | 0.360 | 27.5 | 35.4 | 13 | 15 |
| Spinach cooked in salted water | 100 | 2.90 | 1.680 | 1.31 | 1.240 | 45.5 | 41.3 | | |
| Spinach cooked in distilled water | 100 | 2.80 | 1.750 | 1.09 | 1.100 | 39.5 | 39.8 | 6 | 3 |

Table 16 - Continued.

| Vegetable | Weight of raw vege- table | Iron in raw vegetables | Iron in cooked vegetable obtained | Iron in cook- ing water | | Percentage of total Iron lost | | Differences in loss in cook- ing in salted water | |
|--|---------------------------------|---------------------------|--|----------------------------|-----------------|-------------------------------------|-----------------|---|-----------------|
| | | | | deter- mined | calcu- lated | deter- mined | calcu- lated | deter- mined | calcu- lated |
| | gram | mg | mg | mg | mg | % | % | % | % |
| Carrots cooked in salted water | 100 | 0.44 | 0.172 | 0.237 | 0.261 | 53.9 | 59.0 | | |
| Carrots cooked in distilled water | 100 | 0.44 | 0.250 | 0.127 | 0.187 | 29.1 | 41.4 | 25 | 18 |

The milligrams of iron in 100 grams of vegetables after cooking (as calculated) are shown in (Table 17.) These results as well as some of the other determinations show wide variations in the amounts of iron in the same vegetable. If vegetables are cooked in a manner comparable to that prevailing in household practice, it is difficult to select a representative sample of a size which is suitable for analytical work. Our present lack of knowledge, of the distribution of iron in plants may mean that some samples or parts of the vegetable contain more iron than other parts; and that some vegetables may give up their iron more readily than others. There is also a great chance for error when working with such small amounts of iron. An average of ten readings in the colorimeter was made with each determination, and three similar samples of materials were analyzed in each case, so that it would seem that these results show with a fair degree of accuracy the amounts of iron present in the vegetables.

In comparing the milligrams of iron in 100 grams of vegetables after cooking with the milligrams of iron in 100 grams of raw vegetable, the loss of iron is most significant. It emphasizes the necessity for calculating dietaries on the basis of the cooked vegetables rather than on the basis of the raw vegetable, especially where the method of preparation, and serving involves the discarding of a portion of the iron.

It is difficult to explain the increase in the loss of iron in the vegetables cooked in salted water, since the form in which iron exists in plants is still an open question. As

early as 1884, Bunge stated that iron occurs in food solely in the form of complicated organic compounds, ferruginous nucleo albumins, which are built up by the life processes of plants. Macallum (1891) demonstrated microchemically that the iron in vegetables was always a constituent of chromatin. Later (1896) Macallum indicates that iron is an essential constituent of all parts of the chromatin of the higher vegetables organism and that the amount of iron corresponds to the amount of chromatin present. This substance (chromatin) is linked up with nuclein or nucleic acid, but whether the iron is combined in the nuclei or in the nucleic acid in a ferric state is not really known.

The hydrogen ion concentration seemed a possible cause for greater loss of iron with the use of the sodium chloride solution. Consequently, the hydrogen ion concentration of the cooking water from potatoes cooked in distilled water and from those cooked in salted water was determined. The results for salted and unsalted water checked so closely that this theory was not substantiated.

It is possible that the compound in plants which contains iron may be more soluble in sodium chloride solution, than it is in distilled water. It would be of interest to study the relation between the iron losses and the total mineral salts lost, as well as the relationship between iron and nitrogenous losses for vegetables from the same source and prepared in the same way.

Table 17. Milligrams of iron in 100 grams of Raw Vegetables and 100 grams of Vegetables after cooking (calculated)

| Potato | | | Peas | | | Spinach | | | Carrots | | |
|----------|--------------------------------------|---------------------------------|------|--------------------------------------|---------------------------------|---------|--------------------------------------|---------------------------------|---------|--------------------------------------|---------------------------------|
| Raw | Cooked in dis- tilled water | Cooked in salted water | Raw | Cooked in dis- tilled water | Cooked in salted water | Raw | Cooked in dis- tilled water | cooked in salted water | Raw | cooked in dis- tilled water | cooked in salted water |
| mg | mg | mg | mg | mg | mg | mg | mg | mg | mg | mg | mg |
| 0.978 | 0.663 | 0.502 | 0.95 | 0.703 | 0.539 | 2.82 | 1.64 | 1.67 | 9.915 | 0.25 | 0.184 |
| 1.000 | 0.605 | 0.453 | 0.98 | 0.720 | 0.554 | 2.70 | 1.79 | 1.78 | 9.136 | 0.24 | 0.160 |
| 0.993 | 0.588 | 0.467 | 0.32 | 0.690 | 0.532 | 3.12 | 1.81 | 1.60 | | | |
| Av. 0.99 | 0.617 | 0.474 | 1.10 | 0.708 | 0.541 | 2.90 | 1.75 | 1.68 | | 0.25 | 0.172 |

CONCLUSIONS

1. The potassium ferrocyanide method was tested and found satisfactory in the analyses of vegetables where sodium chloride was involved. It was frequently difficult to obtain representative samples for analyses, when working with small amounts of vegetables.
2. A large proportion of the iron content of potatoes, peas, spinach and carrots is lost in the water used in boiling these vegetables.
3. The loss of iron is considerably increased when these vegetables are cooked in a 1.5 percent salt solution. Potatoes lose 17-24 percent; peas 13-15 percent; spinach 3-6 percent; and carrots 18-25 percent more iron when cooked in a 1.5 percent salt solution than when cooked in distilled water.
4. Discarding the salted water in which vegetables are cooked means a loss of over 50 percent of the total iron in potatoes; approximately 45 percent in peas; 43 percent in spinach and over 50 percent in carrots. Since the iron content of the cooking water is so high, it is advisable to use this water, whenever possible.
5. According to variations in the methods of cooking vegetables and the differences in the loss of iron, a dietary computed on the analyses of the iron in the raw vegetables might greatly over estimate the amounts of iron.

LITERATURE CITED

- Bell, Carter, Determination of Iron in Water; J. Soc. Chem. Ind., 8, (1889), p. 175.
- Berry, J. T. Losses of Iron in Cooking Vegetables, J. Home Econ. 9, (1917) 213 - 218.
- Blunt, K. and Otis F. Losses of Iron in Cooking Vegetables, J. Home Econ., 9, (1917) 213 - 218.
- Bunge
Z. Physiol. Chem. 9, (1884 - 85) p. 49.
Cited by Sherman, H. C. Iron in Food and its Functions in Nutrition (1907) p. 7
- Bureau Standards, Circular 40. Sodium Oxalate as a Standard in Volumetric Analysis 3rd edition (1920) p. 5
- Claudius, M., Micro-Tests for Iron, Hospital stindende (Copenhagen) 61, (1918) 930 - 935
- Cook, F. C. Composition of Tubers, Skins and Sprouts of Three Varieties of Potatoes. J. Agr. Research, Vol. 20 (1921) 623 - 635
- Courtney, A. Fales, H. L. and Bartlett, F. H. Some Analyses of Vegetables Showing the Effect of the Method of Cooking; Am. J. Diseases Children, 14, (1917) 34 - 39
- Curtman, L. J. and Harris, B. R., The Systematic Detection of Thiocyanates; J. Am. Chem. Soc., 38, (1916) 2622 - 2629.
- Denton, M. Changes in the Food Value of Vegetables; J. Home Econ., 9, (1919) 200 - 209
- Frisby, A. J. and Bryant, A. P. U. S. Dept. Agr. Exp. Sta. Bull., 43, (1897) 25 - 31.
Losses in cooking Vegetables.

- Glynne, M. D. and Jackson, V. G. The Distribution of Dry Matter and Nitrogen in the Potato Tuber. Variety, King Edwards. J. Agr. Sci. Vol. 9, (1919) 237 - 258.
- Haensel, E., Iron and Phosphorous Content of Edible Vegetables; Biochem. Z., 16, (1909) p. 9.
- Halverson, J. O., Modified Benedict Method for the Estimation of Sulphur in Feeds, Feces and Foods; J. Am. Chem. Soc., 41, (1909) 1494 - 1503.
- Krüss, G. and Moraht, H. The Thiocyanate Method for the Determination of Iron in the Colorimeter, Ber. 22, (1889) 2054 - 2065 Bodinus, Losses in the Cooking of Vegetables, Chem. Zentr. 2, (1915) p.37.
- Macallum, A. B.
Proc. Roy. Soc. (London), 50 (1891-92) 277
Trans. Canad. Inst., 1 (1891), pt. 2, p. 247
Quart. Jour. Micros. Sci. (London), 38 (1896), p. 175. Cited by Sherman, H. C. Iron in Food and its Functions in Nutrition. (1907), p.22
- Mahin, E. Oxidation and Reduction, Quantitative Analysis, (1919) 246 - 252
- Marriat, W. and Wolf, C. Determination of Small Quantities of Iron; J. Biol. Chem. 26 - 27, I (1905 - 1906) 451 - 460.
- Masters, H. and Garbutt, P. Investigations of the Methods Employed for Cooking Vegetables with Special Reference to the Losses Incurred II Green Vegetables. Biochem. J. 14, (1920) 75 - 90.
- Moore, E. Quantitative Chemical Analysis by Electrolysis. Chem. News. 53, (1886) 209.

- Nottbohn, F. and Weiszwange, W. Study of Milk Ash,
Z. Nahr-Genussm, 23, (1912) 514.
- Prescott, A. B. and Johnson O. C. The Thiocyanate Reaction
Qual. Anal., 1903, p. 155.
- Sherman, H. C., Iron in Typical Food Materials, Chemistry of
Foods and Nutrition (1919) p. 302
- Snyder, H., Losses in Boiling Vegetables; U. S. Dep. Agr.
Off. Exp. Sta. Bull., 43, (1897) 7-19
- Sutton, F., Volumetric Analysis, (1911) Determination of
Iron by Colorimetric Methods, 238 - 239
- Treadwell, F. P. and Hall, W. T., Iron Analytical Chemistry
Vol. I. (1915) p. 120.
- Vorländer, D. Berlin Blue Reaction, Ber., 46, (1913) 181 -
192.
- Viehvoever, A., and Johns C. O. Determination of Hydrocyanic
Acid; J. Am. Chem. Soc. 37, (1915) 601 - 607