

# IX. AN INVESTIGATION OF THE METHODS EMPLOYED FOR COOKING VEGETABLES, WITH SPECIAL REFERENCE TO THE LOSSES INCURRED.

## PART II. GREEN VEGETABLES.

BY HELEN MASTERS AND PHYLLIS GARBUTT.

*From the Household and Social Science Department,  
King's College for Women.*

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THESE investigations were undertaken, as indicated in Part I [Masters, 1918], primarily with a view to obtaining some comparison of the different methods of cooking vegetables, with special references to the losses incurred and the time required for cooking. It was hoped that in this manner some method of cooking might be devised, which would be economical both as regards food material and as regards fuel, and that some further information concerning the changes which take place during the cooking process might be obtained.

Katherine Williams [1892] gives the results of a number of analyses of cooked and uncooked vegetables, but does not indicate how these results would be modified by different methods of cooking.

Other observers [Harden and Zilva, 1918; Delf, 1918] have shown that the antiscorbutic properties of vegetables may be destroyed by the action of dilute alkaline solutions or of heat. This is a physiological problem and the question whether or not it is advisable from a dietetic point of view that heat or alkaline solutions should be used in the preparation of vegetables hardly comes within the scope of this paper. It is hoped, however, that these investigations may prove of some assistance in arriving at a decision on such matters.

Numerous kinds of green vegetables are made use of for edible purposes, but the varieties available vary according to the season of the year and it was found impossible to work with the same variety throughout. To obviate this difficulty as far as possible, a number of experiments were made with each variety, and the nature of the vegetable used is stated in each case; but this variation in the nature of the material has hampered the work considerably and increased the difficulty of obtaining reliable results. The vegetables principally employed were cabbage, spring greens and Brussels sprouts.

In cooking green vegetables it is necessary not only to consider the losses on cooking and the time of cooking, but also the extent to which it is possible to preserve the original green colour of the vegetable, since no method of cooking can be considered satisfactory from a practical point of view unless the vegetables are a "good colour."

Some investigations were therefore first made of the colour changes which occur when green vegetables are cooked under various conditions.

#### COLOUR CHANGES PRODUCED IN GREEN VEGETABLES ON COOKING.

It appears to be fairly generally accepted that the preservation of the colour of green vegetables during the process of cooking can best be effected in the following ways:

(1) By cooking in a considerable volume of rapidly boiling water in an *open* vessel, *i.e.* in a vessel without a lid.

(2) By the addition of a small amount of alkali, usually sodium bicarbonate, to the cooking water.

Preliminary experiments indicated that there was considerable foundation for these ideas. Vegetables cooked in a covered vessel were undoubtedly inferior in colour to those cooked in an open vessel. The addition of ordinary salt to the cooking water appeared to improve the colour slightly, but the difference was not very marked. The cooking water was slightly acid to litmus.

The addition of small amounts of sodium bicarbonate to the cooking water had a marked effect on the colour of the vegetables. A bright green colour, more pronounced than that of the uncooked vegetables, was produced in most cases. It was also noticed that the alkaline cooking water was dark in colour, and that the veins and stems of the leaves of the vegetable, which are usually white, were coloured green, as though the colouring matter had been spread or developed by the action of the alkali.

Conversely, it was noted that if a little acid, *e.g.* acetic acid, were added to the cooking water, the vegetables rapidly changed in colour and became brown, but that the cooking water was only slightly coloured.

Chlorophyll, it is stated [Allen, 1909], is soluble in alkaline solutions and is rapidly decomposed after the death of the cell, a transformation to a brownish green chlorophyllan occurring unless alkali is present; the brown colour of badly cooked vegetables is attributed to the formation of this substance.

A preparation of chlorophyll was examined and was found to be insoluble in water, but readily soluble in water containing a little sodium bicarbonate; the solution thus obtained gave no colour change on treatment with dilute acids, and it was thought possible that the chlorophyll had been specially treated to render the colour stable.

On extracting some of the fresh green vegetable with alcohol, however, a solution which was deep green in colour was obtained, and this colour was

rapidly changed to brown on the addition of a few drops of acetic acid. The same effect was produced with other acids, but with sulphuretted hydrogen (see below) the reaction was slow, the colour changing gradually on standing for a few minutes at the room temperature.

Thus, in order to preserve the green colour of the vegetables, the presence of any acid reacting substance in the water should be avoided. This may, of course, be effected by rendering the water alkaline by the addition of sodium bicarbonate. The other effects observed on the addition of the bicarbonate, *i.e.* the dark colour of the cooking water and the stained appearance of the white portions of the leaf, may be attributed to the solubility of the chlorophyll in the alkaline solution. (For the effect of the addition of sodium bicarbonate on the time of cooking, etc., see pp. 82, 83.)

The action of acid on chlorophyll, taken in conjunction with the fact that the cooking water was found to be acid unless sodium bicarbonate was added, seemed to indicate that acid substances might be produced from the vegetables on cooking. Such acids, if volatile in steam, would, to a great extent, be removed if the vegetables were cooked in an open vessel of rapidly boiling water, but would be mostly retained if a covered vessel were used, and this might afford an explanation of the differences in colour observed with vegetables cooked in open and in covered pans.

Further information as regards the production of acid substances on cooking therefore appeared to be needed, and experiments were made to investigate the nature of the acids produced.

#### *Acid substances produced on cooking green vegetables.*

In order to determine whether volatile acids were produced on cooking, green vegetables were cooked in a large distilling flask attached to a condenser, and the distillate was collected in portions of about 100 cc.

It was found that the distillate was at first acid but on continuing the distillation it afterwards became slightly alkaline.

#### *Examination of the distillate.*

Since the distillate was only slightly acid, it appeared hardly feasible to identify the acids present without some further process of separation and concentration. It was, therefore, proposed to separate the acids in the form of their lead salts, by adding lead carbonate to a considerable volume of the distillate. On the addition of lead carbonate, however, a brown coloration was obtained which seemed to indicate the presence of sulphide.

This was confirmed by adding a few drops of a dilute solution of sodium nitroprusside to another portion of the distillate, which had previously been rendered *slightly* alkaline by the addition of ammonia. The characteristic violet colour produced by sulphides was obtained.

*Determination of volatile sulphide in the cooking water.*

Since it seemed probable that the amount of volatile sulphide produced might vary with the nature of the vegetable, and also with the method of cooking, it appeared of interest to try and devise some method for obtaining a measure of the amount of sulphide present in the cooking water, and a number of experiments were made with this object in view. The amount of sulphide produced is very small in comparison with the weight of vegetable cooked. The composition of the vegetable itself is by no means constant even when the same type of vegetable is used, and it is difficult to obtain any very consistent results.

After several methods had been tried and found unsuitable, a method was finally devised which gave results of sufficient accuracy to be of value for practical purposes, but before describing this method and the results obtained, a brief summary of the other methods and the difficulties met with may be given here for the benefit of other observers.

In the first experiments, 100 g. of cabbage were cooked in water in a flask attached to a condenser and the distillate was collected in portions of 100 cc. in Nessler cylinders. The amount of sulphide in each portion was determined colorimetrically.

The amount of sulphide in the first portion of the distillate was small, increased as distillation proceeded and then decreased again becoming fairly constant, but it was impossible to obtain any definite end-point, and after a time the distillate became cloudy.

It seemed probable that sulphide would continue to be evolved as long as the cooking was continued, and it was noted that sulphide was produced even when the distillate was no longer acid.

In further experiments, the vegetables were cooked for a definite time only under a reflux condenser and the cooking water distilled after straining off the solid matter. It was found that the sulphide could not be completely separated from the cooking water by distillation and that some of the sulphide underwent decomposition during this process.

There was also a considerable loss of sulphide from the condenser during the first part of the experiment in spite of a device arranged to minimise such loss. These observations were confirmed by some experiments made with dilute solutions of hydrogen sulphide of known concentration, which showed that a large proportion of the sulphide was decomposed when such solutions were heated and distilled under conditions similar to those employed in the experiments.

It appears hardly possible to obtain a reliable measure of the amount of sulphide produced, during cooking, but it was thought that if some method, which did not involve a distillation process, could be devised, it might be possible to obtain a measure of the amount of sulphide left in the cooking water at the end of the experiment, and that if all experiments were carried

out under the same conditions such information might be of value for comparative purposes, even though it did not represent the total amount of sulphide produced during cooking. For this purpose, a modification of the method described by Winkler [1917] was adopted, and was found to give more consistent results than the methods previously described.

*Method used for the determination of the volatile sulphide in the cooking water of green vegetables.*

The vegetable was cooked as before under a reflux condenser for one hour. Carbon dioxide was bubbled through a measured volume of the cooking water carrying with it the volatile sulphide, which was absorbed in a solution of hydrogen peroxide and thus oxidised to sulphuric acid, the amount of which was determined by titration with sodium hydroxide after all the carbon dioxide had been removed by boiling.

The determination was made as follows: 100 g. of the vegetable were cooked in 750 cc. water under a reflux condenser for one hour. The cooking water was made up to a litre and 250 cc. placed in a flask connected with a carbon dioxide Kipp and an absorption apparatus consisting of three conical flasks, each containing 150 cc. of a 0.15 % hydrogen peroxide solution. Carbon dioxide was bubbled through the cooking water, carrying with it the hydrogen sulphide, which was absorbed by the hydrogen peroxide and oxidised to sulphuric acid. The contents of the absorption flasks were washed into a beaker, and after the carbon dioxide had been expelled by boiling and the solution evaporated to about one-eighth of its original bulk, the sulphuric acid formed was determined by titration with *N*/100 sodium hydroxide solution. Correction was in each case made for the acidity of the hydrogen peroxide solution.

Several experiments were made and the average results obtained were as follows:

Table I.

Nature of vegetable	g. of hydrogen sulphide in cooking water from 100 g. of vegetable
Cabbage I	0.0017
" II	0.0015
Green leaf of cabbage	0.0049
White " "	0.0011
Brussels sprouts I	0.0094
" " II	0.0084

The results indicate that there is considerable variation in the amount of sulphide produced from the two types of vegetable used in the experiments, the average results for the Brussels sprouts being considerably higher than those obtained for cabbage.

Some further experiments were made in this connection, in which the green portions of the cabbage were separated from the white portions, and

cooked separately, the amount of sulphide left in the cooking water being determined in each case (see Table I above).

These results show that sulphide is liberated from both portions, but that less is liberated from the white leaf than from the green. Thus the relatively high results obtained with Brussels sprouts may be partly accounted for by the relatively small portion of white leaf found in this vegetable.

In addition to determining the sulphide present in the cooking water, determinations of the nitrogen and sulphur contents of the vegetables and portions of the vegetables were made.

#### *Determination of sulphur in cabbage.*

The sulphur was determined by fusing the dried vegetable with sodium peroxide, the sulphate thus formed being subsequently precipitated and determined as barium sulphate [see the method described in the Official and Provisional Methods of Analysis issued by the United States Department of Agriculture].

#### *Determination of protein.*

The nitrogen was determined by the Kjeldahl process, on about 3 g. of the dried vegetable, and the results were calculated as protein on 100 g. of uncooked vegetable and not on the dried vegetable.

Table II.

	Nature of vegetable	g. sulphur present in 100 g. uncooked vegetable	g. protein in 100 g. uncooked vegetable
I.	Cabbage (whole)	0.160	1.9
	"  green portion	0.162	2.2
	"  white  "	—	1.6
II.	Cabbage, green portion	—	1.9
	"  white  "	—	1.5
I.	Brussels sprouts	0.135	3.9
II.	"  "	—	3.5

These results, when compared with those of Table I, indicate that there is no definite correspondence between the sulphur content and the volatile sulphide in the cooking water.

As regards the nitrogen content, the results obtained appear to be in agreement with those arrived at by other observers.

Dugast [1882] found that generally speaking the protein in the leaf of the vegetable was greater than that in the stalk and that in the former case it varied from 11.9–21.2 % and in the latter from 7.3–13.3 % calculated on the *dried* vegetable.

Comparison with Table I shows that the yield of volatile sulphide is greatest where the protein content is high and *vice versa*. This suggests the possibility that the sulphide is produced by the decomposition of protein material, and it may be noted in this connection that Rettger [1906] showed that volatile

sulphide is liberated from heated milk and attributes this to the partial decomposition of the proteins.

The possibility of the sulphide being produced from alkyl sulphides<sup>1</sup> was also considered and attempts have been made to isolate such bodies by extracting some of the dried vegetable with ether in a Soxhlet extractor; so far no indication of their presence has been obtained, but further investigations in this connection are needed.

*Other volatile acids produced on cooking.*

In the experiments thus far described, the production and determination of volatile sulphide has been principally considered, but the possibility of the liberation of other volatile acids during the cooking process was also borne in mind and in some of the preliminary experiments the acidity of the distillate from the cooking water as well as the amount of sulphide present were determined. The results obtained for the acidity showed considerable variation even when samples of the same vegetable were used, the differences being still more marked when the experiments were made with different vegetables. It has been shown in the foregoing that such variations are almost inevitable in experiments of this character. In spite of this variation in the determined acidities, some evidence was obtained that the acidity of the distillate was greater than could be entirely accounted for by the volatile sulphide present.

Other observers have shown the presence of such acids as acetic and formic in vegetables. Borgmann [1883] found that a great number of plants, both in the presence and in the absence of chlorophyll, contained formic and acetic acids, and that in the case of chlorophyll-bearing plants the percentage of acids rises when assimilation is repressed.

Nelson and Beck [1918] showed that propionic and acetic acids could be isolated from fermenting cabbage (*sauerkraut*) and that in two cases formic acid had also been detected.

It, therefore, appeared by no means improbable that volatile organic acids might be liberated from green vegetables during the process of cooking. In order to verify this, it was first necessary to devise some method of removing the volatile sulphide in such a manner that other volatile acids would be left in solution.

Some experiments made with dilute solutions of formic and acetic acids containing hydrogen sulphide showed that, if the sulphide were expelled by bubbling carbon dioxide through the solution, in the manner previously described, the excess of carbon dioxide could be removed without loss of the acetic and formic acids, by heating the solution under a reflux condenser for about half-an-hour. If the time of heating exceeded one hour there was a slight loss of volatile acid, but heating for half-an-hour was found to be sufficient to expel the carbon dioxide. This method was next applied to the examination of the cooking water in which green vegetables had been cooked.

<sup>1</sup> Tibbles [1912] states that most of the Cruciferae contain allyl sulphides.

*Examination of the cooking water for acids other than hydrogen sulphide.*

The vegetable was cooked in a flask attached to a condenser for one hour. The distillate was diluted to a measured volume with distilled water and divided into two portions. The acidity of one portion was determined directly by titration with standard acid. The volatile sulphide was removed from the other portion and the acidity of the solution then determined by titration.

It is, perhaps, necessary to point out that such determinations do not, for the reasons already stated, give any exact measure of the volatile acids produced on cooking, but it was thought that they might furnish some evidence as to the presence or absence of volatile acids other than hydrogen sulphide.

The acid in the distillate from 100 g. of cabbage was found on the average to require 0.014 g. of sodium hydroxide for complete neutralisation, whilst after the removal of volatile sulphide the sodium hydroxide required for neutralisation averaged 0.005 g. Thus the solution is still slightly acid after the removal of the volatile sulphide, but the amount of acid present is extremely small and it is difficult to obtain consistent results.

Qualitative tests for formic and acetic acids were also carried out with this distillate, and some indication of the presence of these acids was obtained, but in dealing with such small quantities these tests can hardly be regarded as conclusive.

*Total acidity of the cooking water.*

In addition to determining the volatile acidity of the cooking water, some determinations of the total acidity were made. Owing to the dark colour obtained on the addition of alkali, phenolphthalein could not be used as indicator, but it was found that if turmeric paper were used as an outside indicator a moderately good end-point could be obtained. The acid in the cooking water from 100 g. of cabbage was found to require, on the average, 0.055 g. of sodium hydroxide for complete neutralisation. Thus the total acidity of the cooking water is considerably greater than the volatile acidity measured as described above. This may be partly accounted for by the loss of volatile sulphide on distillation and also the difficulty of separating the volatile acids completely by distillation, but it is also possible that non-volatile acid substances are present in the cooking water and further investigations are in progress.

*The addition of sodium bicarbonate to the cooking water.*

If sodium bicarbonate is added to the cooking water, any acids produced during the cooking process are neutralised and the cooking water at the end of the experiment is alkaline. It was found that if this alkaline cooking water were distilled, using a trap as in a Kjeldahl determination to prevent non-volatile alkali passing over, an alkaline distillate which contained appreciable quantities of sulphide was obtained.

It was observed that the vegetables cooked and disintegrated more rapidly in the presence of alkali. This is possibly because the cell walls are composed of a hydrated form of cellulose, which is more or less soluble in alkaline solutions [Cross and Bevan, 1903]. It also seemed possible that the amount of sulphide produced would be greater than when water only was used, but owing to the difficulty of determining such small quantities of sulphide in an alkaline solution, it is not possible at present to make any definite statement on this point.

As regards the alkalinity of the distillate from the cooking water when sodium bicarbonate is used, it should be noted that it was observed that the distillate from the cooking water became alkaline after a time, as the cooking proceeded, even when bicarbonate was not employed.

It was thought that this alkalinity might possibly be due to the evolution of ammonia or substituted ammonias formed as decomposition products during cooking, and that, if this were the case, the ammonia would probably be liberated more rapidly from a solution containing alkali.

Some preliminary experiments appear to give support to this theory, as some evidence has been obtained that the amount of alkali liberated is considerably greater when sodium bicarbonate is employed. These results, however, need further confirmation.

#### SUMMARY AND CONCLUSIONS.

The changes in colour observed on cooking green vegetables appear to be chiefly due to the action of acids liberated during cooking on the chlorophyll, the characteristic green colour of which is destroyed by the action of acids. During cooking, hydrogen sulphide and probably also volatile organic acids are liberated; these acids may to some extent be neutralised by other products of decomposition, but unless sodium bicarbonate is added, the cooking water is acid at the end of the experiment.

Green vegetables are usually cooked in an open vessel containing rapidly boiling water, and in this way there is a maximum loss of volatile acids, but if, on the other hand, they are cooked in a covered vessel then these volatile acids are retained in the vessel for a time at least. Although the volatile acidity is comparatively small, it is possible that the action of acids on the chlorophyll may be specially harmful during the earlier stages of cooking, and hence conditions which tend to prevent a free and rapid loss of volatile acids have a deleterious effect on the colour of the cooked vegetable, and this probably explains the poor colour of green vegetables cooked in a covered vessel.

It may also be noted that many cooks advocate the use of a large volume of water for cooking in order to preserve the colour; this would have the effect of diluting the acids produced.

If sodium bicarbonate is added, the cooking water does not become acid although volatile sulphide is produced. The neutralisation of the acids pro-

duced during cooking does not, however, entirely explain the action of the bicarbonate. The alkali has a solvent action on the chlorophyll, and also, probably because of its action on the plant cellulose, it causes a decrease in the time required for cooking. This latter effect also tends to improve the colour, since prolonged cooking renders the vegetables a bad colour.

In dealing with the action of bicarbonate, it is perhaps necessary to draw attention to a popular fallacy. It is frequently stated that the bicarbonate is added to soften the water and that this renders the vegetables a good colour. Careful observations, however, show that the colour of green vegetables cooked in really soft water, *i.e.* distilled water, compares unfavourably with that of those cooked in ordinary London tap water. This difference is, in all probability, due to the alkalinity of the tap water.

#### LOSSES INCURRED DURING COOKING AND TIME REQUIRED FOR COOKING.

The question of colour having been dealt with, a comparison of the different methods of cooking as regards losses incurred and time of cooking was next considered.

The methods most frequently employed for cooking green vegetables appear to be the following:

- I. Boiling in water, with or without the addition of sodium bicarbonate and salt.
- II. Steaming.
- III. Conservative method.

Vegetables were cooked by each of the above methods and the time of cooking, loss of solids, and loss of mineral matter compared.

As mentioned in Part I, it is difficult in carrying out experiments of this type to obtain consistent results, owing to variations in the nature of the material used for the experiments, the absence of any very definite endpoint, and the difficulty of working under exactly similar conditions without adopting precautions which would not ordinarily be employed, and which, if introduced, might render the results less valuable from a practical point of view.

In the case of fresh green vegetables, the variation in composition is much more marked than with the dried vegetables dealt with in Part I; also, as already stated, the type of vegetable available varies according to the season of the year. Thus it is often impossible to repeat experiments, or confirm results obtained at an earlier period of the investigations. For these reasons, it was deemed advisable to carry out several experiments in each case and to take an average and also, in comparing the different methods of cooking, to make a control experiment with each sample of vegetable, by boiling a portion in water and comparing the results with those already obtained.

The methods adopted for cooking were as follows.

### I. *Boiling in water.*

(a) 100 g. of the vegetable were washed with cold water in a strainer and were then immersed in 1000 cc. of boiling water, heated in an open pan and the boiling continued until the vegetables were quite soft as indicated by gently piercing with a fork. The time of cooking was noted. The vegetables were strained off, the cooking water evaporated to dryness on a water-bath and the residue heated in a steam-oven until a constant weight was obtained. This gave the weight of solid matter lost during the cooking process. The residue was then ignited over a flame until completely ashed, to obtain the weight of mineral matter.

#### (b) *The addition of sodium bicarbonate to the cooking water.*

The above experiments were repeated with the addition of 0.5 g. of sodium bicarbonate to the cooking water. The weights of residue and mineral matter were determined as before, a correction being made for the sodium bicarbonate added.

#### (c) *The addition of salt to the cooking water.*

The above experiments were repeated with the addition of 2.0 g. of salt to the cooking water. The weights of residue and mineral matter were determined as before, a correction being made for the sodium chloride added.

### II. *Steaming.*

100 g. of the vegetable were washed with cold water in a strainer, and placed in a steamer, covered with a lid, over a pan of boiling water. The cooking was continued until the vegetables were soft, and the time of cooking noted.

The vegetables were allowed to drain for a few minutes over the pan and were then removed from the steamer. The steamer was washed down with a little distilled water, and the washings added to the cooking water. The solids and mineral matter in the cooking water were determined as described above.

### III. *Conservative method.*

In the so-called "conservative" method of cooking vegetables, the vegetables are cooked in a very small quantity of water, so that the water is all absorbed by the vegetables during the cooking process. The vegetables are served without straining and there is practically no loss on cooking except volatile matter. 100 g. of the vegetable were covered with about 50–60 cc. of water and gently heated in a covered pan until quite soft. The time of cooking was noted.

The average results obtained for the different methods are given below (Table III). It should be noted, however, that the uncooked vegetable used for the experiments contains a large proportion of water, on the average about 89 %, the residues obtained therefore represent the loss on 100 g. of uncooked vegetable or on 11 g. of solid matter on the average, and the results

have been expressed as the loss both on 100 g. of vegetable and also on 100 g. of solids.

Table III.

Nature of vegetable	Method of cooking	Time of cooking	Loss of solids		Loss of mineral matter	
			(a) on 100 g. of raw vegetable	(b) on 100 g. of solids	(a) on 100 g. of raw vegetable	(b) on 100 g. of solids
I. Cabbage	Boiling	30 mins.	4.45	40.45	—	—
"	" + 0.5 g. sodium bicarbonate	20 "	3.37	30.64	—	—
"	Boiling	30 "	3.19	26.94	0.689	5.82
"	" + 0.5 g. sodium bicarbonate	20 "	2.26	19.10	0.438	3.70
"	Boiling	35 "	3.81	39.64	0.437	4.55
"	" + 0.5 g. sodium bicarbonate	22 "	3.41	35.48	0.421	4.38
II. Spring greens	Boiling	20 "	5.17	37.68	1.023	7.49
"	" + 2 g. salt	20 "	4.50	32.77	0.800	5.83
"	"	25 "	3.39	33.50	0.803	7.95
"	" + 2 g. salt	30 "	3.49	34.55	0.892	8.83
III. Cabbage	"	35 "	3.81	39.64	0.437	4.55
"	" + 2 g. salt	30 "	3.55	36.94	—	—
IV. Cabbage	Boiling	45 "	3.80	41.99	0.428	4.75
"	Steaming	1½ hrs.	0.88	9.72	0.224	2.48
"	Boiling	30 mins.	3.56	39.33	0.555	6.13
"	Steaming	45 "	1.44	15.91	0.304	3.35
"	Boiling	35 "	3.81	39.64	0.437	4.55
"	Steaming	1 hr.	0.92	9.61	0.303	3.15

These results show that the addition of sodium bicarbonate to the cooking water decreases the time required for cooking (compare I, Table III) and that the loss in solid matter is slightly less. This latter effect is probably due to the shorter time required for cooking. (Compare the action of ammonium carbonate in steaming vegetables.)

The addition of salt does not appear to have any marked effect either on the losses or on the time of cooking.

As would be expected, the loss in solid matter when the vegetables are steamed is considerably less than when they are cooked in boiling water, though the time of cooking is somewhat greater. It should be noted, however, that in cooking with steam it is necessary to use a covered vessel in order to retain the steam, and this applies also to the conservative method of cooking. The vegetables have, therefore, in both cases a bad colour, this effect being probably enhanced by the relatively long time required for cooking, and both methods are, for this reason, open to objection from a practical point of view.

*The addition of ammonium carbonate to the water used for steaming green vegetables.*

The experiments previously described, in connection with the action of alkali on the colouring matter of green vegetables, seemed to indicate that if the steam could be rendered alkaline this difficulty might possibly be obviated: Some experiments were, therefore, made in which green vegetables were steamed over boiling water to which a little ammonium carbonate had been added.

Preliminary experiments showed that the colour of the vegetables was greatly improved in this way. The experiments also showed that, provided only small quantities of the carbonate were employed, the cooked vegetables did not taste or smell of ammonia. The addition of the alkali appeared, as in the case of the addition of sodium bicarbonate to the water used for boiling, to decrease the time required for cooking, and if too much were added the vegetables rapidly became slimy and disintegrated.

Several experiments were made in order to determine the most suitable proportions of ammonium carbonate to use.

These experiments showed that some vegetables disintegrated more rapidly than others, but that on the whole the best results were obtained when 0.5–1.0 g. of ammonium carbonate was added to 1000 cc. of water for steaming, and when 0.1–0.2 g. was added to 100 g. of vegetable for the conservative method.

The losses of solid and mineral matter when 100 g. of the vegetable were steamed by this method were determined and the average results obtained were as follows:

Table IV.

Nature of vegetable	Method of cooking	Amount of ammonium carbonate added to 1000 cc. water	Time of cooking	Loss of solids		Loss of mineral matter	
				(a) on 100 g. of raw vegetable	(b) on 100 g. of solids	(a) on 100 g. of raw vegetable	(b) on 100 g. of solids
I. Cabbage	Boiling	—	34 mins.	3.81	39.64	0.437	4.55
	Steaming	—	1 hr.	0.92	9.61	0.303	3.15
	„	0.5 g.	18 mins.	0.48	5.01	0.157	1.63
II. Cabbage	Steaming	—	1 hr.	0.90	8.17	0.261	2.37
	„	2.4 g.	15 mins.	0.47	4.26	0.148	1.34
III. Cabbage	Steaming	—	30 mins. (not completely cooked)	0.52	4.72	—	—
	„	2.4 g.	30 mins. (slightly overcooked)	0.66	5.96	—	—

*Conservative method.*

Nature of vegetable	Method of cooking	Amount of ammonium carbonate added to 60 cc. water	Time of cooking
I. Cabbage	Boiling	—	30 mins.
„	Conservative	—	1 hr.
„	„	0.14 g.	30 mins.
II. Cabbage	Conservative	—	1 hr.
„	„	0.3 g.	12 mins.

The results show that the losses of solid and mineral matter are less than in the case of vegetables steamed in the ordinary manner without the addition of ammonium carbonate, and this in spite of the fact that the vegetables appear to disintegrate more rapidly when ammonium carbonate is used. The explanation of this result probably lies in the shorter time required for cooking in the presence of the alkali.

In order to illustrate this point some experiments were carried out in which portions of the same cabbage were cooked (*a*) over water, (*b*) over water containing excess of ammonium carbonate (2.4 g. of ammonium carbonate per litre). In the first experiment, the cabbage was cooked completely in both cases, the time of cooking noted and the loss of solid matter determined. In the second experiment, the cabbage was cooked for the same length of time in both cases and the loss of solid matter determined.

These results (see Table IV) show that if the time of cooking is increased, the losses increase, and if the vegetables are cooked for the same length of time only, the loss when ammonium carbonate is added is slightly greater than when water only is used.

Although the preliminary experiments indicated that the cooked vegetables had no appreciable taste or smell of ammonia, if only a small quantity of ammonium carbonate were used, it was thought advisable to carry out a few experiments in order to determine whether any considerable quantity of the ammonium salt were retained in the vegetable, as if this were the case its addition to the cooking water might be considered undesirable.

*Determination of the proportion of the ammonium carbonate retained by the cooked vegetable.*

The vegetables were cooked in a steamer of wire gauze suspended in the neck of a wide necked flask. The flask was connected with an upright condenser, the end of which dipped below the surface of a measured volume of standard acid contained in a beaker. 35 g. of the vegetable were used for each experiment. A weighed quantity of ammonium carbonate was added to the water in the flask and the water boiled for half-an-hour. The amount of ammonium carbonate left in the flask and the amount absorbed by the acid in the beaker were determined, and the difference between the sum of

these amounts and the amount of ammonium carbonate originally added was taken as a measure of the amount of ammonium carbonate absorbed by the vegetable (see Table V).

Table V.

Weight of cabbage	Volume of cooking water	Weight of ammonium carbonate added	Weight of ammonium carbonate left in flask	Weight of ammonium carbonate in beaker	Total ammonium carbonate in flask and beaker	Loss of ammonium carbonate
35	500	0.248	0.154	0.041	0.195	0.053
35	500	0.246	0.151	0.055	0.206	0.040
					<i>Mean ...</i>	0.046

The results indicate that the cooking water and distillate together contain most of the ammonium carbonate originally added, but a small proportion is lost and is presumably absorbed by the vegetable. It is possible that, by the time the vegetable has been cut up and dished ready for table, some of the ammonia at first absorbed will have escaped and that the proportion finally retained by the vegetable is less than that indicated by the experimental results.

Delf [1918] in dealing with the loss of antiscorbutic properties on cooking cabbage states that in general the loss is greater the longer the time of heating and that slow cooking at a low temperature is more deleterious than more rapid cooking at a higher temperature. It would be interesting if information could be obtained in order to show whether cooking for a short time in steam rendered slightly alkaline is less or more deleterious than cooking in steam without the addition of alkali for a longer period.

#### SUMMARY.

A comparison of the different methods of cooking green vegetables shows that the addition of a small quantity of alkali to the cooking water, in addition to having a marked effect upon the colour, also decreases the time required for cooking, and slightly decreases the losses incurred; this latter effect being probably due to the decrease in the time of cooking.

The addition of salt to the cooking water appears to have no appreciable effect either on the time of cooking or on the losses incurred.

The losses of solid and mineral matter when the vegetables are steamed are less than when they are cooked in boiling water. Cooking by steaming and also by the conservative method in which there is practically no loss is, however, open to the objection that the vegetables are in both cases cooked in a covered vessel, and have, therefore, usually a bad colour; also the time required for cooking is greater than when the vegetables are boiled in water.

Both these difficulties may be obviated, and in the case of steamed vegetables the losses incurred reduced by the addition of a small amount of ammonium carbonate to the water from which the steam is generated. The

addition of excess of alkali, either of ammonium carbonate in steaming or of sodium bicarbonate in boiling vegetables, is to be avoided or the vegetables become slimy and tend to disintegrate. (See also Summary, p. 83.)

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