

R&D REPORT
NO. 18

**The Effects of Domestic Cooking
and Preparation Techniques on the
Nutritional Composition of
Vegetables**

August 1995



Campden & Chorleywood
Food Research Association



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R&D Report No. 18
Project No. 12443

The Effects of Domestic Cooking and Preparation Techniques on the Nutritional Composition of Vegetables

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August 1995

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EXECUTIVE SUMMARY

Aims and Objectives

Many different cooking methods are now used in domestic kitchens, but data on the effects of these methods on nutritional composition is very sparse. With a growing interest and awareness among the general public for healthy eating and the nutritional importance of foods, and Government concerns as expressed in "Health of the Nation," more information is required on the influence of cooking methods on the nutrient content of the food. A range of vegetables commonly consumed in the UK, including frozen peas, spring greens, Dutch white cabbage, Savoy cabbage, young and old carrots, cauliflower, courgettes, French beans, sweet corn, Chinese vegetable stir-fry mix and a chilled vegetable mix, was prepared to the point of consumption, by a variety of cooking techniques: microwaving, steaming, baking, stir-frying, pressure cooking, traditional methods of boiling. Cooked samples were analysed for the minerals sodium, potassium, iron, magnesium and calcium, the vitamins B₁, B₂, B₅, B₆, folic acid, C, E, α and β -carotene and biotin and fibre and fat. The results were compared with values obtained from raw samples in order to determine the effect of different cooking methods on nutritional composition.

Results

The results showed that all methods of preparation and cooking result in some losses of minerals and vitamins from the vegetables studied. In general, for nutrients which are readily soluble in water such as the B vitamins and potassium, methods using smaller amounts of water such as microwaving result in better nutrient retention than methods using larger amounts of water, such as boiling.

Main Implications of the Findings

For most vegetables, the best nutrient retention during preparation and cooking is achieved by the use of methods which involve short periods of cooking and the minimum amount of water. Water-soluble nutrients such as potassium, folate and the B group vitamins are particularly susceptible to loss by leaching into the cooking water; for these nutrients, methods which reduce the amount of water used are likely to result in better nutrient retention. Addition of salt during cooking is much more significant for sodium levels than any other effect of cooking method, but sodium uptake could be reduced by pre-soaking in water or the use of excess cooking water.

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INTRODUCTION

The importance of vegetables in the diet is due particularly to their contribution of vitamin C, thiamin, folate, β -carotene, iron, potassium, magnesium, calcium and dietary fibre. It is accepted that nutrient losses occur in foods during preparation and cooking. At present, however, most of the information available for vegetables relates only to nutrient losses on boiling. See, for example, Holland, Unwin and Buss (1991).

The major nutrient losses during cooking are due to leaching into the cooking water. However, other losses occur due to oxidation, denaturation, and heat sensitivity of certain vitamins.

β -carotene is thought to be stable under most cooking and processing conditions. However, folate, vitamin C and thiamin are all water soluble and heat sensitive, whilst vitamin C and folate are also readily destroyed by oxidation during the preparation process. Due to these similarities, vitamin C stability is often used as an indicator for folate behaviour during preparation and cooking. Since the important minerals are water soluble, they are also readily lost by leaching into the cooking water.

There is some evidence that certain sectors of the UK population may not have nutritionally adequate diets. A London Food Commission survey (Sheppard, 1987) showed that a significant number of children were receiving lower than recommended levels of vitamin A, riboflavin, thiamin and vitamin C, with the elderly also especially at risk from micronutrient deficiency. Vitamin C is still one of the few nutrients which can often be deficient in the British diet. As fruit and vegetables are the main sources of most of these micronutrients, it is especially important to know what is happening in terms of nutrient losses during home preparation and cooking. An increasing percentage of the population follow vegan or vegetarian diets for reasons of ethnic culture, health or moral beliefs, and the nutritional quality of cooked vegetables is also of particular importance to this sector of the public.

Many different domestic cooking methods are now used. With a growing interest and awareness among the general public for healthy eating and the nutritional importance of foods, more information is required on the influence of these different cooking methods on nutritional composition.

This project set out to provide data on the effect of a range of modern domestic cooking methods (e.g., microwaving and stir-frying) on the nutritional composition of a number of commonly-consumed vegetables, excluding potatoes, which have been extensively studied elsewhere (e.g., Finglas and Faulks, 1984). Modifications to more traditional methods were also studied where appropriate. These included boiling vegetables with or without salt, and variations in the length of cooking time employed and the proportions of water to vegetables. The work concentrated on those analytes most likely to be affected by preparation and cooking, the minerals and vitamins, whilst moisture content was measured to allow for changes in water content and thus provide a basis for the calculations of changes in nutritional composition. Data were compared with results from raw vegetables and from traditional cooking methods.

EXPERIMENTAL METHODS

Cooking Methods

Each vegetable product underwent standard domestic preparation and cooking techniques as detailed below. Preparation and cooking methods were taken from domestic cookery books such as the "Good Housekeeping Cookery Book" (Good Housekeeping Institute, 1992) with some variations to represent overcooking or other abuse. Frozen or chilled vegetables were prepared according to packet instructions, again with variations to represent overcooking or abuse.

Vegetable Product	Preparation/Cooking Method
1). Frozen Peas	<ul style="list-style-type: none">a). Uncooked.b). 300g frozen peas boiled for 5 minutes in 188ml water with 0.35% NaCl.c). as b). but boiled 10 minutes.d). 300g frozen peas and 30ml water microwaved 5 minutes.e). as d). but microwaved 10 minutes.
2). Spring Greens	<p>Samples were trimmed of outer leaves, shredded and treated:-</p> <ul style="list-style-type: none">a). Uncooked.b). 500g spring greens boiled 10 minutes in 250ml water with 0.35% NaCl.c). 500g spring greens steamed 15 minutes.d). 500g spring greens pressure cooked 4 minutes over 250ml water.e). 500g spring greens microwaved 10 minutes with 15ml water.
3). Dutch White Cabbage	<p>Samples were trimmed of outer leaves, finely shredded and treated:-</p> <ul style="list-style-type: none">a). Uncooked.b). 400g cabbage boiled for 10 minutes in 2 litres water with 0.35% NaCl.c). 400g cabbage stir-fried for 5 minutes in sunflower oil.

4). Savoy Cabbage

Samples were trimmed of outer leaves, shredded and treated:

- a). Uncooked.
- b). 200g cabbage boiled for 10 minutes in 1 litre water with 0.35% NaCl.
- c). as b). but boiled for 30 minutes.
- d). as b). but with no added NaCl.
- e). as b). but boiled in 2 litres water.
- f). as b). but with 5 hours pre-soaking.
- g). 227g cabbage steamed 20 minutes.
- h). 200g cabbage steamed 30 minutes.
- i). 200g cabbage pressure cooked 4 minutes with 250ml water.
- j). as i). but cooked for 8 minutes.
- h). 227g cabbage microwaved for 10 minutes with 20ml water.

5). Young Carrots

Samples were washed, sliced and treated:-

- a). Uncooked.
- b). 400g carrots boiled for 15 minutes in 700ml water with 0.35% NaCl.
- c). 400g carrots steamed for 20 minutes.
- d). 400g carrots pressure cooked for 5 minutes with 250ml water.
- e). 300g carrots microwaved for 8 minutes with 15ml water.

6). Old Carrots

Samples were peeled, sliced and treated:-

- a). Uncooked.
- b). 300g carrots boiled for 5 minutes in 188ml water with 0.35% NaCl.
- c). 300g carrots boiled for 10 minutes in 188ml water with 0.35% NaCl.
- d). 300g carrots pressure cooked for 4 minutes.
- e). 300g carrots steamed for 15 minutes.
- f). 300g carrots microwaved for 6 minutes.

7). Cauliflower

Samples were trimmed, divided into florets and treated:-

- a). Uncooked.
- b). 400g cauliflower boiled for 10 minutes in 700ml water with 0.35% NaCl.
- c). 400g cauliflower steamed for 20 minutes.
- d). 400g cauliflower pressure cooked for 4 minutes over 250ml water.
- e). 400g cauliflower microwaved for 6 minutes with 15ml water.

8). Courgettes

Samples were washed, sliced and treated:-

- a). Uncooked.
- b). 500g courgettes boiled for 10 minutes in 250ml water with 0.35% NaCl.
- c). 500g courgettes steamed for 20 minutes.
- d). Whole courgettes baked @ 180°C for 80 minutes.
- e). 400g courgettes microwaved for 10 minutes with 40ml water.

9). French Beans

Samples were washed, trimmed and treated:-

- a). Uncooked.
- b). 400g beans boiled for 10 minutes in 250ml water with 0.35% NaCl.
- c). 400g beans steamed for 20 minutes.
- d). 400g beans pressure cooked for 4 minutes over 250ml water.
- e). 400g beans microwaved for 6 minutes with 15ml water.

10). Sweetcorn Frozen Kernels

- a). Uncooked.
- b). 400g sweetcorn boiled for 5 minutes in 750ml water with 0.35% NaCl.
- c). 400g sweetcorn microwaved for 6 minutes with 25ml water.

- | | |
|--|--|
| 11). Chinese Vegetable Stir-Fry Mix | a). Uncooked.
b). Stir-fried in olive oil for 10 minutes.
c). Stir-fried in olive oil for 15 minutes.
d). Stir-fried in sunflower oil for 10 minutes.
e). Stir-fried in walnut oil for 10 minutes. |
| 12). Chilled Vegetable Mix -
Leeks, Aubergines,
Mushrooms,
Red/Green/Yellow Peppers | a). Uncooked.
b). Stir-fried in sunflower oil for 6 minutes.
c). Baked in greased, covered casserole dish @ 180°C for 75 minutes. |

The microwave oven used was a Sanyo 650W oven used at full power.

Samples were prepared to the point of consumption and then analysed immediately, or rapidly frozen in liquid nitrogen and kept frozen until they could be analysed.

Analytical Methods

The analytical methods used are summarised as follows.

Analyte		Method of Analysis
Moisture		Vacuum oven
Minerals (Na, K, Fe, Ca, Mg)		Atomic absorption spectroscopy following ashing in a muffle furnace
Vitamin	B ₁ (Thiamin)	HPLC
	B ₂ (Riboflavin)	HPLC
	B ₅ (Pantothenic acid)	Microbiological assay: <i>Lactobacillus plantarum</i>
	B ₆ (Pyridoxine group)	Microbiological assay: <i>Saccharomyces cerevisiae</i>

Folate	Microbiological assay: <i>Lactobacillus casei</i>
Vitamin C	Autoanalyser (ascorbic and dehydroascorbic acid)
α and β -carotenes (Vitamin A)	HPLC
Vitamin E	HPLC
Biotin	Immunoassay: Ridascreen test kit
Dietary Fibre	Englyst methodology, colorimetric end-point
Fat	Acid hydrolysis, solvent extraction (Tecator Soxtec system)

Each vegetable was tested for the most appropriate nutrients in each case, as shown in table 1 below:

Table 1. Nutrients analysed in each vegetable studied

Analyte	Samples Analysed
Moisture	All vegetables.
Minerals	All vegetables.
Vitamin B ₁	All vegetables.
B ₂	All vegetables.
B ₅	Peas, young and old carrots, chilled vegetable mix.
B ₆	All vegetables.
Folate	All vegetables.
Vitamin C	All vegetables.
Carotenes	Young carrots, spring greens, savoy cabbage.
Vitamin E	White cabbage, Chinese vegetable stir-fry mix.
Biotin	Peas, young and old carrots, chilled vegetable mix, raw and boiled courgettes.
Dietary fibre	Peas, spring greens.
Fat	Chinese vegetable stir-fry mix.

Statistical Treatment of Results

Five replicate samples were cooked and analysed for each cooking treatment for each vegetable. Results were calculated as % True Retention using the formula:

$$\frac{(\text{Concentration of nutrient in cooked food})}{(\text{Concentration of nutrient in raw food})} \times \frac{(\text{Wt. food after cooking})}{(\text{Wt. food before cooking})} \times 100$$

Analysis of variance was carried out to compare the effects of different cooking treatments and significant differences were identified.

RESULTS

Full tables of results are given in Appendix I (% retention values) and Appendix II (raw mean data). Since the object of the study was to compare the nutrient retention of different cooking methods, the following results and discussion refer to % retention values.

Moisture content

Small but statistically significant changes in water content were observed for most treatments. Most cooking treatments reduced the water content slightly, but this was most marked in microwaved and stir-fried vegetables, where losses exceeded 10%. Baking also reduced the moisture content of courgettes by 5%. This may account in part for the apparent high retention values of some analytes cooked by these methods, although the method of calculating true retention should eliminate this effect. Boiling, pressure-cooking and steaming tended to increase the water content of vegetables such as cabbage, spring greens and cauliflower by up to 42%, possibly because it was impossible to remove all surface water from the samples before analysis. In contrast, these treatments tended to reduce the water content of carrots by as much as 8%.

Sodium

Vegetables naturally contain rather low levels of sodium, as shown in published tables (e.g., Holland, Welch et. al., 1991) and in the raw mean data for uncooked vegetables (Appendix II). In normal domestic cooking, any changes caused by cooking methods are far outweighed by the effect of salt added during cooking. In the results obtained in this work, added salt raised sodium contents to as much as 20 times the content of the raw vegetables. The only decreases in sodium content observed as a result of cooking methods were in stir-fried white cabbage (74% retention) and Chinese vegetables cooked in olive or walnut oils (49-82% retention), and also in microwaved sweetcorn (23% retention). These cooking methods appeared to be particularly effective in leaching sodium from those vegetables. It was also observed that cooking in excess water and pre-soaking both substantially reduced the amount of added salt taken up by Savoy cabbage (928% and 740% retention compared with 1471%). In contrast, overcooking increased the amount of salt taken up (2087% retention compared with 1471%).

Potassium

Potassium is the most abundant cation in plant tissue, but it is very water-soluble, and hence readily lost in cooking methods involving water. Nevertheless, there were large increases in potassium levels in microwaved young carrots (133% retention) and sweetcorn (114% retention), in Chinese vegetables stir-fried in olive oil (114% retention) and in Savoy cabbage steamed for 20 minutes (112% retention). Smaller increases were observed in other steamed, stir-fried or microwaved samples. Generally, however, cooking resulted in losses of potassium of up to 72%, particularly for boiled, steamed and pressure-cooked vegetables, with smaller losses, generally less than 10%, for microwaved and stir-fried samples.

Iron

Most of the changes observed in iron content were not statistically significant, indicating that it is not a mineral which is particularly susceptible to changes as a result of domestic preparation. The only significant changes were observed in Savoy cabbage, French beans and sweetcorn. There were increases in boiled French beans (115% retention) and in Savoy cabbage which had been steamed (145% retention), boiled in excess water (112% retention) or without salt (157% retention). There were decreases in boiled and microwaved sweet corn (86 and 93% retention respectively), in pressure-cooked or microwaved French beans (80 and 81% retention), and in Savoy cabbage which had been pressure-cooked for four minutes (72% retention) or boiled with a pre-soak (61% retention).

Magnesium

In most cases, preparation and cooking produced either no significant change in magnesium levels or a loss of magnesium. The only exceptions to this were Savoy cabbage which had been pressure-cooked for eight minutes (112% retention) or steamed (133% retention), and in steamed spring greens (108% retention). The major losses of magnesium across a range of vegetables were due to boiling and pressure-cooking, and also stir-frying of white cabbage and microwaving of old carrots.

Calcium

As with iron, most of the changes observed in calcium content as a result of preparation and cooking were not statistically significant. The only increases in calcium content which were statistically significant were in boiled white cabbage, boiled, steamed or microwaved Savoy cabbage (up to 140% retention), in Chinese vegetables stir-fried in sunflower or walnut oil (143 and 115% retention), and in baked chilled vegetables (132% retention). The only significant decreases were in stir-fries (white cabbage, and Chinese vegetables cooked in olive oil), pressure-cooked Savoy cabbage and in boiled, pressure-cooked, steamed and microwaved French beans with as little as 62% retention. In most cases, boiling, steaming, pressure-cooking and microwaving made no statistically significant difference.

Vitamin B₁ (Thiamin)

In most cases, preparation and cooking resulted in statistically significant losses of vitamin B₁. Boiling, pressure-cooking, steaming and microwaving of a range of vegetables all resulted in substantial losses of up to 50% of the vitamin. However, no significant changes were observed for courgettes, cauliflower or Chinese vegetable stir-fry. Statistically significant increases in vitamin B₁ levels were observed in boiled French beans (118% retention) and in microwaved peas (116-118% retention), in contrast to the other cooking treatments for these vegetables, which resulted in losses of 20% in the case of peas, and up to 50% in the case of French beans.

Vitamin B₂ (Riboflavin)

The results for vitamin B₂ showed some similarity to those for vitamin B₁. Again, boiling, pressure-cooking, steaming and microwaving all produced substantial losses of up to 50% in many of the vegetables studied. However, courgettes, French beans and spring greens showed no significant differences between treatments. Peas again showed a slight increase in vitamin B₂ levels when microwaved, but losses of 25% when boiled. Similarly, stir-fried white cabbage and mixed vegetables stir-fried in olive oil showed increases in vitamin B₂ content, whilst boiled white cabbage and mixed vegetables stir-fried in sunflower or walnut oils showed decreases. Increases in vitamin B₂ content were also observed in Savoy cabbage when steamed, pressure-cooked or microwaved, and in steamed or microwaved old carrots, whilst other cooking methods reduced the amount of vitamin B₂ in these vegetables.

Vitamin B₅ (Pantothenic acid)

Pantothenic acid was analysed in peas and young and old carrots. In each case, microwaving resulted in the highest increased level of the vitamin (up to 130% retention). Boiling of peas and pressure-cooking of old carrots also resulted in slight increases, whilst in old carrots boiling resulted in losses of over 10%. There were no significant changes in the other samples analysed, chilled vegetable mix.

Vitamin B₆ (Pyridoxine group)

The results for vitamin B₆ again showed some similarity to those for vitamins B₁, B₂ and B₅, although in this case the major factor resulting in loss of vitamin B₆ was boiling, together with pressure cooking or microwaving of cauliflower and spring greens. No significant differences in vitamin B₆ content between cooking methods were observed for courgettes, Savoy cabbage, sweetcorn and old carrots. As with vitamins B₁, B₂ and B₅, microwaving resulted in vitamin B₆ retention of up to 116% in peas, and lower levels in boiled peas. Similarly, in young carrots, steaming and microwaving resulted in increases in vitamin B₆, whilst boiling resulted in losses of up to 17%. Stir-frying of Chinese vegetables in olive oil resulted in increases of up to 67% in vitamin B₆, whilst the use of sunflower or walnut oils resulted in losses, paralleling results for vitamin B₂. Stir-frying of white cabbage also increased levels of vitamin B₆ (140% retention), whilst boiling resulted in losses (59% retention).

Folate

As with the B vitamins, boiling was generally the most destructive treatment, although in some vegetables steaming, baking or pressure-cooking also resulted in losses of folate, as did stir-frying of mixed vegetables. Peas also showed a similar pattern to that seen with the B vitamins, microwaving resulting in higher levels of folate (up to 119% retention), whilst boiling resulted in retentions as low as 76%. Microwaving also resulted in smaller losses than boiling in courgettes and young carrots. No significant differences between cooking methods were observed in spring greens, white cabbage, cauliflower, sweetcorn, old carrots and French beans.

Vitamin C

Statistically significant differences between treatments were observed for vitamin C levels in all vegetables studied apart from sweetcorn. In general, boiling, steaming, pressure-cooking and microwaving all resulted in substantial losses of vitamin C. Exceptions to this included microwaving of cauliflower and Savoy cabbage, which gave better retention, longer boiling or steaming of old carrots, which appeared to result in increased levels of vitamin C, and pre-soaking, steaming, and pressure-cooking of Savoy cabbage, which appeared to have a protective effect.

α and β -Carotenes (Vitamin A)

Carotenes were analysed in young and old carrots, Savoy cabbage and spring greens, but the results were somewhat inconclusive. In young carrots the only statistically significant result was for β -carotene, which showed a slight increase (105% retention) after pressure-cooking, a slight decrease (91% retention) on boiling and a more substantial loss (74% retention) as a result of microwaving. However, total carotenes showed no significant differences. In the other vegetables, no significant differences were found in spring greens, while the results for old carrots and Savoy cabbage showed large fluctuations between individual samples, and so were not included.

Vitamin E

Vitamin E results are available for Dutch white cabbage. Levels in raw and boiled samples were below the limits of detection, but 9.37mg/kg was detected in stir-fried white cabbage, taken up from the cooking oil. Vitamin E was also analysed in Chinese vegetable stir-fry mix. However, results were very variable, possibly due to observed variation in the amount of fat taken up by different replicate samples and variations in the composition of the commercial vegetable mix.

Biotin

Biotin was analysed in peas, courgettes, young carrots, chilled vegetable mix and Savoy cabbage, and no significant differences between treatments were observed in the results.

Fibre

Fibre was analysed in spring greens and peas and statistically significant differences were observed for spring greens only. Boiling and pressure-cooking resulted in substantial losses (23 and 52% retention respectively), whilst retention was much better for microwaved spring greens (88% retention).

Fat

Fat content was analysed in stir-fried Chinese vegetables, and differences between treatments were only significant at the 5% level, cooking in walnut oil resulting in slightly higher fat uptake than sunflower or olive oil. Cooking time influenced fat uptake, a 15 minute cook in olive oil resulting in about 30% more fat being taken up than a 10 minute cook.

DISCUSSION

As with most other studies of the nutritional composition of foods, the results obtained indicate the analytical availability of the nutrients, which may not necessarily be the same as the bioavailability. Some minerals and also some vitamins may be bound in such a way as to make them unavailable during digestion, and so analytical values may give an overestimate of the amount of the nutrient which is actually available. Similarly, and particularly in the case of fibre and some vitamins, analytical methods may not measure all of the forms of the nutrient that are biologically available, resulting in an underestimate of the available nutrient. The uncertainty is further compounded by the fact that the preparation and cooking treatments may also affect the analytical availability of some nutrients, particularly some vitamins, in a way which does not necessarily reflect their biological availability.

Minerals

Minerals in the diet have been shown to have a direct influence on health. For instance, magnesium deficiencies have been associated with coronary heart disease and lack of control of blood lipid concentrations. Excess sodium has been linked with hypertension, and it is generally accepted that a diet low in sodium and high in potassium may have beneficial effects. Vegetables tend to have this favourable ratio of sodium to potassium (Blackholly, 1989).

Modern analytical data on the effect of cooking methods on the mineral content of vegetables are quite sparse. Many of the data in food tables (e.g., Holland, Welch et al., 1991) are derived from rather old studies. Modern studies on cooking methods have tended to concentrate on the retention of vitamins and improved analytical methods for vitamins.

The behaviour of minerals during preparation and cooking is related closely to their solubility. Minerals are generally stable to most of the conditions encountered in cooking of foods, e.g., heat, oxidation, acid or alkali (Hall and Pither, 1991). Sodium is unique in the sense that it is naturally present in relatively low concentrations in raw vegetables, but it is frequently added in substantial quantities as part of the cooking process, generally to improve the flavour of the cooked vegetables. The results of this study show this effect quite clearly, with substantial increases in the sodium content of

vegetables when this is done. However, increases of up to 90% were also observed in many treatments where salt was not deliberately added. This may have been due to pick-up from cooking water or oil, or because the natural levels of sodium in plant tissue are close to the detection limit for the method used in this part of the study. Small errors at this level are therefore likely to lead to apparent increases in sodium levels.

Of the minerals present in plant tissue, potassium is by far the most abundant, but because of its high solubility in water it is extremely mobile and is easily lost by leaching in both domestic cooking and commercial food processing. Losses in domestic cooking procedures are clearly shown in the results, confirming previous work (e.g., Hall and Edwards, 1989).

In contrast to potassium, iron is present in plant tissue in much lower concentrations, and principally in bound forms. Hence, it tends not to be readily lost, and indeed many of the results show little statistically significant movement of iron at all.

Calcium and magnesium are generally present in plant tissue in bound form, and hence, like iron, are not readily lost by leaching. However, they were also both present in the tap water used in the study, at levels of 99 mg/litre calcium and 4.2 mg/litre magnesium (water company analysis for the period of the experiment). This is typical of tap water present in areas with hard water, and these elements are known to be taken up by vegetables during cooking in water (Hall and Edwards, 1989). Movement of magnesium and calcium into and out of vegetables during cooking was principally observed in leafy vegetables such as cabbage and spring greens, reflecting the large surface to volume ratio of these vegetables. Other vegetables, such as sweet corn, carrots and courgettes, with lower surface to volume ratios showed less movement. It is therefore likely that the amount of chopping of vegetables prior to cooking will affect the movement of calcium and magnesium, as well as other more mobile minerals such as potassium; there is likely to be a trade-off between loss of vitamins as a result of a large surface area against longer cooking times for more coarsely cut vegetables. However, there appeared to be differences in the mechanisms of uptake and loss of calcium and magnesium in leafy vegetables; for example, levels of magnesium in Savoy cabbage tended to increase in cooking methods involving minimal amounts of water such as microwaving or steaming, whereas all cooking methods apart from pressure cooking increased the levels of calcium in the same vegetable.

Vitamins

The compounds comprising the B vitamin complex have little in common with each other, except that they are all intimately involved in catalysing metabolic reactions. All are water-soluble.

Vitamin B₁ (Thiamin)

The contribution to thiamin intake in the UK made by vegetables is relatively small (Holland, Welch et al., 1991), with the exception of the potato. Most of the published values for thiamin in food tables have been obtained by microbiological assay (Bell, 1974) or by a modified fluorimetric procedure (AOAC, 1984), based upon the original thiochrome procedure (Society of Public Analysts and other Analytical Chemists, 1951). Both procedures are time-consuming and, in addition, the inadequate recoveries of thiamin in the clean-up stage of the thiochrome procedure may result in underestimation (Wills et al., 1985). The specificity and sensitivity of the HPLC method used in this study not only gives determinations less susceptible to interference, but also reduces the time required for analysis, since the clean-up step is no longer required (Finglas and Faulks, 1987). The losses of vitamin B₁ on boiling, pressure cooking and steaming observed in this study are all consistent with leaching of the vitamin into the cooking water.

Vitamin B₂ (Riboflavin)

As with thiamin, the contribution to riboflavin intake in the UK made by vegetables is fairly low. HPLC determinations of riboflavin have resulted in rather lower values than were obtained previously by microbiological assay (Kwiatkowska et al., 1989), but the more modern data probably reflect improved methodology rather than a real drop in riboflavin levels.

Vitamin B₅ (Pantothenic acid)

Pantothenic acid is stable and quite soluble in water, but it is easily destroyed by acids, alkalis or heat. Its importance in nutrition lies in its conversion to co-enzyme A. Vegetables contribute about 26% of the pantothenic acid dietary intake in the UK (Tyler et al., 1989). The similar pattern to the other B vitamins, with microwaving giving the best retention, is consistent with previous work indicating that leaching by water is the major factor in vitamin losses.

Vitamin B₆ group

Vitamin B₆ is a term which is applied to three primary forms of 3-hydroxy-5-hydroxymethyl-2-methyl pyridine (Leklem, 1988). The three forms are pyridoxine, pyridoxamine, and pyridoxal. Each of these can exist in foods as the free and phosphorylated forms, the proportion and amount varying between foods. Pyridoxamine levels after cooking have been found to be more stable than those of the other two forms; this may be due to greater heat stability of pyridoxamine, or to conversion of the other forms to pyridoxamine (Kwiatkowska et al., 1989). The vitamin also occurs in plants as the glucoside form, which is biologically active, but is not detected by the microbiological method used in some studies from which published values are derived unless it is first hydrolysed to release the pyridoxine molecule. Some hydrolysis of the glucoside may occur during preparation and cooking, raising the apparent amount of the vitamin when assays are carried out by this method. Nevertheless, HPLC methods for vitamin B₆ generally appear to give reasonably good agreement with results from microbiological assays as used in this study (Kwiatkowska et al., 1989). Over 30% of the UK dietary intake of vitamin B₆ comes from vegetables (Tyler et al., 1989).

It is clear from the results that the B vitamins behave in a very similar way to each other in a number of the vegetables studied. The clearest examples of this are the finding that microwaving results in higher retention levels of all the B-vitamins (and folate and pantothenic acid) in peas than does boiling. Similarly, there were no significant differences due to cooking method for any of the B vitamins in courgettes. The reason for this is most likely to be the high water solubility of the B vitamins. As a result of this, losses of B vitamins may be expected to be due principally to leaching, thus explaining why microwaving results in better retention of B vitamins in peas than boiling. In this respect, the B vitamins behave in a similar manner to potassium, and indeed principal components analysis shows strong correlations between all the B vitamins and potassium in most of the vegetables studied. Karlin (1977) showed that losses of B vitamins from a range of vegetables were greater after boiling than after steaming. As with all vitamin analyses, the results may be affected by analytical availability, and this may be responsible for the apparent increases in the B vitamins in some treatments.

Vitamins B₁ and B₂ are both reasonably heat resistant for short periods, whilst vitamin B₆ is much less stable to moist heat than to dry heat. Vitamin B₁, B₂ and B₅ become less stable in alkaline conditions, and so variations in the pH of the tap water used as a result of varying levels of hardness may have some effect on the stability of the vitamins. This may also help to explain why boiling is relatively highly destructive of the B vitamins.

Folate (folic acid)

Vegetables are a major source of folate in the diet and contribute about 30% of the total daily intake of the vitamin in the UK (Paul and Southgate, 1978; MAFF, 1985).

Folic acid (folacin) is mono-pteryl glutamic acid. Its main function is as tetrahydrofolic acid, which acts as a co-enzyme concerned with the metabolism of one-carbon units. While bound as the co-enzyme, the one-carbon unit may be oxidised or reduced, or undergo other changes. These structures are then closely associated with the metabolism of many purines, pyrimidines, amino acids, and, indirectly, haem. The heat and pH stability of folic acid vary according to the number of glutamyl residues on the molecule and the nature of any attached one-carbon units. When heated in neutral or alkaline conditions, however, it undergoes fairly rapid decomposition.

It has been reported that the microbiological assay for folate (Bell, 1974) gives serious underestimates (Phillips and Wright, 1983; Wright and Phillips, 1985), although more recent changes in the conditions of the assay have corrected this to a large extent, so that all forms of folate give equivalent responses. The data from this study may therefore include lower values than some appearing in the literature. However, there does not appear to be any evidence that this compromises estimates of percentage retention of the vitamin, since all samples in this study were assayed in the same way. A study of boiled vegetables indicated that loss of folate during cooking is caused by extraction of the vitamin into the cooking water rather than by destruction (Leichter et al., 1978). In the present study, this general finding was confirmed, folate behaving in a similar manner to the B vitamins in most cases.

Vitamin C

Vegetables are a particularly important source of vitamin C in the UK diet, contributing almost 45% of the total intake (Tyler et al., 1989). Vitamin C values are expressed as total ascorbate, the combination of ascorbic acid (AA) and dehydroascorbic acid (DHAA). Both forms are active as vitamin C, and DHAA can be converted back to ascorbic acid. However, it is unstable and can also be readily converted by an irreversible ring-opening reaction to diketogulonic acid, which is inactive as vitamin C and is incapable of being converted back to ascorbic acid. Hence, formation of DHAA can represent a loss of vitamin activity. This can often occur due to oxidation during initial preparation, and so

it is important that the food is prepared rapidly after this stage. A loss of about 20% in ascorbate has been found during the shredding of cabbage prior to cooking (Paul and Southgate, 1978). However, significant losses can also occur during storage of fresh vegetables prior to preparation and cooking (Hall and Edwards, 1989).

Blumenthal et al. (1980), Meier-Ploeger et al. (1981), Somogyi (1975) and Tempelhoff et al. (1978) found that steaming of vegetables resulted in better vitamin C retention than pressure-cooking or boiling. Eheart and Gott (1965) compared stir-frying, microwaving, steaming and boiling of broccoli and beans and concluded that steaming gave better ascorbic acid retention than microwaving or boiling. Data on vitamin retention after microwaving are generally conflicting. This may be due to differing microwave capabilities, food quantities, and the technical changes in microwave ovens between the first studies carried out in the 1960s and the present day (Rumm-Kreuter and Demmel, 1990). More recent work showed significantly higher levels of ascorbic acid in frozen vegetables which had been microwaved than in boiled frozen vegetables (Gould and Golledge, 1989). Hall and Edwards (1989) obtained similar results with fresh peas. The results of the present study were generally consistent with previous work.

Martinsen and Ostrander (1984) studied the effect of cooking vegetables with and without surrounding water, and showed that steaming gave better retention of ascorbic acid and riboflavin in peas than did boiling. Similar results were obtained with thiamin and riboflavin content of carrots and cabbage, although Geervani and Theophilus (1980) found that boiling gave better retention of thiamin and riboflavin in chickpeas than did pressure cooking. However, this may have been due to the higher pressure used.

α and β -Carotenes (Vitamin A)

Vegetables contribute over 20% of the dietary intake of carotenes in the UK (Tyler et al., 1989). Whilst the major sources are limited to a few vegetables, such as carrots, green leafy vegetables can also be useful sources, their green colour masking the orange carotene.

A wide range of carotenoids is found in vegetables, of which α -carotene and β -carotene are active as vitamin A. Many researchers have reported substantial losses of carotenoids as a result of cooking or processing vegetables (see Khachik et al. (1992) for a summary). Most losses appear to be due to thermal degradation and isomerisation of these compounds rather than leaching, as might be expected from a fat-soluble vitamin. This may well explain the higher losses of carotenes in microwaved carrots than in other treatments in this study.

Vitamin E

The vitamin E in food is present as various tocopherols and tocotrienols, each having a different level of vitamin E activity. The inner leaves of cabbage contain much lower levels of vitamin E than the inner leaves used for stir-frying in this study (Holland, Welch et. al., 1991). In this case, the extra vitamin E obtained from the oil used for stir-frying therefore becomes quite significant.

Biotin

Biotin occurs as the prosthetic group of many enzymes catalysing carboxylation reactions such as the conversion of pyruvate to oxaloacetate. Biotin is reported to be quite stable to cooking and processing procedures. It is sparingly soluble in cold water, stable to heat but labile to oxidising agents and strong acid or alkali. The insolubility in water reduces the extent to which it is leached during cooking, so the effect on vitamin levels of methods such as boiling is not as marked as with the B vitamins. This may explain the absence of any significant differences due to cooking methods in the present study.

Fibre

The definition of dietary fibre is the object of an on-going debate in food science, since analytical values may not necessarily be related to the metabolic significance of the various fractions. Different methods give different estimates of the total fibre content of a food. Dietary fibre appears to be important in reducing the risk of coronary heart disease, hypertension, large bowel cancer and other gastrointestinal disorders (Blackholly, 1989). Vegetables contribute over 40% of the fibre in the UK diet (Tyler et al., 1989).

The results presented here indicated that the best retention of fibre in spring greens was achieved by steaming, with the other methods resulting in significant losses. Lintas and Cappelloni (1988) found that cooking had little effect on the total dietary fibre content of a range of vegetables, but that cooking consistently caused a re-distribution from insoluble to soluble fibre components. This may have been due to modification of cell wall components during cooking; heat treatments are known to change the chemical characteristics and solubility of polysaccharides in foods (Varo et al. 1984). In contrast, although Reistad and Frolich (1984) found that cooking had little effect on the dietary fibre content of carrot, cabbage, cauliflower and rutabaga, they found no changes either

in the content or composition of total neutral non-starch polysaccharides. It is possible that the different cooking methods employed in the present study produced varying changes in cell wall polysaccharides, leading to the changes in total fibre content observed. However, comparison of results of dietary fibre analyses must be carried out with particular care, as the method used can have profound effects on the results obtained. Lintas and Cappelloni (1988) used a modification of the enzymatic-gravimetric AOAC method (Prosky et al., 1985), and Reistad and Frolich (1984) used both an enzymatic-gravimetric method and an earlier version of the Englyst method, whereas this study used current Englyst methodology (Englyst and Cummings, 1988).

Fat

Most raw vegetables contain very low natural levels of fat, and the significance of fat analyses in this study is in the assessment of fat uptake as a result of different frying methods. Most modern western diets contain higher fat intakes than appear to be desirable on health grounds, and so methods of reducing fat uptake during cooking are important. In this study, the finding that extended cooking in oil increases fat uptake is consistent with other studies on food such as potato chips and crisps. The differences between the oils used were unexpected, and warrant further investigation.

CONCLUSIONS

1. Steaming and microwaving tended to give the best retention of nutrients in most of the vegetables studied.
2. Pressure cooking resulted in some marked losses of vitamins, possibly due to elevated temperatures and the additional time in reaching cooking pressures and cooking.
3. Water-soluble nutrients such as potassium, folate and the B group vitamins were found to be particularly susceptible to loss by leaching into the cooking water; for these nutrients, methods which reduce the amount of water used are likely to result in better nutrient retention.
4. Similarly, a high surface area/volume ratio was found to increase the losses of water-soluble nutrients. To prevent this, fine chopping of vegetables, leading to increased cell damage and more exposed surface area, should be avoided.
5. In samples where only boiling, baking and stir-frying were carried out, stir-frying gave the best overall nutrient retention.
6. Addition of salt during cooking is much more significant for sodium levels than any other effect of cooking method, but sodium uptake could be reduced by pre-soaking in water or the use of excess cooking water.
7. Some interesting and unexplained differences were found between nutrient retention values when different oils were used for stir-frying. This warrants further investigation.

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ACKNOWLEDGEMENTS

The authors would like to thank Melinda Frier and Darren Mullan for help with preparation, cooking and chemical analyses, and David Evans for assistance with statistical analyses.

Appendix I

Calculated mean True % Retention for different cooking methods showing residual standard deviations (RSD) and the statistical significance of the difference between cooking methods.

Significance (sign)

*** = very highly significant ($p < .001$)

** = highly significant ($p < .01$)

* = significant ($p < .05$)

NS = Not significant

Frozen Peas

Analyte	Boiled 5min	Boiled 10min	Microwave 5min	Microwave 10min	RSD	Sign
H ₂ O	87	87	92	79	3	***
Na	1056	1107	174	191	9	***
K	68	66	83	86	7	**
Fe	111	99	98	96	13	NS
Mg	100	77	97	97	9	**
Ca	91	85	96	101	11	NS
B ₁	79	80	118	116	12	***
B ₂	75	75	100	105	4	***
B ₅	104	102	128	131	14	**
B ₆	82	90	103	116	13	**
Folate	95	76	119	106	18	*
C	63	65	72	72	6	*
Biotin	83	49	96	118	41	NS
Fibre	103	94	95	91		NS

Spring Greens

Analyte	Boiled	Pressure cooked	Steamed	Micro- waved	RSD	Sign
H ₂ O	96	107	102	89	22	***
Na	2060	252	290	239	129	NS
K	87	88	76	93	11	NS
Fe	148	133	133	117	30	NS
Mg	69	64	108	90	9	***
Ca	127	82	108	112	22	NS
B ₁	32	48	46	71	11	***
B ₂	83	77	87	95	14	NS
B ₆	90	75	93	79	5	***
Folate	87	118	86	97	22	NS
C	81	68	83	44	10	***
Tot.Car	97	102	96	80	14	NS
Fibre	23	52	103	88	9	**

Dutch White Cabbage

Analyte	Boiled	Stir- fried	RSD	Sign
H ₂ O	106	74	4	***
Na	566	74	130	***
K	52	102	7	***
Fe	104	85	27	NS
Mg	97	62	10	***
Ca	107	70	11	**
B ₁	47	88	12	***
B ₂	50	107	7	***
B ₆	59	140	23	***
Folate	70	46	21	NS
C	66	87	9	**

Savoy Cabbage

Analyte	Boiled 10min +salt	Boiled 30min +salt	Boiled 10min	Boiled 10min +xsH ₂ O	Boiled 10min +P/soak	Steam 20min
H ₂ O	132	117	140	138	142	89
Na	1471	2087	131	928	740	120
K	60	43	60	37	28	112
Fe	98	99	157	112	61	145
Mg	88	73	96	70	46	133
Ca	119	107	125	127	106	140
B ₁	64	54	69			
B ₂	55	44	55	106	90	198
B ₆	80	88	88	102	88	108
Folate	3	2	2	2	4	13
C	63	57	89	55	127	198
Biotin	46	47	83	81	44	3479

Savoy Cabbage

Analyte	Pressure cooked 4min	Pressure cooked 8min	Microwave 10min	RSD	Sign
H ₂ O	115	111	111	3	***
Na	71	80	107	189	***
K	61	53	96	10	***
Fe	72	99	100	34	**
Mg	81	112	102	18	***
Ca	69	100	129	26	*
B ₁				4	**
B ₂	178	187	151	22	***
B ₆	150	118	90	40	NS
Folate	5	4	3	1	**
C	161	99	92	34	***
Biotin	4166	134	95	40	NS

Young Carrots

Analyte	Boiled	Pressure cooked	Steamed	Micro- waved	RSD	Sign.
H ₂ O	98	96	92	88	20	***
Na	424	114	120	133	24	***
K	68	83	105	110	11	***
Fe	84	56	71	59	24	NS
Mg	76	---	97	---	10	*
Ca	130	87	94	69	32	NS
B ₁	46	54	62	65	8	**
B ₂	56	62	69	77	10	*
B ₅	69	85	82	86	19	**
B ₆	83	103	130	135	24	*
Folate	55	97	76	95	10	***
α-Car	70	59	66	61	27	NS
β-Car	91	105	95	74	22	**
Tot. car	126	134	128	104	34	NS
Biotin	84	113	83	103	23	NS

Old Carrots

Analyte	Boiled 5min	Boiled 10min	Pressure cooked	Steam	Micro- waved	RSD	Sign
H ₂ O	99	98	98	96	90	15	***
Na	218	246	119	125	141	32	***
K	70	72	86	69	90	17	NS
Fe	77	97	85	68	73	15	NS
Mg	59	64	71	68	82	10	*
Ca	76	84	87	96	86	11	NS
B ₁	80	87	71	52	35	24	*
B ₂	75	79	91	104	110	15	**
B ₅	89	82	114	99	125	18	**
B ₆	75	79	84	86	81	19	NS
Folate	68	100	88	89	90	19	NS
C	60	134	71	106	87	37	*

Cauliflower

Analyte	Boiled	Steamed	Pressure waved	Micro-	RSD	Sign
H ₂ O	107	105	103	91	28	***
Na	1431	138	148	137	40	NS
K	50	88	70	87	12	***
Fe	104	123	124	137	16	NS
Mg	85	101	106	125	19	NS
Ca	106	98	102	103	20	NS
B ₁	0.0	14	0.0	2	9	NS
B ₂	53	91	78	82	9	***
B ₆	53	81	85	75	11	**
Folate	81	80	80	83	7	NS
C	31	52	59	94	10	***

Courgettes

Analyte	Boiled	Steamed	Micro- waved	Baked	RSD	Sign.
H ₂ O	100	102	83	95	4	***
K	77	88	106	94	10	**
Fe	98	87	103	87	15	NS
Mg	74	81	112	85	15	NS
Ca	95	82	77	82	20	NS
B ₁	102	87	118	94	42	NS
B ₂	115	104	136	112	35	NS
B ₆	88	93	112	100	19	NS
Folate	75	102	93	76	11	**
C	76	47	49	24	15	**
Biotin	97					NS

French Beans

Analyte	Boiled	Pressure	Steamed	Micro-waved	RSD	Sign
H ₂ O	104	102	191	96	5	NS
K	80	56	102	73	9	***
Fe	115	80	99	81	13	**
Mg	85	67	99	90	8	***
Ca	82	62	91	65	10	**
B ₁	118	48	78	66	20	**
B ₂	78	73	91	83	10	NS
Folate	73	78	83	78	6	NS
C	65	46	85	42	9	***

Sweetcorn

Analyte	Boiled	Micro-waved	RSD	Sign.
H ₂ O	104	106	4	NS
Na	1230	23	469	*
K	81	114	6	*
Fe	86	93	12	*
Mg	82	94	8	NS
Ca	160	121	28	NS
B ₁	61	97	8	***
B ₂	85	101	3	***
B ₆	84	125	28	NS
Folate	71	80	11	NS
C	67	81	17	NS

Chinese Vegetable Stir-fry Mix

Analyte	Sunflower 10min	Olive oil 10min	Olive oil 15min	Walnut 10min	RSD	Sign.
H ₂ O	80	80	68	81	6	***
Fat	3270	3103	4200	4330	726	*
Na	140	53	49	82	6	***
K	86	114	118	93	8	***
Fe	80	77	90	95	14	NS
Mg	107	108	106	110	10	NS
Ca	143	95	94	115	14	***
B ₁	194	124	110	111	90	NS
B ₂	69	192	209	84	47	***
B ₆	46	167	142	97	40	**
Folate	28	37	30	37	3	**
C	55	102	65	55	22	*

Chilled Vegetable Mix

Analyte	Stir-fried	Baked	RSD	Sign.
H ₂ O	66	95	3	***
Na	1524	1540	562	NS
K	86	117	19	*
Fe	31	25	9	NS
Mg	83	79	8	NS
Ca	61	132	22	***
B ₁	50	28	14	NS
B ₂	104	49	21	**
B ₅	70	81	7	NS
B ₆	87	76	17	NS
Folate	79	84	8	NS
C	54	26	6	***
Biotin	78	86	8	NS

Appendix II Raw Mean Data

Frozen Peas

Minerals mg/100g

Cooking method	Dietary Fibre g/100g Mean	Na		K		Fe		Mg		Ca		H ₂ O g/100g SD		MeanSDMeanSD
		SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Uncooked	5.00	0.26	5.50	0.77	219	19.8	1.53	0.19	27.5	0.53			36.02.7478.00.55	
Boiled 5min	5.89	0.30	66.5	6.04	171	2.35	1.95	0.11	31.6	5.29			37.74.8977.71.33	
Boiled 10min	5.73	0.89	69.5	3.23	165	9.27	1.73	0.15	24.3	1.82			35.02.2477.30.99	
Micro- waved 5min	5.15	0.17	10.4	4.09	196	19.9	1.63	0.11	29.1	0.41			37.33.8378.00.68	
Micro- waved 10min	5.53	1.02	12.6	6.20	230	30.0	1.78	0.42	32.4	0.66			44.26.8274.62.19	

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Biotin µg/100g		Folate µg/100g		B ₅ mg/kg		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	1.64	0.08	0.95	0.01	0.53	0.04	2.63	0.75	87.8	7.29	1.300.0820.91.66			
Boiled 5min	1.48	0.22	0.82	0.07	0.50	0.03	2.48	0.77	95.1	24.4	1.550.0615.11.10			
Boiled 10min	1.49	0.13	0.82	0.04	0.54	0.04	1.46	0.25	76.3	6.84	1.520.0415.60.82			
Micro-waved 5min	2.10	0.37	1.04	0.05	0.59	0.10	2.72	1.39	114	17.6	1.800.3316.31.29			
Micro-waved 10min	2.29	0.24	1.22	0.05	0.74	0.10	3.74	1.76	113	19.3	2.060.0918.22.07			

Spring Greens

Minerals mg/100g

Cooking Method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	4.48	0.66	430	34.2	1.12	0.35	22.9	2.97	276	15.6	90.6	0.74
Boiled	92.4	32.2	377	64.1	1.65	0.27	16.0	0.91	352	63.9	87.6	0.80
PressureCook	10.5	6.26	357	39.3	1.40	0.42	13.8	1.24	214	64.4	90.9	0.53
Steamed	12.4	4.32	311	31.9	1.42	0.38	23.5	2.47	286	66.9	88.3	1.02
Microwaved	11.8	6.46	442	64.2	1.44	0.19	22.7	2.68	341	34.6	88.5	1.18

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		α-Car mg/kg		β-Car mg/kg		Folate µg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.67	0.16	1.11	0.17	1.10	0.10	5.21	0.57	11.3	0.51	126	13.2	59.9	11.7
Boiled	0.22	0.05	0.93	0.11	0.99	0.07	5.04	1.13	9.82	1.57	29.3	17.7	49.0	5.27
Pressure Cook	0.31	0.04	0.81	0.22	0.78	0.04	5.03	0.76	12.5	2.33	61.9	1.41	38.3	6.17
Steamed	0.30	0.06	0.93	0.17	0.98	0.07	4.77	0.35	9.30	2.48	124	12.9	47.2	3.16
Micro-waved	0.53	0.13	1.16	0.10	0.96	0.06	4.62	0.58	12.1	3.30	121	10.3	29.0	8.64

Dutch White Cabbage

Minerals mg/100g

Cooking method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	19.1	3.42	256	16.8	0.92	0.10	9.97	1.60	93.6	9.68	90.1	0.54
Boiled	104	34.7	128	14.2	0.93	0.28	9.34	0.92	96.7	6.69	92.7	0.94
Stir-fried	17.2	5.32	322	32.5	0.95	0.18	7.59	1.29	80.6	14.8	82.1	1.15

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Vit E mg/kg		Folate µg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.53	0.04	0.21	0.01	0.58	0.08	*	*	31.0	6.05	38.6	11.1
Boiled	0.24	0.06	0.10	0.02	0.33	0.14	*	*	21.1	8.97	24.5	4.21
Stir-fried	0.58	0.11	0.28	0.02	1.00	0.10	43.8	9.37	17.5	1.57	41.3	2.73

Savoy Cabbage

Minerals mg/100g

Cooking method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	21.3	4.67	812	52.6	1.78	0.29	34.2	6.04	131	15.5	86.0	1.30
Boiled	250	40.1	392	52.6	1.38	0.75	24.0	1.13	125	36.3	90.5	1.03
10min+S												
Boiled	401	80.7	315	65.1	1.58	0.71	22.4	2.77	126	25.9	90.1	0.62
30min+S												
Boiled	21.1	1.27	368	38.7	2.10	0.18	24.9	2.09	124	28.2	91.4	0.41
10min												
Boil 10min	150	56.4	228	95.3	1.51	0.75	18.2	5.65	127	22.0	90.2	0.77
+S+XS H ₂ O												
Boil 10min	118	13.5	169	34.9	0.81	0.04	11.8	1.08	104	10.4	91.3	0.72
+S+presoak												
Steamed	27.7	7.07	982	139	2.78	0.52	49.4	5.93	199	47.0	83.3	1.19
20min												
Steamed	21.6	5.32	776	66.0	1.91	0.37	37.4	7.84	132	29.0	86.4	1.21
30min												
Pressure	13.1	5.57	429	18.5	1.10	0.11	24.2	2.94	79.5	18.2	86.2	0.92
Cook 4min												
Pressure	15.6	6.29	394	49.0	1.61	0.63	34.9	9.93	119	35.0	86.7	0.60
Cook 8min												
Micro-waved	21.0	3.42	716	42.8	1.62	0.31	32.1	7.10	156	26.6	87.7	0.77

Savoy Cabbage

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Biotin µg/100g		Folate µg/100g		AA mg/100g		Total Vitamin C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.60	0.03	0.5700	0.03	0.42	0.13	0.11	0.15	900	234	5.60	1.86	8.88	2.02
Boiled	0.31	0.02	0.25	0.06	0.27	0.07	0.04	0.00	24.0	4.08	1.48	1.33	4.5	1.43
10min+S														
Boiled	0.29	0.02	0.22	0.05	0.33	0.08	0.05	0.03	16.0	0.92	2.17	0.78	4.48	1.85
30min+S														
Boiled	0.31	0.02	0.24	0.05	0.28	0.05	0.07	0.03	16.1	1.13	5.03	0.90	5.99	0.91
10min														
Boil 10min	*	*	0.46	0.10	0.33	0.13	0.07	0.04	16.3	1.71	3.21	0.69	3.73	0.85
+S+XS H ₂ O														
Boil 10min	*	*	0.38	0.10	0.27	0.02	0.04	0.01	29.7	9.75	4.62	0.47	8.46	3.23
+S+presoak														
Steamed	*	*	1.22	0.09	0.49	0.05	4.03	5.61	132	26.4	11.5	2.10	19.0	2.05
20min														
Steamed	*	*	0.97	0.20	0.53	0.35	0.03	0.03	19.0	6.89	10.8	3.74	13.0	3.59
30min														
Pressure	*	*	0.88	0.07	0.54	0.10	4.03	5.62	39.0	5.41	9.28	3.91	12.4	2.59
Cook 4min														
Pressure	*	*	0.97	0.10	0.44	0.18	0.14	0.07	29.7	9.61	8.07	6.12	8.08	2.32
Cook 8min														
Micro-waved	*	8.00	0.79	0.07	0.34	0.10	0.10	0.04	25.5	1.26	6.22	1.36	7.52	2.32

AA = Ascorbic Acid.

Young Carrots

Cooking method	Fe		Na		K		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	38.1	15.8	279	60.5	0.35	0.07	0.71	0.05	17.1	3.52	89.9	0.26
Boiled	169	17.6	199	28.2	0.31	0.09	0.57	0.08	23.4	5.88	92.6	0.52
Pressure Cook	46.0	5.41	247	22.8	0.21	0.05	*	*	15.8	8.79	91.5	0.34
Steamed	49.8	4.02	318	11.0	0.27	0.13	0.75	0.00	17.4	0.36	90.1	0.40
Micro-waved	56.4	7.01	341	49.0	0.23	0.04	*	*	13.3	4.65	88.3	0.62

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Biotin μg/100g		B ₅ mg/kg		Folate μg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.24	0.03	0.25	0.03	0.42	0.20	0.10	0.03	2.42	0.16	32.9	9.00
Boiled	0.11	0.01	0.14	0.03	0.37	0.14	0.0	0.03	1.76	0.11	19.1	2.89
Pressure Cook	0.13	0.02	0.16	0.02	0.46	0.09	0.12	0.01	2.18	0.15	33.9	3.05
Steamed	0.16	0.02	0.18	0.01	0.60	0.11	0.09	0.03	2.14	0.11	27.2	4.95
Micro-waved	0.17	0.03	0.21	0.04	0.64	0.09	0.12	0.02	2.32	0.13	34.7	1.91

Vitamins

Cooking method	C mg/100g		α Car. mg/kg		β Car. mg/kg		TotalCar. mg/kg	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	4.86	0.45	15.2	3.95	30.6	5.76	47.8	11.2
Boiled	2.20	0.69	11.1	1.87	29.4	3.59	40.5	4.23
Pressure Cook	1.50	0.48	9.47	1.70	33.9	2.54	43.2	3.54
Steamed	2.94	0.35	10.9	6.15	31.5	8.73	42.4	14.7
Micro-waved	2.10	0.50	10.2	5.35	24.8	9.52	35.0	14.3

Old Carrots

Minerals mg/100g

Cooking Method	Na		K		Fe		Mg		Ca	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	38.7	13.0	276	32.6	0.37	0.06	9.74	1.50	31.4	1.84
Boiled 5min	92.3	9.5	207	22.8	0.31	0.05	6.28	0.74	26.0	4.21
Boiled 10min		98.9	8.6	207	35.2	0.38	0.03	6.50	0.97	27.5
PressureCook		47.8	12.1	243	50.2	0.32	0.07	7.17	0.72	28.0
Steamed	50.6	18.6	199	12.5	0.27	0.03	6.88	0.85	31.2	2.16
Microwaved	59.7	11.8	271	81.1	0.30	0.09	8.68	0.85	29.5	3.43

Vitamins

Cooking Method	B ₁		B ₂		B ₆		Folate		H ₂ O		B ₅		C	
	mg/kg Mean	SD	mg/kg Mean	SD	mg/kg Mean	SD	µg/100g Mean	SD	g/100g Mean	SD	mg/kg Mean	SD	mg/100g Mean	SD
Uncooked	0.44	0.02	0.31	0.09	0.68	0.02	76.0	4.61	87.9	0.78	1.92	0.26	4.58	1.31
Boiled 5min	0.36	0.20	0.25	0.04	0.55	0.14	55.9	7.15	89.9	0.65	1.84	0.22	2.88	2.23
Boiled 10min	0.39	0.06	0.26	0.02	0.56	0.13	79.0	16.8	89.4	1.06	1.65	0.16	6.43	1.85
Pressure Cook	0.32	0.08	0.29	0.04	0.59	0.11	68.7	14.7	88.7	1.17	2.26	0.40	3.33	1.04
Steamed	0.24	0.13	0.33	0.04	0.61	0.12	70.8	18.9	88.4	0.98	1.98	0.33	5.08	2.22
Micro-waved	0.17	0.07	0.37	0.08	0.61	0.15	75.3	16.5	86.8	0.81	2.62	0.52	4.36	1.22

Cauliflower

Minerals mg/100g

Cooking method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	13.9	1.74	331	51.8	0.83	0.10	21.3	2.99	14.9	1.95	92.7	0.51
Boiled	188	22.8	156	21.9	0.82	0.13	17.2	3.49	15.1	1.65	93.6	0.39
Steamed	19.2	5.54	224	15.8	0.99	0.10	21.6	3.44	14.6	2.91	92.3	0.48
PressureCook	5.73	18.0	276	60.8	0.96	0.15	20.2	4.10	13.8	3.51	91.6	0.25
Microwaved	19.4	3.18	308	27.4	1.20	0.09	28.7	1.92	16.6	1.72	90.3	0.38

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		AA mg/100g		Folate µg/100g		Total Vitamin C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.29	0.03	0.78	0.05	0.90	0.15	30.0	9.20	63.3	2.55	32.8	5.80
Boiled	0.00	0.00	0.39	0.08	0.45	0.05	7.44	3.45	48.6	5.83	9.48	2.30
Steamed	0.00	0.00	0.59	0.04	0.74	0.15	18.6	1.98	49.0	3.79	18.6	1.98
Pressure Cook	0.04	0.05	0.67	0.07	0.69	0.06	13.1	5.42	48.0	5.28	16.1	2.80
Micro-waved	0.004	0.01	0.67	0.08	0.71	0.04	32.1	4.61	55.5	1.17	32.1	4.61

AA = Ascorbic Acid.

Courgettes

Minerals mg/100g

Cooking method	K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	190	2.92	0.81	0.06	31.4	0.18	33.2	2.67	93.3	0.14
Boiled	146	12.3	0.79	0.08	23.1	2.11	31.5	6.82	93.7	0.35
Steamed	165	11.3	0.69	0.06	25.1	5.35	26.9	5.59	93.4	0.30
Microwaved	237	29.2	0.99	0.27	41.2	5.13	30.3	8.47	90.5	0.81
Baked	187	23.2	0.74	0.12	27.6	3.69	28.4	7.12	92.5	0.53

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		Biotin mg/kg		B ₆ mg/kg		Folate μg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.35	0.09	0.51	0.17	2.16	0.08	0.65	0.17	366	33.3	26.1	0.42
Boiled	0.36	0.12	0.58	0.08	2.09	0.05	0.58	0.04	274	15.9	18.4	1.58
Steamed	0.29	0.16	0.52	0.23	*	*	0.60	0.14	370	17.4	12.0	3.63
Micro-waved	0.48	0.21	0.82	0.25	*	*	0.86	0.20	401	63.5	14.9	4.74
Baked	0.35	0.06	0.61	0.16	*	*	0.68	0.10	295	71.2	6.50	5.07

French Beans

Minerals mg/100g

Cooking method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	4.80	1.45	349	24.1	0.94	0.09	25.3	0.95	65.7	5.28	85.4	0.40
Boiled	32.2	1.70	270	9.21	1.05	0.15	20.9	1.26	65.7	5.87	86.2	1.01
PressureCook	3.38	1.37	199	22.0	0.76	0.11	17.3	2.22	41.4	8.97	88.2	0.53
Steamed	4.48	1.65	351	47.7	0.91	0.12	24.7	2.14	58.9	4.97	84.9	0.81
Microwaved	6.08	2.48	269	28.9	0.81	0.08	24.0	0.96	45.6	4.88	87.2	1.02

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		AA mg/100g		Total Vitamin C mg/100g		Folate µg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.54	0.11	1.37	0.11	*	*	10.0	1.22	12.2	1.48	81.3	4.16
Boiled	0.62	0.15	1.04	0.14	0.53	0.09	5.82	1.46	7.80	1.09	57.7	3.36
Pressure Cook	0.26	0.08	1.02	0.05	0.45	0.04	2.83	0.64	5.76	0.75	64.2	3.64
Steamed	0.43	0.06	1.24	0.18	0.61	0.10	6.14	0.54	10.3	1.41	66.5	2.48
Micro-waved	0.38	0.12	1.21	0.10	0.54	0.05	2.68	0.46	5.36	0.77	67.1	3.43

AA = Ascorbic Acid.

Sweetcorn

Minerals mg/100g

Cooking method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	14.4	4.89	502	15.2	0.93	0.16	45.3	3.74	22.2	4.71	72.6	0.37
Boiled	176	94.1	404	36.5	0.79	0.11	36.4	4.76	34.8	5.88	74.7	1.32
Micro-waved	3.29	0.83	451	17.8	0.83	0.12	40.6	1.51	25.7	5.53	73.8	1.74

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Folate µg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.62	0.06	0.59	0.01	0.66	0.15	93.7	14.9	8.60	1.56
Boiled	0.38	0.03	0.50	0.02	0.55	0.12	65.5	8.97	5.69	1.45
Micro-waved	0.58	0.07	0.57	0.03	0.78	0.21	71.3	8.81	6.75	1.40

Chinese Vegetable Stir-fry Mix

Cooking method	Minerals mg/100g									
	Na		K		Fe		Mg		Ca	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	15.0	7.52	164	18.5	0.57	0.11	12.4	1.58	20.3	2.15
Sunflower Oil 10min	25.0	0.93	168	7.00	0.54	0.15	15.8	0.80	34.8	4.69
OliveOil 10min	9.54	1.09	223	17.8	0.53	0.06	16.0	1.01	23.2	3.80
OliveOil 15min	10.1	1.98	267	20.7	0.70	0.09	18.2	2.14	26.4	4.16
Walnut Oil 10min	14.3	6.54	180	29.9	0.64	0.06	16.1	1.91	27.7	2.76
									85.2	0.74
									88.9	0.31
									1.73	0.46
									2.54	0.12
									0.04	0.02

Vitamins

Cooking method	B ₁ mg/kg		B ₂ mg/kg		B ₆ mg/kg		Folate µg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.50	0.08	0.20	0.18	0.73	0.44	49.3	8.31	15.9	12.1
Sunflower Oil 10min	1.17	1.11	0.17	0.09	0.41	0.03	16.6	1.15	10.5	2.12
OliveOil 10min	0.74	0.05	0.47	0.08	1.46	0.18	21.9	1.71	19.5	6.80
OliveOil 15min	0.76	0.11	0.60	0.13	1.48	0.15	20.4	1.73	14.1	2.08
Walnut Oil 10min	0.65	0.13	0.21	0.20	0.85	0.69	21.9	3.01	10.2	3.77

Chilled Vegetable Mix

Minerals mg/100g

Cooking Method	Na		K		Fe		Mg		Ca		H ₂ O g/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	25.4	5.3	233	39.6	0.26	0.06	22.2	1.85	31.7	5.97	92.6	0.38
Stir-fried	15.2	6.4	260	45.4	0.31	0.08	23.8	1.30	25.1	7.22	79.7	2.90
Baked	15.4	4.8	291	53.2	0.25	0.09	18.8	2.21	44.7	9.09	93.2	0.34

Vitamins

Cooking Method	B ₁ mg/kg		B ₂ mg/kg		B ₅ mg/kg		B ₆ mg/kg		Biotin mg/kg		Folate µg/100g		C mg/100g	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Uncooked	0.24	0.10	1.14	0.37	1.16	0.11	0.80	0.15	0.18	0.01	27.8	0.74	6.00	0.69
Stir-fried	0.16	0.05	1.54	0.42	1.18	0.16	0.91	0.11	0.18	0.02	25.3	1.05	4.26	0.46
Baked	0.07	0.04	0.60	0.16	1.06	0.11	0.65	0.16	0.16	0.01	24.1	3.78	1.68	0.31