THE DISTRIBUTION OF VITAMIN C IN FOODS SOLD ON THE OPEN MARKET

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(With 6 Figures in the Text)

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Introduction

As early as the thirteenth century cases of scurvy were recorded amongst Crusaders. Although scurvy was thought to be peculiarly a disease of seafaring men, it was, for centuries, of common occurrence amongst civil populations in northern Europe (Harris, 1938).

As early as 1639 "the excellence of juyce of lemmons" as a cure for scurvy was remarked on in a work on military and domestic surgery published by John Woodall. The incidence of scurvy became much diminished after the discovery by Kramer, in 1720, that "three or four ounces of orange or lime juice will cure this dreadful disease without other help".

Despite advances in the diagnosis, prevention and treatment of scurvy, and instructions through the popular press and other media as to protective dietaries, there are still persons who suffer from a lack of ascorbic acid. In 1937 cases were reported in Copenhagen by Lazarus, and in 1939 four were reported by Kark & Lozner in Boston City Hospital. In 1937 also seven cases in adults were reported in Manchuria by Kobayashi & Doi. It has been recognized that dyspeptic people who adhere for long periods to special diets may suffer from vitamin deficiency. Cases of this kind have been described by Archer & Graham (1936), Platt (1936), Hawksley (1939), and others. Bruce Young (1938)

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described a case of scurvy which was admitted to the National Temperance Hospital in August 1934. He states that "poverty is another common cause of faulty diets but ignorance of food values may cause even the well-to-do to suffer from vitamin deficiency".

Practically all recent cases of vitamin C deficiency have occurred amongst men and women living alone and catering for themselves at a low cost. The deficiency in such cases may be due either to an improper dietary or to a low content of vitamin C in the foods purchased. It has been demonstrated by many workers (Olliver, 1940; Paech, 1938; Thornton, 1938; and others) that the antiscorbutic vitamin is rapidly destroyed when foods containing it are stored, particularly when they are in contact with air. These observations suggested that foods exposed for sale in poor districts might be more stale than those sold in expensive stores, and therefore that the vitamin C content of these cheaper foods might be insufficient to maintain health on an average consumption, especially as persons living on a minimal food supply tend to eat but little fresh fruit and raw vegetables. E. F. Armstrong went so far as to tell the Society of Chemical Industry at its Pittsburg meeting in 1936 that "green vegetables exposed for sale in the East End of London three or four days after picking are found to be almost completely devoid of vitamin". In view of the experimental results described in this paper this statement is too sweeping.

Scope of the work undertaken

This work was undertaken to discover whether foods sold in street markets and cheap stores in England actually have sufficient vitamin C in them, when purchased, to furnish the daily requirement of 19–27 mg. of vitamin C for an adult of 60 kg. (Gothlin) when average quantities of them are consumed.

Methods

The least expensive foods were purchased at street markets in the poorest quarter of London and at cheap shops in country districts, and were examined on the day of purchase, as soon after buying as possible. During the period intervening between purchase and examination, the material was kept in normal larder conditions of temperature and humidity.

The chemical method of estimation of ascorbic acid devised by Tillmans and later modified by Birch, Harris & Ray (1933) was used for all determinations.

A representative sample of the raw food to be examined was ground with sand and extracted several times with sufficient 20 % trichloracetic acid to give a final concentration of 5 %. The filtered extract was run from a microburette into a 0·08 % solution of 2 : 6-dichlorophenolindophenol, stabilized with a phosphate buffer. The dye was standardized daily against ascorbic acid, which was titrated against iodine to check its purity.

After some of the work had been done the following modifications (L. J. Harris, personal communication) were adopted:

A 20% solution of trichloracetic acid was mixed with a 20% solution of metaphosphoric acid and used for extraction. The quantities of each solution taken were adjusted to give a concentration of 5% trichloracetic acid and 2% metaphosphoric acid in the final extract. The food sample was ground with 5–10 g. of sand and approximately one-fifth of the total acid to be used. Grinding was completed after the addition of half of the remaining acid. The mixture was rapidly filtered through fine muslin, extraction being aided by pressure with a glass rod. The residue was then returned to the mortar and extraction repeated with the remaining acid. The residue was next washed with recently boiled, copper-free, cold, distilled water, and the solution made up to the required volume. This solution was filtered through a no. 1 Whatman filter paper and titrated within 10 min. of the preliminary grinding with sand. Not more than 20 g. of material were used for an estimation, as complete extraction is difficult when the concentration of the material is high, and some oxidation of ascorbic acid may occur during the longer time required for grinding a larger sample. In cases of a low ascorbic acid content in tissues, the strength of the indicator was adjusted. As an alternative, a back titration was made. If more than 2 c.c. of food solution were required to decolorize the dye the titrations were completed with orange juice (made up in trichloracetic acid to 20%) from a third burette. The vitamin value of the juice was determined by separate titration, and the amount of ascorbic acid in the sample of food was estimated from the resultant titrations.

For deeply coloured extracts, a rough estimate of the vitamin C content of the material was obtained by direct titration and the use of a control tube. After this preliminary determination, an accurate estimate was made, using a modification of the method of McHenry & Graham. Two ml. of a freshly prepared filtered extract of the material were placed in a long-pointed centrifuge tube with 2 ml. of chloroform. The 2 : 6-dichlorophenolindophenol was introduced at once into the upper extract layer which was agitated by a constant stream of oxygen-free carbon dioxide. The 0·08% indicator was added to within 0·02–0·05 ml. of the necessary volume (calculated approximately from the direct titration). The two layers were then mixed by introducing the inlet tube of the CO_2 into the lower layer. The indicator was added until the chloroform layer developed a definite pink colour after mixing with the aqueous layer. If the indicator is allowed to come into direct contact with the chloroform, a pink colour, not discharged by ascorbic acid, may develop, and it is therefore essential that the indicator and extract be well mixed before the chloroform and extract layers are allowed to mix.

Since all vitamin C in growing plants is in the reduced form, the omission of H_2S treatment was considered permissible.

In the case of liver, which contains proteins, these substances were precipitated by mercuric acetate before testing for vitamin C.

THE RESULTS OF EXAMINATIONS OF CHEAP FOODS

The results given in Table 1 are those for the cheapest foods obtained.

All reputed biological values were taken from the results of Harris & Ray (1933) except (*a*) from Eddy *et al.* (1926 *b*) and Bracewell *et al.* (1930); (*b*) from Hahn & Scheunert (1932); (*c*) from Bukin & Povolotzkaya (1935); (*d*) from Kohman *et al.* (1925); (*e*) from Kohman *et al.* (1928); and (*f*) from Campbell & Chick (1919).

All fruit juices were tested at their natural *p*H value from several varieties of each fruit.

It may be that the results found for banana are lower than those which actually obtain in that fruit, since Thornton (1938) states that enzymes present in banana tissue will cause a 50% reduction in the ascorbic acid present in a

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Table 1. *Ascorbic acid content of fruits and vegetables sold at cheap markets (raw)*

Fruit or vegetable	Range of values Mg. C per 100 g. solid. Mg. C per 100 ml. juices	Mean value	Biological protective dose, g. Calculated from mean value (1 mg. basis) to second significant figure	Biological protective dose, g. Reputed value
Cox's Orange Pippin apple (peel)	10·0	10·0	10·0	3–20 (*a*)
Cox's Orange Pippin apple (cortex)	1·4	1·4	71·0	—
Bramley's Seedling (peel)	37·0–80·3	58·6	1·7	1
Bramley's Seedling (cortex)	7·3–10·0	8·65	12·0	3·5
Jonathan apple	Trace	—	—	—
Jerusalem artichoke	5·2–5·8	5·5	18·0	—
Apricot (S. African)	5·8–6·1	5·95	17·0	—
Banana (under-ripe)	6·4	6·4	16·0	5–10
Banana (ripe)	11·3–11·7	11·5	8·7	5–10
French bean	4·8–9·1	6·95	14·4	5 (runner bean) (*f*)
Brussels sprouts	33·6–89·2	61·4	1·6	2·0 (*b*)
Black currant	120·0–205·7	162·8	0·61	0·25–0·50 (*c*)
Cabbage (green)	114·2–115·0	114·6	0·87	1·0
Cauliflower (flower)	35·6	35·6	2·8	—
Cauliflower (leaf)	18·5	18·5	5·4	—
Carrot (old)	2·1–2·8	2·45	41	10–35
Celery (stem)	5·4–8·8	7·1	14·0	—
Date	1·8	1·8	56	—
Grapes (red and white, South American and Californian)	0·18–0·22	0·20	500	20, 40
Gooseberry	36·3	36·3	2·8	7 (yellow) (*b*)
Grapefruit juice	26·8–31·0	28·9	3·5	1·5–2·0
Curly kale	34·8–50·6	42·7	2·3	—
Seakale	33·8–34·1	34	2·9	—
Leek	15·9–19·2	17·6	5·7	—
Lemon juice	27·2–44·0	35·6	2·9	1·5
Liver (chilled sheep's)	20·7	20·7	4·8	—
Mint leaves	34·8	34·8	2·9	—
Lettuce	4·9–5·0	4·95	20·0	—
Mushrooms	3·5–3·6	3·55	28	—
Onion	9·3–9·6	9·45	11·0	—
Orange juice	26·8–83·5	60·15	1·7	1·5–3
Tangerine orange juice	24·2	24·2	4·1	—
Green pea	4·97–15·9	10·44	9·6	2 (*d*)
Parsley	138·0–251·0	194·5	0·51	—
Pear (peel)	1·8	1·8	56·0	20–25 (*b*)
Pear (cortex)	0·83	0·83	120·0	—
Parsnip	4·7–5·0	4·85	20·6	—
Potato (old)	3·1–3·6	3·35	30·0	—
Potato (new)	11·6–12·2	11·9	8·4	6–10
Peach (South African)	3·1–4·0	3·55	28·2	—
Plum (Victoria)	0·55–0·97	0·76	132·0	20 (*b*)
Prune	4·1	4·1	24·0	—
Radish	21·1	21·1	4·7	—
Rhubarb	10·2–10·7	10·5	9·5	12
Raspberry	30·3–31·7	31·0	3·2	5 (*b*)
Strawberry	31·8–38·2	35·0	3·0	1·5–3 (*e*)
Spring greens	49·1–94·5	71·8	1·4	1·0 (cabbage)
Tomato	14·4–37·6	26·0	3·8	—
Tomato juice	12·3–20·7	16·5	6·1	3·5
Swede (old)	21·2–29·3	25·3	4·0	—
Savoy cabbage	48·9–50·2	49·6	2	1
Turnip (old)	14·0–20·8	17·4	5·7	6 (*b*)
Watercress	68·3	68·3	1·5	1·0

period of 1 min. if 8 % CCl_3COOH and 2 % HPO_3 are used in extraction. He suggests that only acids as strong as 1, 2 or 3*N* H_2SO_4 or 0·25*N* HPO_3 will inactivate the enzyme.

The results given in Table 1 are unexpectedly high in view of Armstrong's assertion and the high figures given by M. Olliver (1936) for the percentage loss of vitamin C in stored green vegetables. The results obtained from foods bought at inexpensive markets indicate that the poorer classes need suffer no vitamin C deficiency.

It must be admitted that in a few instances the amount of ascorbic acid contained in the food examined was less than the present accepted minimum, taking the tables compiled by Boas Fixsen & Roscoe (1938–40), and by Daniel & Munsell (1937) as a basis for comparison.

Brussels sprouts were found to contain as little as 33·6 mg. vitamin C per 100 g. leaf on the day of purchase. Previous records gave figures from 70 mg. upwards. This low result may well be due to the destruction of the vitamin while the food was exposed for sale. Similarly, cauliflower leaf was found to have 18·5 mg. vitamin C per 100 g., and Boas Fixsen *et al.* (1938–40) give 113 mg. vitamin C per 100 g. Old parsnip roots gave a result as low as 4·7 mg. ascorbic acid per 100 g., but as this was only 0·3 mg.% lower than the previous minimum figure it is of no importance and would make a very insignificant alteration in the biological protective dose.

Strawberries from cheap markets contained from 31·8 mg. vitamin C per 100 g., and the figures usually accepted are from 46 mg. C per 100 g. This result may be accounted for either by a long period of exposure for sale, during which time the vitamin is slowly oxidized, or by the natural decline in the ascorbic acid content of fully matured soft berries. Turnip roots gave values of 14·0, 15·5 and 16·9 mg. vitamin C per 100 g., as well as higher ones of approximately 20 mg. ascorbic acid. The lower figures were obtained from large old roots, and it may be that the natural vitamin content of the old vegetable is frequently lower than the 17 mg. given by Rudra (1936).

It will be seen, therefore, that these results do not warrant alarm as to the sufficiency of the antiscorbutic factor in cheap foods, and some of them contained very large amounts of vitamin C, notably parsley with 251 mg. per 100 g., black currant with 205·7 mg. per 100 g., and cabbage with 115 mg. per 100 g.

Attention is called to the figures for peas and tomatoes, both of which are within the limiting values previously set down for these foods, because of the view put forward by Kohman & Sanborn (1937) that the estimation of vitamin C by the dye method is complicated for these two vegetables by the presence of other reducing bodies. If this view is correct the true vitamin content will be lower than the figures obtained, but throughout this work all samples of peas and tomatoes were examined in an identical manner, so that for purposes of comparison the results may be considered satisfactory.

The higher vitamin content of ripe bananas as opposed to that of under-ripe fruit is in keeping with results obtained by Leverton (1937), although the reverse appears to be true of tomatoes. The soft, over-ripe tomatoes had a lower ascorbic acid content than the firm, ripe ones, values ranging from 11·93, 14·4, 15·5 and 20·19 mg. C per 100 g. for very ripe, and 22·46 to 37·6 mg. for firm examples. Average results for 100 ml. of expressed juice gave 15·5 and 20·7 mg. vitamin C respectively. Tripp, Satterfield & Holmes (1937) record similar observations, though Maclinn, Fellers & Buck (1937) found no correlation between the degree of ripeness and vitamin C content. As there was no information as to whether the tomatoes tested had been picked before or at the time of full maturity, it may be that the over-ripe fruit was picked when firm and suffered a subsequent decline in vitamin content by exposure for sale.

The results of examinations of expensive foods

It was considered of interest to examine foods exposed for sale at fashionable, expensive markets, in order to ascertain whether their content of vitamin C is notably higher than that of cheap vegetables. Representative samples were purchased and examined as before, as soon after purchase as possible. When foods were kept any period of time before use they were stored in normal larder conditions. For purposes of comparison, the most expensive foods were chosen.

Table 2 gives the ascorbic acid content of raw foods from expensive markets.

It is interesting to note that the mean value for the vitamin C content of swedes was as high as 33·6 mg. per 100 g. on the expensive market. The highest experimental value obtained was 36·9 mg. 3 per 100 g., which is as high as that of some samples of orange juice. As far as can be discovered, no earlier estimation of the vitamin C content of the swede has been made. Hopkins used swede juice in his classical experiments on accessory factors in diet, but that was before the vitamins had been differentiated and, in any case, rats do not need vitamin C.

It has been suggested that the production of vitamin C is associated with the presence of plant pigments and this may be an illustration of that point. If the yellow pigment in swedes is carotene, it may be that its reducing properties prevent the oxidation of ascorbic acid (Garrett *et al.* 1938) and preserve a high content of the vitamin even in an old vegetable.

In Table 2 there are some foods which contained less ascorbic acid than is normally found, for example, brussels sprouts contained from 62·5 mg. C per 100 g., the reputed value being from 70 mg. C per 100 g.; cauliflower leaves from 35·0 mg. C per 100 g., the reputed value being from 113 mg. C per 100 g.; endive from 5·7 mg. C per 100 g., the reputed value being from 19·0 mg. per 100 g.; parsley from 63 mg. C per 100 g., the reputed value being from 140 mg. C per 100 g.; strawberry from 42 mg. C per 100 g., the reputed value being from 46 mg. per 100 g., and turnip from 10·8 mg. C per 100 g., the reputed value being from 17 mg. per 100 g.

Table 2. *The ascorbic acid content of foods from expensive markets. All juices tested at their natural p*H *values*

Fruit or vegetable	Range of values Mg. C per 100 g. solid. Mg. C per 100 ml. juice	Mean value	Biological protective dose, g. Calculated from mean value (1 mg. basis) to second significant figure	Biological protective dose, g. Reputed value
Cox's Orange Pippin apple (peel)	9·6–11·5	10·5	9·4	—
Cox's Orange Pippin apple (cortex)	1·8–3·8	2·8	36·0	3–20 (*a*)
Bramley's Seedling (peel)	72·0	72·0	1·4	1
Bramley's Seedling (cortex)	11·5	11·5	8·7	3·5
Jonathan apple	Trace	—	—	—
Worcester Pearmain (peel)	0·13	0·13	769·0	—
Worcester Pearmain (cortex)	4·98	4·98	20·0	20 (*g*)
Jerusalem artichoke	4·2–5·3	4·8	21·0	—
Apricot (South African)	1·7–2·6	2·2	45·5	—
Banana (under-ripe)	8·7	8·7	11·5	5–10
Banana (ripe)	11·7–12·1	11·9	8·0	5–10
French bean	4·1–5·2	4·7	21·0	5 (runner bean) (*f*)
Beetroot	9·5–10·7	10·1	10	—
Brussels sprouts	62·5–75·8	69·2	1·5	2 (*b*)
Black currant	160·0–185·8	172·9	0·6	0·25–0·5 (*c*)
Cabbage (green)	32·4–37·2	34·8	2·9	1
Cauliflower (flower)	73·2	73·2	1·4	—
Cauliflower (leaf)	35·1	35·1	2·8	—
Carrot	5·1–5·2	5·15	19·0	10–35
Celery (stem)	5·3–5·5	5·4	18·5	—
Date	0·97	0·97	103·0	—
Grapes (red and white, South American and Californian)	0·20–0·83	0·52	192·0	20, 40
Grapefruit juice	34·2–36·5	35·4	2·8	1·5–2·0
Gooseberry	26·6–29·8	28·2	3·5	7 (yellow) (*b*)
Curly kale	27·8–102·8	65·3	1·5	—
Seakale	35·5–36·3	35·9	3·0	—
Endive	5·7–20·7	13·2	7·6	—
Leek	18·5–23·6	21·1	4·7	—
Lemon juice	34·1–69·4	51·8	2·0	1·5
Liver (ox)	49·9	49·9	2·0	1·3
Lettuce	1·2–15·7	8·5	12·0	—
Mint leaves	3·7	3·7	27·0	—
Mushroom	2·3–6·0	4·2	24·0	—
Onion	11·8–12·9	12·4	8·0	—
Orange juice	53·3–87·5	70·4	1·4	1·5–3·0
Tangerine orange juice	12·3	12·3	8·1	—
Green pea	9·5–18·3	13·9	7·2	2·0 (*d*)
Parsley	63–152	107·5	0·93	—
Pear (peel)	2·7	2·7	37·0	—
Pear (cortex)	1·2	1·2	83·0	20–25 (*b*)
Parsnip	4·7–5·9	5·3	2·0	—
Potato (old)	2·2–3·0	2·6	38·0	—
Potato (new)	10–12·8	11·4	9	6–10
Peach	3·1–4·0	3·6	28·0	—
Plum (Victoria)	0·375–0·378	0·4	250·0	20 (*b*)
Prune	7·7	7·7	13·0	—
Radish	13·6	13·6	7·0	—
Rhubarb	8·5–9·3	8·9	11·0	12
Raspberry	28·8	28·8	3·5	5 (*b*)
Strawberry	41·7–41·8	41·8	2·0	1·5–3·0 (*e*)
Spring greens	55·1–75·1	65·1	1·5	1·0 (cabbage)
Tomato	11·9–16·6	14·3	7·0	—
Tomato juice	15·5–15·7	15·6	6·4	3–5
Swede	30·3–36·9	33·6	3·0	—
Savoy cabbage	41·6–43·8	42·7	2·3	1
Turnip	10·8–22·1	16·5	6·0	—
Turnip greens	96·8–98·9	97·9	1·0	—
Watercress	71·8	71·8	1·0	1

All biological protective doses in column 4 as for Table 1, with the addition of (*g*) "Vitamins" M.R.C. 1932.

In mint leaves a value of 3·7 mg. per 100 g. was found. It should be mentioned, however, that though Levy & Fox (1935) found as much as 63 mg. ascorbic acid per 100 g. in the leaves, Ahmad (1935) found none. There may, however, be wide differences in the values of different varieties of mint, so that the 3·7 mg. actually found may be a satisfactory result for the variety examined.

Despite the fact that expensive foods might be expected to give higher results than very cheap ones, it will be seen that the results in Table 2 differ very little from those in Table 1. The differences between poor and expensive markets were very small and consequently the presence of scurvy amongst the poorer classes cannot be attributed to a lack of vitamin C in the food due to prolonged exposure.

Probably, however, the main source of vitamin C in the diet of the working class is the potato. As recently as 1917 sporadic outbreaks of scurvy occurred at Glasgow and other Scottish towns, Newcastle and Manchester, due to a shortage of potatoes. These outbreaks suggest that new potatoes should be eaten early in the season as their ascorbic acid content is higher than that of old potatoes, and also that it is important that as much vitamin as possible should be preserved during the storage of old potatoes. Mathiesen (1939) records that potatoes which gave vitamin C values from 0·2 to 0·33 mg. per g., when newly harvested in September, were stored at an average temperature of 12° C. in a cellar. Periodic estimations showed a fall in all varieties. By January, values were 0·09–0·11 mg. per g., and by April, about 0·06 mg. per g. When potatoes were stored in the usual way, the value did not fall below 0·05 mg. per g., even by the end of June. It is interesting to compare these results with those obtained for potatoes used in those experiments.

The values found for potatoes from both cheap and expensive markets were 0·022–0·036 mg. per g., which is a very low content for a food which is an important source of vitamin C. These figures were obtained from different varieties of potatoes examined from January to April. For comparison, garden grown Red Skin potatoes were dug in September and stored until the following January in a cool outhouse. They were found to contain 0·061–0·077 mg. C per g. at that date. These figures indicate that home storage may preserve more ascorbic acid than the commercial storage employed, of which the times and temperatures were unknown. Home-grown, home-stored potatoes are therefore advocated.

In work of this kind, where foods are purchased at random on the open market, there is necessarily a wide variation in results from every batch tested, because retailers mix stocks from various wholesalers. One set of results cannot be held to be representative of the quality of food from one store. The sum total of all results can merely give a ratio which may, or may not, demonstrate a regular difference between cheap and expensive samples.

By comparing the mean value of all results obtained for each food in each market, certain conclusions can be drawn. Table 3 brings out the fact that there

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is little difference between results obtained in the two series. In column 3 of this table the percentage relation between the series is set out.

Table 3. *Mean values of foods analysed from cheap and expensive markets and their percentage relationship (mg. vitamin per* 100 *g. or per* 100 *ml.)*

Fruit or vegetable	Mean value, cheap market	Mean value, expensive market	Results from cheap market expressed as % of those from expensive market
Cox's Orange Pippin apple (peel)	10·0	10·5	95·2
Cox's Orange Pippin apple (cortex)	1·4	2·8	50
Bramley (peel)	58·6	72·0	81·4
Bramley (cortex)	8·65	11·5	75·2
Apricot	5·95	2·2	270·5
Banana (under-ripe)	6·4	8·7	73·6
Banana (ripe)	11·5	11·9	96·6
Black currant	162·8	172·9	94·2
Gooseberry	36·3	28·2	128·7
Grape	0·20	0·52	38·5
Grapefruit juice	28·9	35·4	81·6
Lemon juice	35·6	51·8	68·7
Orange juice	60·2	70·4	85·4
Tangerine juice	24·2	12·3	196·7
Pear (peel)	1·8	2·7	66·7
Pear (cortex)	0·83	1·2	69·2
Peach	3·55	3·6	98·6
Plum (Victoria)	0·76	0·4	190·0
Raspberry	31·0	28·8	107·6
Strawberry	35·0	41·8	83·7
Date	1·8	0·97	185·6
Prune	4·1	7·7	53·2
Artichoke	5·5	4·75	105·3
French bean	6·95	4·7	147·9
Brussels sprouts	61·4	69·2	88·7
Cabbage	114·6	34·8	329·3
Cauliflower	35·6	73·2	48·6
Cauliflower (leaf)	18·5	35·1	52·7
Carrot	2·5	5·15	47·6
Celery (stem)	7·1	5·4	131·5
Seakale	34·0	35·9	94·7
Curly kale	42·7	65·3	65·4
Leek	17·6	21·1	83·4
Lettuce	4·95	8·5	58·2
Mint leaves	34·8	3·7	94·1
Mushroom	3·6	4·2	84·5
Onion	9·5	12·4	76·2
Green pea	10·44	13·9	75·1
Parsley	194·5	107·5	180·9
Parsnip (old)	4·85	5·3	91·5
Potato (old)	3·35	3·84	114·6
Potato (new)	11·9	11·4	104·3
Radish	21·1	13·6	155·1
Rhubarb	10·5	8·9	117·9
Spring greens	71·8	65·1	110·3
Tomato	26·0	14·3	181·8
Tomato juice	16·5	15·6	105·8
Swede	25·3	33·6	75·29
Savoy cabbage	49·6	42·7	116·2
Turnip (old)	17·4	16·5	105·5
Watercress	68·3	71·8	95·1

An analysis of the results in Table 3 shows that about 75 % of fruits purchased in cheap markets contained less ascorbic acid than similar fruits purchased at the same time in expensive markets, the average difference in value being 22·77 %.

51·73 % of cheap vegetables had less vitamin than their expensive counterparts, with an average difference of 24·59 %.

50 % dried fruits had less and 50 % had more vitamin than the product from the expensive market.

Of the cheap fruits 25 % had more vitamin than those from the expensive market, the average difference being 78·7 %. Of the vegetables 48·27 % had more vitamin than those from the expensive market, the average difference in this being 43·31 %.

It seems therefore that expensive fruits and vegetables contain a greater amount of vitamin C than very inexpensive ones, though the latter contain sufficient amounts of ascorbic acid to maintain health when a well-balanced average dietary is taken.

If, for purposes of comparison, the figure given in Table 3 for the ascorbic acid content of each expensive fruit or vegetable is taken as 100 %, it will be seen that 7/10ths of the cheap fruits contain 75 % or over and another 2·5/10ths contain 50 % or over. In the case of vegetables, the corresponding figures show that 8/10ths contain over 75 % and 1/10th over 50 %. In both categories, 9/10ths of the cheap material examined had more than half the vitamin content of its expensive counterpart, and these figures refute statements to the effect that vegetables sold in the East End of London contain no vitamin.

It was noted that green vegetables purchased from stalls in slum streets had a good vitamin content. This was almost invariably greater than that of foods from small shops and, occasionally, greater than that of foods from fashionable stores. A plausible explanation is that stalls have to be sold out almost each night, whereas large stores and small shops can keep their stocks for long periods and expose them for sale each day. The market stall usually has a ready sale, necessitating frequent replacements with fresh vegetables, and from the results obtained it seems that exposure on the stall does not cause a serious depletion of the vitamin C content.

Comparison of garden and market produce

As any food, sold in large or small shops or on stalls, may stand about for some time before purchase, neither cheap nor expensive foods from the open market can be considered perfectly fresh. If this is the case, they will give lower results, when tested for ascorbic acid, than fresh field and garden produce. In support of this statement the mean values obtained for some foods are compared in Table 4 either with those obtained for garden grown vegetables or with the results of Olliver (1936) for fresh field and garden fruits and vegetables.

With the exception of carrots (expensive market), onions (both markets) and apples (for which Olliver names no variety), the market results are all lower than those given by fresh garden produce. The different varieties of carrots and onions tested by Olliver may explain this discrepancy in results.

Table 4. *A comparison between garden and market fruits and vegetables*

Food	Mean value for fresh product (Olliver)	Cheap market, mean value	Mg. C per 100 g. material, expensive market, mean value
Black currant	196·1	162·8	172·9
Strawberry	66·1	35·0	41·8
Gooseberry	36·6	36·3	28·2
Raspberry	30·5	31·0	28·8
Apple (cortex)	8·3 Variety unspecified	8·6 Bramley seedling	11·5 Bramley seedling
Pear	4·4 Whole fruit	0·83 Cortex	1·2 Cortex
Plum	4·6 No variety	0·76 Victoria	0·4 Victoria
New potatoes	34·8	11·9	11·4
Turnips	26·1	17·4	16·5
Peas	24·8	10·5	13·9
Onions	7·4	9·5	12·4
Carrot	4·0	2·5	5·2
	Freshly cut garden produce		
Sprouts	110·9	61·4	69·2
Parsley	208·8	194·5	107·5
Potato (old)	7·04	3·35	2·6

The figures in Table 4 indicate that plums, sprouts, potatoes and peas suffer the greatest loss of vitamin on exposure for sale, and that the soft fruits, e.g. black currants, gooseberries and raspberries, do not suffer such a great loss. This may be accounted for by an increase in ascorbic acid content due to maturing processes in the fruits which offsets the loss of vitamin on storage. The root vegetables show the least change.

It should be emphasized that these figures indicate the conditions in uncooked materials and further losses of vitamin occur during cooking (Scheunert & Reschke, 1938). To determine the respective losses of vitamin potency in foods purchased from cheap and expensive sources when cooked by normal domestic methods would require further research.

The work carried out by Olliver (1936) on the effect of household cooking on vitamin C has shown that the greatest loss is brought about by its extraction in the liquor and not by its destruction. The extraction varies with the amount of water used and the time of cooking. Long, slow boiling in a large volume of liquid causes a much greater loss of vitamin C than does rapid boiling in a small quantity of water. Approximately 25 % of the vitamin was found to be retained in cooked green vegetables and as much as 61 % remained in old potatoes after cooking.

Olliver has also shown (1940) that the addition of a small quantity of sodium carbonate or sodium bicarbonate to boiling greens has an effect which is negligible compared with the differences due to different methods and times of cooking. The natural ascorbic acid is now known to be far more stable than was anticipated from earlier work.

In careful household cookery the destruction of vitamin C can be almost negligible. Rapid boiling prevents the occurrence of much oxidation and the use of small volumes of liquid reduces the amount of vitamin which is extracted from the vegetable. Leaving the lid off is no longer considered necessary.

It is evident, therefore, that greater use should be made of raw vegetables in order that the destruction of natural ascorbic acid by cooking should be avoided. Many root and green vegetables, which are usually served after cooking, may be grated and used in salads.

Effect of storage in the home

Further losses of vitamin C may occur when foods are stored for any length of time between purchase and consumption. In a few experiments the observations of other workers (Olliver, 1936, 1940; Paech, 1938 *a*, *b*) on the destruction of vitamin C on storage were confirmed.

In investigations on practical points it is necessary to arrange the experiments so that their results may be applicable to the smallest households. For this reason, in my investigations, all foods stored were kept at room temperature in a larder communicating with a kitchen where cooking was done. As the communicating door was opened, the warm, moist air from the kitchen caused fluctuations in the larder temperature. Losses of vitamin C at different temperatures were not studied because it is impossible or impracticable to control such temperatures in the majority of houses where cheap foods must be used. For the same reason no food was refrigerated during storage.

As a representative green vegetable, brussels sprouts from both expensive and inexpensive markets were tested daily for 7 days. A number was purchased on the first day and a different vegetable was used each day, the remainder being stored under the conditions mentioned. The results fluctuated from day to day, because a whole vegetable was used for each determination and there was, therefore, no control of the value to be expected for that vegetable. Presumably each one purchased had a different value from every other one in the same batch. It was found, however, that a definite steady fall occurred in the ascorbic acid content.

Table 5. *Average results for the ascorbic acid content of brussels sprouts during household storage* (*mg. C per* 100 *g. whole outer leaves*)

Days from date of purchase	Cheap market	Expensive market
1st	33·6	62·5
2nd	33·2	58·1
3rd	34·3	44·8
4th	30·7	33·8
5th	10·1 Withered leaves	30·5
6th	27·5	31·5
7th	18·4	28·8

Similar results were obtained for outer leaves of sprouts and for heart clusters.

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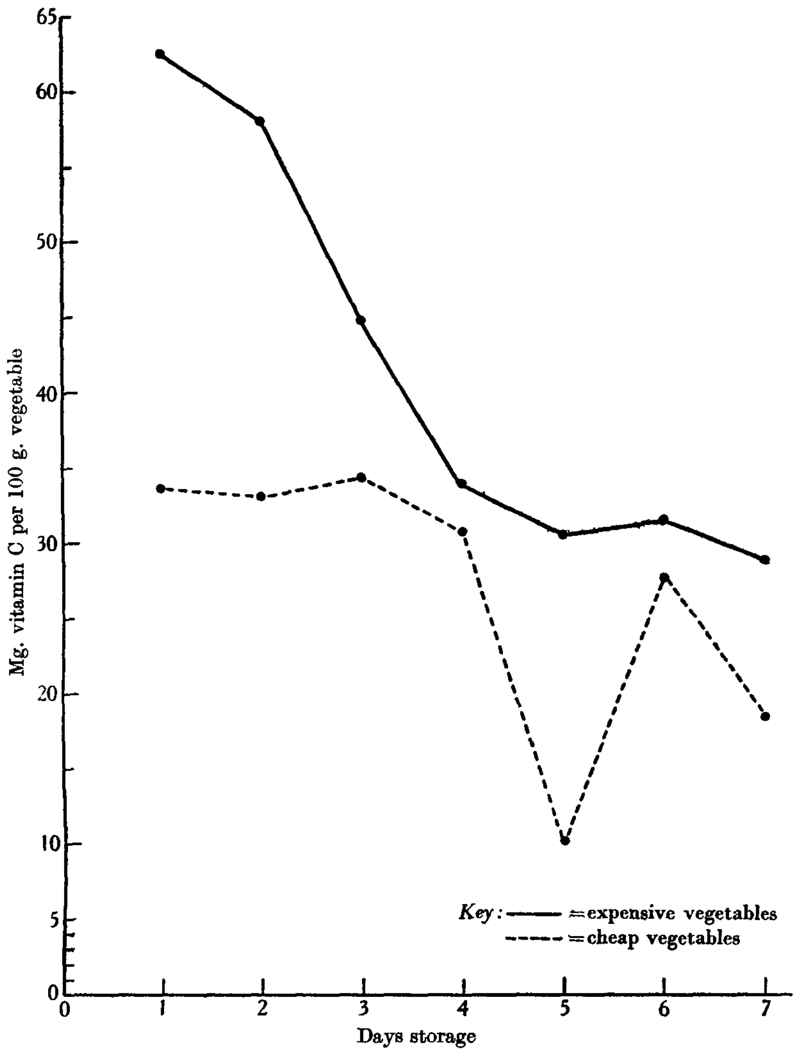

Fig. 1. Brussels sprouts. Outer leaves. Loss of vitamin C on storage.

Heart leaves

Days from date of purchase	Cheap market	Expensive market
1st	51·8	87·6
2nd	43·0	72·7
3rd	44·4	61·4
4th	41·6	46·7
5th	19·5	42·4
6th	28·0	39·2
7th	28·0	28·0

In this series the results given by cheap-market samples on the 5th day were very low. This was caused by the analysis of a very limp and old example which gave an extremely low result and reduced the average. A rise on the

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6th and 7th days, in spite of the fact that the material had been stored longer, was considered proof that the low result of the 5th day was exceptional. Percentage losses of vitamin C were therefore determined between the results found on the day of purchase and the last day of storage.

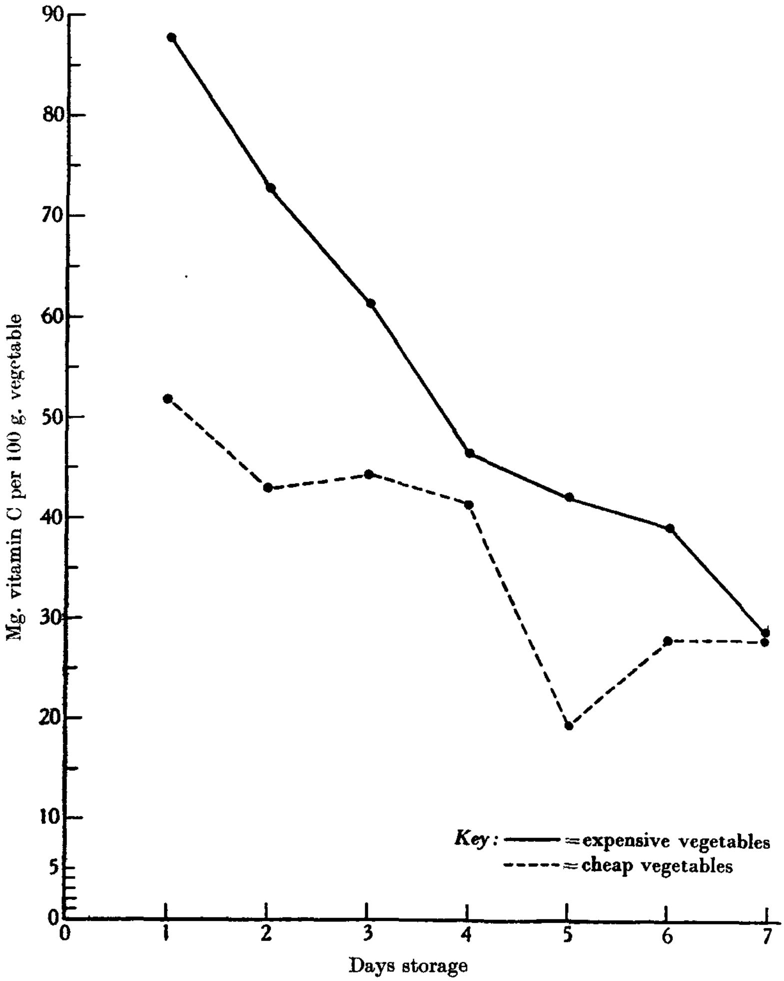

Fig. 2. Brussels sprouts. Heart leaves. Loss of vitamin C on storage.

		% loss between 1st and last days
Cheap market, outer leaves	...	45·23
Expensive market, outer leaves	...	53·92
Cheap market, heart leaves	...	45·94
Expensive market, heart leaves	...	67·12

The percentage loss in both cases was higher in food purchased on the expensive market, and was higher in heart leaves than outer leaves in both sets of experiments. At the date of purchase the vegetables appeared equally fresh, though those from the cheaper store were more bruised and wider open.

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The latter lost less of their vitamin on storage, but their original content was lower than that of the former. The final vitamin contents of sprouts from both markets were in comparatively close agreement.

The biological protective dose (1 mg. basis) of the leaves after 7 days' storage was as follows:

Heart leaf, cheap market	3·7
Outer leaf, cheap market	5·7
Heart leaf, expensive market	3·7
Outer leaf, expensive market	3·7

It will be seen that the expensive vegetables showed a sharp initial fall while the cheap showed a slower and more even fall throughout the period of storage. It may be that the cheap were less fresh when purchased and had already suffered a sharp decline in their ascorbic acid content, and that with the progress of time a low level is reached asymptotically. Both samples of sprouts were grown in the same country locality and probably under closely related conditions of culture. After 7 days the vegetables were too withered for human consumption. The loss of ascorbic acid was greater from the heart leaves than from the outer leaves, which caused a more even final distribution of vitamin throughout the plant. The degree of metabolic activity in the developing tissue of heart leaves was evidently smaller than the destruction of vitamin on storage. The withholding of the plant food supply would retard the metabolic changes in the cells of heart leaves and cause a diminution in the production of ascorbic acid. A tentative explanation of these results is that the oxidase which converts ascorbic acid to dehydro-ascorbic acid in the cut cabbage plant (Stone, 1937) is also present in sprouts, though no reference to its presence can be traced. Fujita & Ebihara (1939), however, claim that oxidized ascorbic acid exists in the green parts of plants. If this is the case, there may be reversibly oxidized ascorbic acid which would, on reduction with H_2S, increase the result obtained for vitamin C in sprouts. It was considered, however, that such reversibly oxidized acid would be converted into the irreversibly oxidized form after 7 days' storage, and only reduced ascorbic acid was tested.

Parsley and mushrooms were also stored in larder temperatures between tests for vitamin C content.

Parsley

Cheap market	Day of purchase	2·51 mg. C per g.
Cheap market	2 days later	1·38 mg. C per g.
	Percentage loss 45·0.	
Expensive market	Day of purchase	1·52 mg. C per g.
Expensive market	2 days later	0·63 mg. C per g.
	Percentage loss 58·6.	

Mushrooms

Close, button mushrooms tested on the day of purchase and on the 3rd and 5th days.

	Cheap market	Expensive market
1st day	0·023 mg. C per g.	0·024 mg. C per g.
3rd day	0·059 mg. C per g.	0·06 mg. C per g.
5th day	0·033 mg. C per g.	0·037 mg. C per g.

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The sharp rise here may be due to an increase in the natural vitamin content as the fungus becomes more mature. After the 4th day the mushrooms began to wither and the vitamin content fell considerably. On the 5th day open mushrooms were purchased and tested to compare them with the stored ones. The values obtained were from 0·035 to 0·036 mg. C per g. These figures may indicate that a limited period of storage does not interfere with the maturing processes of mushrooms, and their vitamin content does not fall until the plant begins to wither. It is interesting to note that the figures obtained for mushrooms are considerably higher than the 1·9 mg. per 100 g. recorded by Levy & Fox (1935).

The loss in vitamin C on storage in the home does not appear to be of very serious import if the foods are used within one or two days of purchase. Experiments have not yet been carried out to determine whether cooking is likely to accelerate the disappearance of vitamin C more considerably in cheap than in expensive vegetables. It is possible that the same percentage would remain but this statement will be tested experimentally.

Citrus fruits were examined for losses in vitamin content on storage. As in the case of sprouts, a control for the value to be expected for each fruit was not obtainable when the whole fruit was stored until tested because each one might have a different value when purchased from all others in the same batch. Both oranges and lemons gave results varying within limits which indicated that there is no appreciable loss in a storage period of 7 days to 3 weeks. Results over this period of time ranged from 39·0 to 39·6, 25·0 to 28·6, 44·9 to 45·9, 39·7 to 40·4, 36·5 to 34·1, 40 to 51·5 mg. C per 100 ml. expressed juice. The results fluctuated daily with each sample tested, but no definite downward trend could be noted. The average given by tests on lemons made each week over a period of 3 weeks was:

1st week	41·04 mg. C per 100 ml. juice
2nd week	50·4 mg. C per 100 ml. juice
3rd week	39·42 mg. C per 100 ml. juice

The difference between the value of 41·04 mg. vitamin and 50·4 mg. was assumed to be that of the natural vitamin content of the fruit as it was no larger than the variation between individual results obtained on one day from lemons of the same batch. Fruits, purchased from a store which had no record of their previous times, temperatures and conditions of storage, may not even have been grown in similar climatic circumstances or on similar soil and are liable to differences greater than 10 mg. C per 100 ml. juice.

It seems, therefore, that household storage of uncut citrus fruits, whether from cheap or expensive sources, for a period of 3 weeks causes no appreciable diminution in the ascorbic acid content.

Experiments on the loss of vitamin C in cut fruits on storage

It is a common practice in some kitchens to use half a citrus fruit for some purpose and to keep the other half for use at a later date. As this cutting seems likely to induce loss of vitamin C, experiments were carried out to discover whether such loss of vitamin occurred. Sections were cut from oranges, lemons and grapefruits purchased on the same day from cheap and expensive sources.

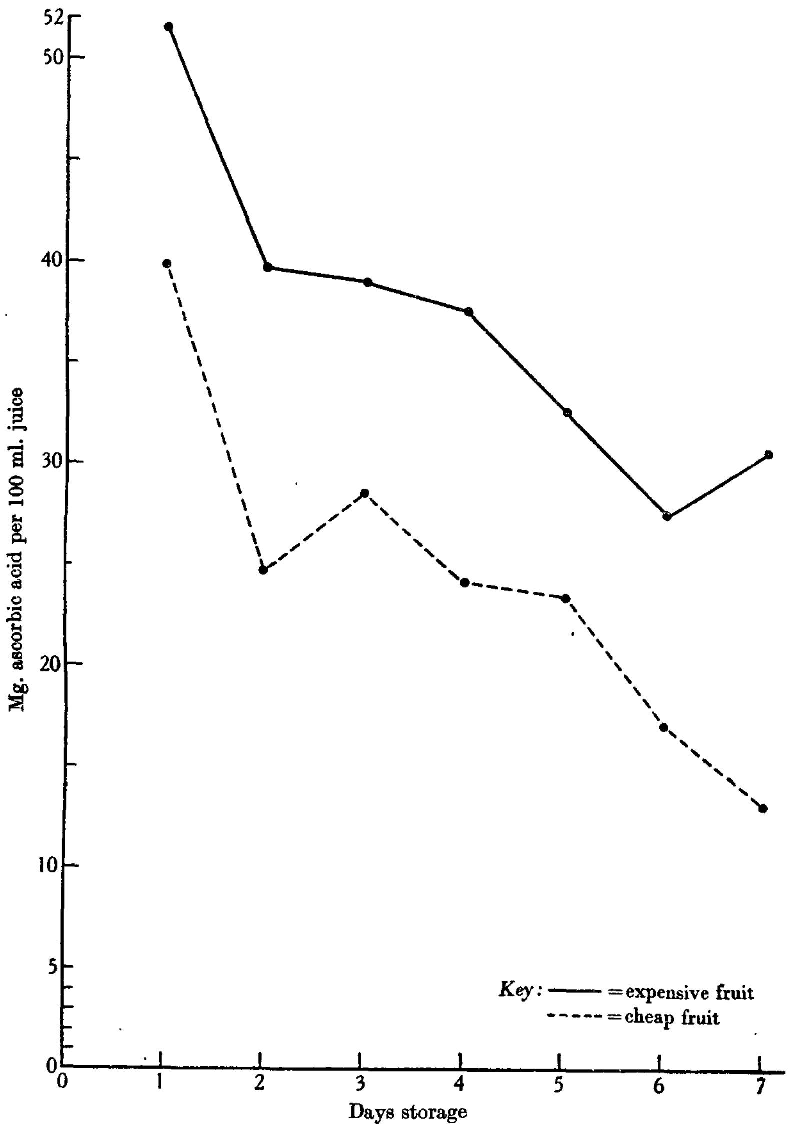

Fig. 3. South African oranges. Loss of vitamin C on storage. Cut fruits.

The sections were cut and tested at the same hour daily for 7 days, the remainder of each fruit being stored in larder conditions until the following day. The juice was tested at its natural pH value.

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Table 6. *South African oranges. Average results in mg. C per* 100 *ml. expressed juice*

Cut fruit day	Cheap market	Expensive market	Notes
1st	39·8	51·5	Both batches of oranges were ripe and juicy, with firm flesh and skin. Fruits of similar sizes and weights were compared.
2nd	24·7	39·6	
3rd	28·6	39·0	
4th	24·1	37·6	
5th	23·4	32·6	
6th	17·1	27·5	
7th	13·1	30·6	

Large Cyprus grapefruits were tested in the same manner.

Table 7. *Cyprus grapefruits. Average results in mg. C per* 100 *ml. expressed juice*

Cut fruit day	Cheap market	Expensive market	Notes
1st	31·0	36·5	Large, firm fruits of similar size and weight were compared with each other.
2nd	29·0	34·2	
3rd	26·8	36·5	
4th	26·2	26·0	
5th	25·4	34·7	
6th	21·9	26·2	
7th	21·0	29·6	

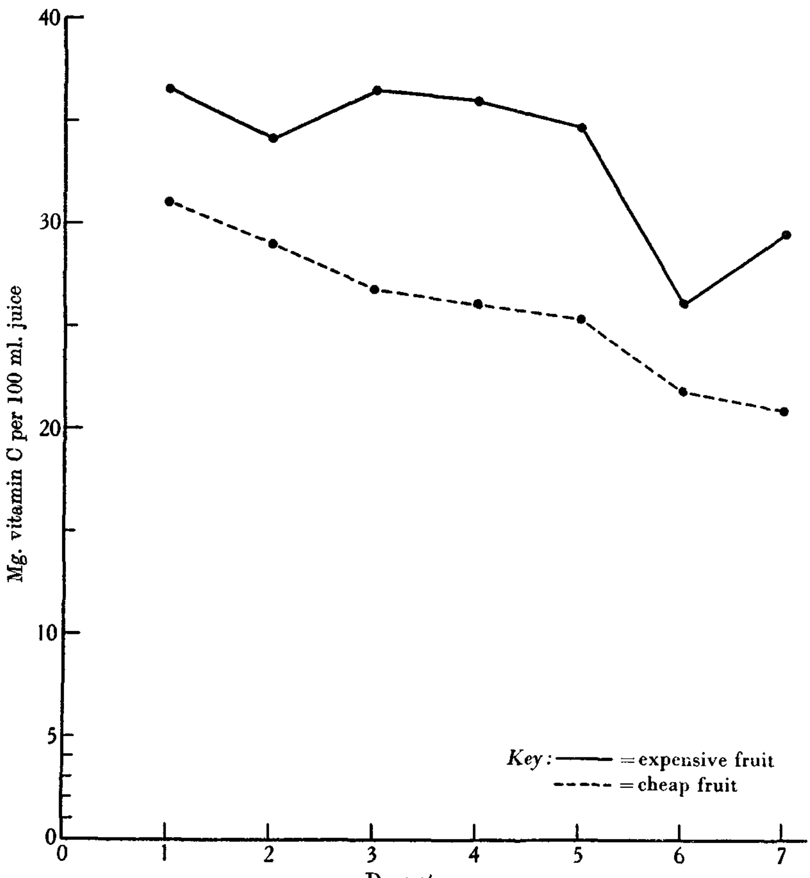

Fig. 4. Cyprus grapefruits. Loss of vitamin C on storage. Cut fruits.

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Italian lemons were also used for similar tests.

Table 8. *Italian lemons. Average results in mg. C per 100 ml. expressed juice*

Cut fruit day	Cheap market	Expensive market	Notes
1st	36·6	44·9	The lemons were of similar size and weight and very firm, but were rather under-ripe, and the peel was hard.
2nd	40·4	45·9	
3rd	39·7	34·1	
4th	34·0	43·2	
5th	29·5	37·2	
6th	21·9	26·2	
7th	20·4	31·5	

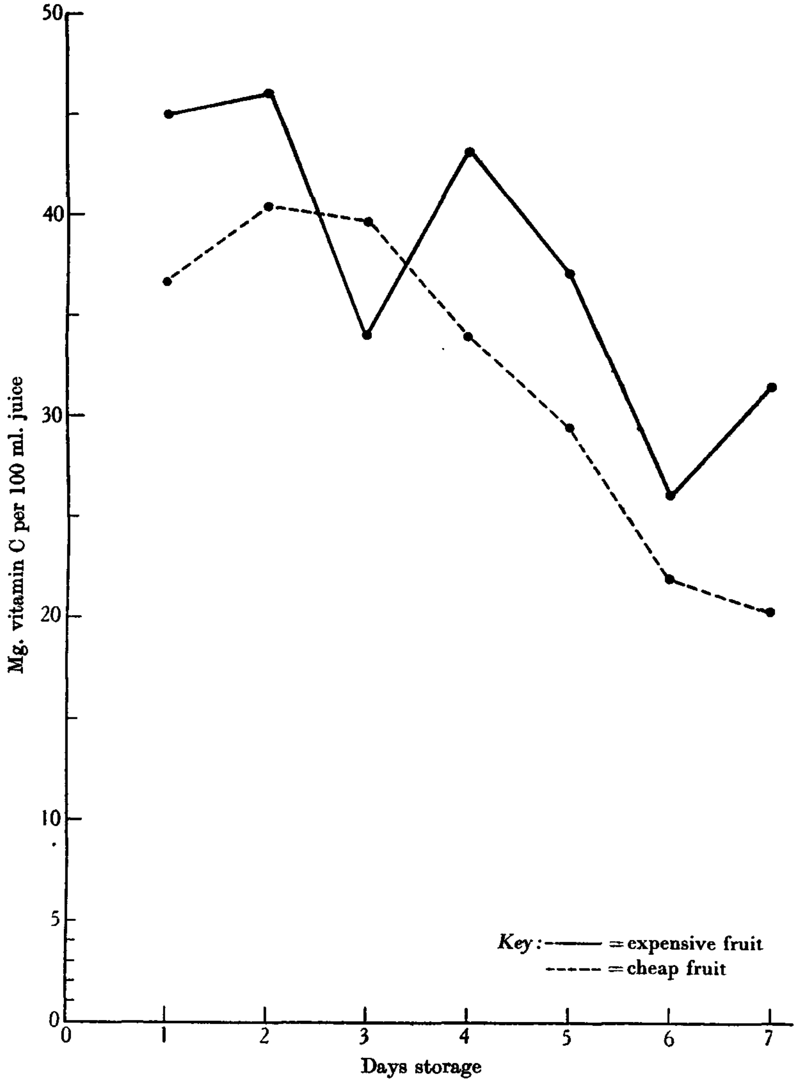

Fig. 5. Italian lemons. Loss of vitamin C on storage. Cut fruits.

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The loss of vitamin in every case was very irregular and did not appear to be governed by the size, weight or original content of juice of each fruit, nor to any great extent by the species. Variations in the ascorbic acid content of fruits of one species occur when plants are grown on different soil and in different climates, under varying conditions of culture. The loss of vitamin C in these experiments was largely peculiar to each fruit.

Maximum percentage losses in ascorbic acid

Cheap orange	67·09
Expensive orange	46·6
Cheap lemon	49·5
Expensive lemon	42·9
Cheap grapefruit...	32·26
Expensive grapefruit	28·21

In some instances the value obtained on the 7th day was not the lowest of the series, so the percentages have also been calculated for the loss of vitamin C between the 1st and 7th days.

Percentage loss between 1st and 7th days

Cheap orange	67·09
Expensive orange	40·58
Cheap lemon	44·26
Expensive lemon	29·84
Cheap grapefruit...	32·26
Expensive grapefruit	18·90

In contradistinction to parsley and to brussels sprouts, the loss in all cases was greater in the fruits from cheap sources which contained a smaller initial amount of available vitamin. At the end of 7 days there was only 13·1 mg. vitamin C %, in the orange from an inexpensive source, as compared with 39·8 mg. on the day of purchase.

In all fruits examined the loss of antiscorbutic potency at the end of 7 days was great, and in the case of oranges the initial loss was rapid. Such food, therefore, should not be prepared for table by cutting or peeling until immediately before serving. On exposure to air, the cut surfaces cause a loss of ascorbic acid by oxidation. Grapefruits appeared to lose less vitamin than oranges or lemons, which may be due to the larger volume of juice (used for estimation) in comparison with the exposed, cut surface of the section. Klodt & Stieb (1938) point out that the systems of stabilizers and oxidases affecting vitamin C vary widely in different species of fruits and vegetables and, therefore, the stability of the vitamin in such materials varies accordingly. Destruction is accelerated by the presence of traces of copper in fruits and vegetables.

Oskima *et al.* (1937) make an interesting claim that after-ripened lemons are richer in vitamin C than those ripened on the tree. This may have great practical value.

Some of the fruits tested in these experiments did not show a consistent fall in vitamin value and on some days there was an apparent rise, which may have been due to uneven ripening of the fruit or to variations in the distribution

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of ascorbic acid throughout the parts of a plant or individual fruit. It was considered important to investigate the cause of this variation.

DISTRIBUTION OF ASCORBIC ACID IN VARIOUS PORTIONS OF PLANT TISSUE

Oranges were quartered longitudinally and the juice and whole peel were examined separately from each quarter. The results obtained confirm Bacharach *et al.'s* (1934) statement that there is an increase in vitamin C content from juice to flavedo.

Table 9. *Distribution of vitamin C in oranges*

	Juice, mg. C per 1 ml. juice	Peel mg. C per 1 g. peel
	Spanish oranges, medium ripe	
1st quarter	0·523	1·86
2nd quarter	0·569	1·99
3rd quarter	0·563	1·94
4th quarter	0·569	1·99
	Brazilian oranges, medium ripe	
1st quarter	0·595	1·98
2nd quarter	0·558	1·79
3rd quarter	0·582	2·03
4th quarter	0·558	1·86
	Brazilian oranges, medium ripe	
1st quarter	0·570	0·510
2nd quarter	0·538	0·492
3rd quarter	0·570	0·479
4th quarter	0·460	0·510
	Jaffa oranges, medium ripe	
1st quarter	0·419	1·14
2nd quarter	0·412	1·21
3rd quarter	0·406	1·14
4th quarter	0·406	1·09

The uneven distribution of vitamin accounts for the apparently uneven fall in vitamin content of the juice of cut citrus fruits, and may be due to differences in pigmentation or variations in the degree of metabolic activity or ripeness of the parts of each fruit.

Bracewell *et al.* (1931) has shown that the concentration of ascorbic acid in Bramley's Seedling apples is greater in the skin than the core and cortex. Paech (1938 *a*) found that the same conditions obtain in German apples, while both Paech (1938 *a*) and Kröner & Völksen (1938) stated that potatoes have a higher concentration of ascorbic acid in the centre than at the periphery, though Ijdo (1936) found a uniform distribution in all layers.

A part of practically every fruit and vegetable is discarded during preparation for table. In the case of Bramley's Seedling apples the part containing the highest concentration of vitamin C is peeled off. Many of the portions normally wasted are edible, and it was thought of interest to discover whether such portions are rich in ascorbic acid. Accordingly, several fruits and vegetables were examined for uneven distribution of their vitamin content.

Table 10. *Distribution of vitamin C in plants (mg. C per g.)*

	Peel	Cortex
Apples and pears		
Cox's Orange Pippin apple	0·100	0·0139
	0·096	0·0184
Bramley's Seedling apple	0·803	0·100
	0·369	0·073
	0·72	0·115
Worcester Pearmain apple	0·0013	0·095
Pear	0·0189	0·008
	0·0271	0·012
Rhubarb from expensive market		
Base of stalk	0·106	0·103
Centre of length of stalk	0·107	0·103
Top of stalk and leaf stem	0·175	0·144
Leaf (inedible)	0·420	0·408
Juice from stalk	0·279	0·262
Mushroom from expensive market		
Stem	0·040	0·042
Gills	0·041	0·045
Peel (inedible)	0·043	0·046
White flesh	0·046	0·049
Seakale from cheap market		
Outer leaf	0·321	0·319
Inner leaf	0·341	0·344
Lower end of heart cluster	0·348	0·353
Upper end of heart cluster and pink leaves	0·335	0·332
Celery from cheap market		
Root	0·0218	0·0180
Lower end of outer stalk	0·0440	0·0383
Upper end of outer stalk	0·0448	0·0386
Lower end of inner stalk	0·0418	0·0367
Upper end of inner stalk	0·0418	0·0369
Heart	0·0464	0·0394
Leaf	0·260	0·246

	Cheap market			Expensive market	
Leek					
Base of stem		0·159	0·186	0·185	
Top, verging into green leaf		0·159	0·193	0·236	
Cabbage					
Outer leaf		1·14	0·324	—	
Heart leaf		1·15	0·372	—	
Savoy cabbage					
Outer leaf		0·489	0·416	—	
Heart leaf		0·502	0·431	—	
Sprouts					
Outer leaf	0·827	0·758	0·698	0·33	1·33
Heart leaf	0·893	1·015	0·797	0·43	1·44
Cauliflower					
Flower	0·356	0·732	—	—	—
Leaf	0·185	0·351	—	—	—
Curly kale					
Heart leaf	0·907	0·333	0·278	0·88	0·903
1st longitudinal half of inner leaf	1·152	0·405	0·207*	1·114	1·152
2nd longitudinal half of inner leaf	1·178	0·418	0·404*	1·119	1·193
1st longitudinal half of outer leaf	0·955	0·394	0·380	0·93	0·994
2nd longitudinal half of outer leaf	1·017	0·397	0·396	0·98	1·028
Midrib from lower end of outer leaf	0·726	0·331	0·348	0·64	0·759

* There is no apparent reason for the discrepancy between the vitamin content of the two halves of this leaf. It appeared fresh and similar to the other longitudinal half.

All the foods examined were used immediately after purchase. Wide variations in the results for curly kale can be explained by the variations in freshness of the different batches purchased at different sources.

The figures for celery are interesting in that the amounts of vitamin in the root, stem and leaves are in the proportion of 1 : 2 : 12. The leaf is usually discarded in preparation but is a good source of ascorbic acid.

The results for green vegetables emphasize the hypotheses that the influencing factor in the amount of ascorbic acid found is the degree of metabolic activity in the tissue. All heart stems, leaves and developing tissue gave higher results than outer stems or leaves.

The experimental results indicate that there is a higher vitamin content in the meristematic parts of the plants examined than in the older tissues. A belief is held in some laboratories that the outer leaves of lettuce or cabbage are richer in antiscorbutic factors than the inner leaves. This is true for vitamin A in cabbage, but the findings as regards vitamin C are ambiguous (Boas Fixsen & Roscoe, 1939–40); therefore the experimental results obtained are held to be true for the foods analysed after purchase on the open market.

The two longitudinal halves of one leaf appear to contain almost identical amounts of vitamin.

New Cyprus potatoes, purchased in January, were also examined. Five separate tubers were cut so that a thin, transverse section (including skin) was obtained. The results for these sections were 0·127, 1·109, 0·102, 0·101, 0·110 mg. vitamin C per g., which shows a close correlation between separate vegetables in one batch. Each potato was then cut for analysis.

	Mean results, mg. ascorbic acid per g.
Thin transverse section, plus peel	0·1096
Thin longitudinal section, plus peel	0·1096
Peel, cut thinly	0·1177
Flesh immediately under peel	0·1126
Flesh from centre of potato	0·1069

These results differ a little from the previously reputed values, there being a slightly higher concentration of vitamin C at the periphery than in the centre. The difference is small, though the usual statement that the best part of the potato is immediately under the skin should be modified, at any rate regarding vitamin C and the "new" Cyprus potato, to which such a distribution may be peculiar.

THE VITAMIN C RATION FROM CHEAP AND EXPENSIVE MARKETS

As so much value is laid on orange juice as an antiscorbutic, it was considered of interest to compare the juices of different varieties in order to determine which of these varieties gave the richest yield of available ascorbic acid.

Oranges were purchased from cheap and expensive sources and tested immediately at their natural *p*H value.

Table 11. *Ascorbic acid content of different varieties of orange (mg. vitamin per* 100 *ml. juice)*

Variety	Average value: Cheap market	Average value: Expensive market
Jaffa	37·8	43·1
Spanish	73·1	70·3
South African	39·8	51·5
Australian	36·0	56·5
Brazilian	53·8	53·4
Tangerine	24·2	12·3

The results for Spanish oranges were high because the earliest fruits of the 1939 crop to reach this country gave values of 87·5 to 89·3 mg. ascorbic acid per 100 ml. juice. They were large, firm, very sweet fruits. Lassablière & Uzan (1938) state that sweet oranges are richer in vitamin C than acid ones, though they lose their vitamin more quickly on standing.

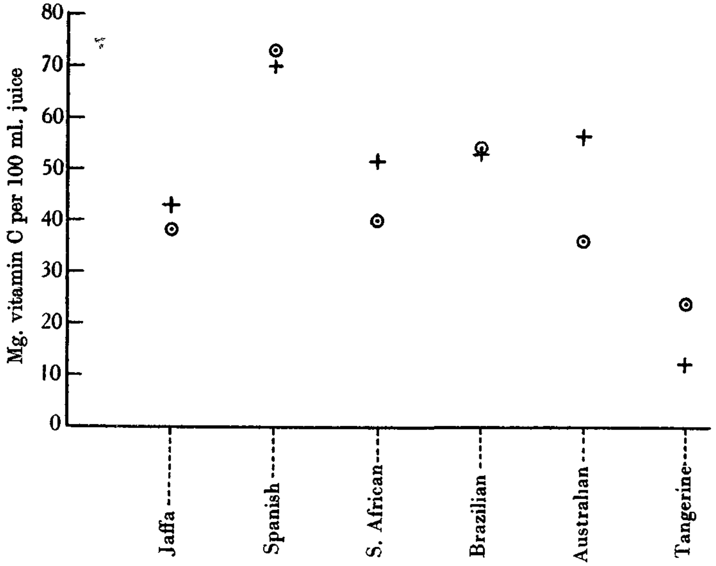

Fig. 6. Average ascorbic acid content of different varieties of oranges.
+ = expensive markets. ⊙ = cheap markets.

Spanish and Brazilian oranges from cheap markets had a slightly higher concentration of vitamin C than those from expensive markets, and tangerine oranges a considerably higher one, but for Jaffa, South African and Australian oranges the expensive market was a better source for ascorbic acid.

The volume of juice required daily to give 30 mg. available vitamin C according to these figures is set out in Table 12.

The amount of juice yielded by oranges was found to vary between one and two ounces, so that, except in the case of tangerine oranges which have a low vitamin content, one to three oranges daily will afford complete protection from vitamin C deficiency.

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Table 12. *Daily requirement of orange juice from different varieties of orange*

Variety	Cheap market	Expensive market
Brazilian	2 oz. or 50·5 ml.	2 oz. or 56·2 ml.
Spanish	1½ oz. or 41·0 ml.	1½ oz. or 42·7 ml.
Australian	3 oz. or 83·3 ml.	2 oz. or 53·0 ml.
Jaffa	2¾ oz. or 79 ml.	2 oz. or 69·6 ml.
South African	2¾ oz. or 75·3 ml.	2 oz. or 58·3 ml.
Tangerine	4½ oz. or 124 ml.	8½ oz. or 244 ml.

THE VITAMIN C CONTENT OF CANNED FRUITS AND VEGETABLES

Tinned foods have become increasingly popular in the last few years and are likely to reach a wider market as it becomes progressively more difficult to obtain fresh fruit and vegetables under war-time conditions of importation, transport and production. It is chiefly the products of the more modern factories, which are careful to use only the freshest fruits and vegetables, and to exhaust the cans before sealing and "processing", that may be expected to be dearer. As the vitamin C content falls on storage, tins from the expensive market may be expected to contain more vitamin than those from the cheaper market. There are, however, many cheap packs on the market which are likely to appeal to persons of limited income. It was sought to determine the vitamin C content of the most popular of these foods, and of those sold in expensive packs. Both sets of results were compared with the figures obtained by tests on the same commodities purchased on the open market in the raw state.

The solid and liquid were both tested from each tin. In the case of fruits, the syrup is usually consumed. As Olliver points out (1936) there is a small decrease in the vitamin C content of canned foods during the first few weeks of packing. Some of her experimental results on the storage of canned fruits also show a certain amount of redistribution of vitamin with an increase in the proportion present in the syrup. The use of canned fruit syrup is usual and beneficial as much of the vitamin in the can is in the syrup. Much ascorbic acid is wasted when the liquid from canned vegetables is thrown away. Its use in sauce making is advocated.

Daniel & Rutherford (1936) have found a steady loss of vitamin in canned tomato juice amounting to 24% during 1–6 months' storage, and Roberts (1937) observed a steady loss of ascorbic acid in canned grapefruit juice. These observations make it advisable that tinned foods be purchased as near the time of consumption as possible. Foods purchased in the winter must have been preserved since the previous season and will have suffered some loss of vitamin before purchase.

The results given in Table 13 are for canned foods tested on the day of purchase. If these had been stored in the house for any length of time a lower series of vitamin C values might have been obtained. The results are compared with the average of results already obtained for these fruits and vegetables purchased raw on the open market.

Table 13. *The ascorbic acid content of canned fruits and vegetables. Weights of containers varied from 1 lb. 1 oz. to 2 lb. (mg. ascorbic acid per g. solid per ml. liquid)*

Fruit or vegetable	Cheap market: Manufacturer, weight and cost	Cheap market: Raw	Cheap market: Solid	Cheap market: Liquid	Expensive market: Manufacturer, weight and cost	Expensive market: Raw	Expensive market: Solid	Expensive market: Liquid
Gooseberry	A 2 lb. 6½*d.*	0·363	0·0261	0·232–0·298	B 1¼ lb. 9½*d.*	0·266–0·298	0·247	0·288
Raspberry	C 1¼ lb. 9½*d.*	0·303–0·317	0·062–0·0751	0·075–0·0843	B 1 lb. 1 oz. 9½*d.*	0·288	0·130–0·184	0·155
Strawberry	D 1¼ lb. 10*d.*	0·318–0·382	0·2344	0·155–0·209	E 1¼ lb. 1*s.* 2*d.*	0·417–0·418–	0·211–0·418	0·188–0·298
Plum (red)	D 1¼ lb. 8½*d.*	0·005–0·0097	0·006–0·009	0·0093	F 1¼ lb. 11*d.*	0·00375–0·00378	0·004	0·010–0·017
Black currant	D 1¼ lb. 10*d.*	1·20–2·06	1·34–1·44	0·823–0·886	G 1¼ lb. 11½*d.*	1·60–1·858	0·914–1·225	0·909–1·114
French beans	D 1 lb. 10 oz. 1*s.* 3*d.*	0·048–0·091	0·040–0·079	0·033–0·0516	B 1 lb. 1 oz. 11*d.*	0·041–0·052	0·045	0·038
Peas	D 1 lb. 8 oz. 4½*d.*	0·0497–0·159	0·017–0·018	0·050–0·053	F 1¼ lb. 6½*d.*	0·095–0·183	0·140–0·148	0·119–0·122
Celery	G 2 lb. 1*s.* 3*d.*	0·054–0·088	0·0213–0·0228	0·023–0·024	F 1¼ lb. 11½*d.*	0·053–0·055	0·028–0·029	0·043–0·046

The range of values found for one kind of vegetable packed by one manufacturer and purchased in several tins at the same time illustrates the variability of ascorbic acid content.

The amount of vitamin available to the consumer is greatly reduced when the liquid from canned vegetables is discarded. Even allowing for the wastage of all liquid there is still an appreciable amount of vitamin in French beans. The values for the vegetable purchased raw in the market ranged from 0·041 to 0·091 mg. per g., while those of the canned vegetable were 0·04–0·079 mg. per g. It should be noted, however, that most canned vegetables are reheated before serving which will result in a further, though small, loss of vitamin C.

In green peas of an expensive pack there were 0·14–0·148 mg. vitamin C per g., whilst raw green peas bought from the market gave from 0·095–0·183 mg. per g. The value found for green peas of a cheap pack was exceptionally low, being only 0·017–0·018 mg. vitamin per g. It was noted, however, that the vegetables in those tins were old and husky and gave every appearance of being soaked dried peas. This value would agree with such an assumption, as Fixsen and Roscoe quote figures from 0–2·7 mg. ascorbic acid % for dried peas.

Celery of an expensive pack retained approximately 25–53 % of the value for celery. The ratio between the vitamin content of solid and liquid was 1 : 1·6, and this liquid is particularly suited for sauce making.

With the exception of cheap raspberries, which contained only 0·062–0·075 mg. vitamin C per g. fruit and 0·75–0·084 mg. per ml. syrup as opposed to 0·303–0·317 mg. per g. of fresh fruit, the vitamin available to the consumer from both solid and syrup together was higher than that from the same quantity of raw fruit purchased on the open market. This may be because selected fresh field or orchard produce in optimum condition is chosen for canning, and therefore its initial ascorbic acid content is probably considerably higher than that of the same product after exposure for sale on the open market. It may also be that the result of heating the plant tissues in canning processes is to soften the cells so that the cell contents are more readily and completely extracted.

If the last suggestion is correct raw foods, though containing higher amounts of vitamin C than cooked ones, may yet have less available vitamin and a greater part of it may be excreted unabsorbed in undigested food residues.

That there is an apparent increase in the vitamin C content of some foods on heating has been demonstrated by several workers (McHenry & Graham, 1935 *a*, *b*; Van Eekelen, 1935; Guha & Sen-Gupta, 1938) and suggestions have been made to explain this phenomenon. Guha & Sen-Gupta put forward the suggestion that vitamin C is present in a combined form which they call "ascorbigen" from which it is released on heating. The "ester" hypothesis of McHenry & Graham is a possible reason, though Mack (1936) rejects this view and offer what would appear to be a more probable one. They claim that an apparent increase is due to the inhibition of the action of ascorbic acid oxidase in the cooked vegetable, while in the raw vegetable it remains fully active and causes progressive destruction of the vitamin throughout the process of extraction. Ascorbic acid oxidases have been found in a number of fruits and vegetables such as apples, bananas, peaches, squash, cabbage, carrot, cauliflower, French beans, lettuce, watercress, beet tops, spinach, parsnip, pea, marrow, cucumber and potato. Stone (1937) denies their existence in peas, lettuce, spinach, lucerne and onions, while Tauber (1936) finds none in lemons, oranges, tangerine-oranges and grapefruits. The oxidase is inactivated by a temperature of 100° C. maintained for one minute.

Kohman *et al.* (1928), using biological methods, found that canning caused no appreciable loss in the vitamin C content of cabbages, apples, spinach, pears, peas and strawberries. Vitamin C has also been added to runner beans and apples, and Zilva, Morris & Perry (1935) found that canning destroyed approximately 25% of the added acid.

From the standpoint of the average housewife it would appear satisfactory to use canned fruits and vegetables where poor material only is available, though fresh garden produce is preferable. Experimental results also indicate that the cheap packs are on an average as good a source of ascorbic acid as the more expensive ones, though in isolated cases abnormally low results may be obtained.

Comparison of the quantity and cost of cheap and expensive raw and canned plant foods required to yield 30 mg. of vitamin C

The economic consideration is important to the housewife catering on a low budget, and a reference to the table of results will show that a 2 lb. tin of gooseberries at $6\frac{1}{2}$*d*. contains 0·261 mg. vitamin C per g. solid and 0·298 mg. per ml. syrup, while a tin weighing $1\frac{1}{4}$ lb. and costing $9\frac{1}{2}$*d*. contains 0·247 mg. vitamin C per g. solid and 0·288 mg. per ml. syrup. The cost of a day's ration of 30 mg. vitamin C from these fruits would be 1*d*. and 2*d*. respectively.

The percentage results of the tins tested shows that 60% of the cheap fruits contain more vitamin than the expensive ones, and $33\frac{1}{3}$% of the vegetables contain more ascorbic acid than their expensive equivalents.

Throughout the course of this work, the cost of all foods was carefully noted in order that due comparison might be made of the price of the average daily protective requirement of the adult body, from cheap and expensive sources.

Many values have been obtained for the vitamin C content of foods from various sources on the open market, and these have been tabulated to show the amounts of each required to furnish 30 mg. vitamin C. Gothlin (1934) considers 19–27 mg. ascorbic acid daily is necessary to protect an adult of 60 kg. from scurvy. 30 mg. was therefore taken as the maximum requirement of any adult.

To this table is appended the cost of this quantity of food, using the mean of the prices ruling when each sample of food was purchased. The effects of the severe weather in early 1940, and of the war, caused a steep rise in the market price level of certain fruits and vegetables. The value given for canned foods is for solid material only.

Table 14. *Table of amounts of raw and canned plant tissue required to give* 30 *mg. of ascorbic acid and the cost of that amount*

Fruit or vegetable	Cheap market, raw (table) oz.	Cost of that quantity	Cheap market, canned oz.	Cost of that quantity	Expensive market, raw (table) oz.	Cost of that quantity	Expensive market, canned oz.	Cost of that quantity
Cox's Orange Pippin apple (cortex)	75	2*s.* 4*d.*	—	—	27¾–58½	10½*d.*–1*s.* 10*d.*	—	—
Bramley's Seedling (cortex)	10½–14	—	—	—	9¼	2*d.*	—	—
Worcester Pearmain (cortex)	—	—	—	—	21	6½*d.*	—	—
Jerusalem artichoke	18–20	2¼*d.*–2½*d.*	—	—	20–25	3*d.*–4*d.*	—	—
Apricot	17–18	11*d.*	—	—	40½–62	2*s.* 11¾*d.*–4*s.* 6¼*d.*	—	—
Banana (under-ripe)	16	3*d.*	—	—	12	2*d.*	—	—
Banana (ripe)	9–9¼	¾*d.*	—	—	8¾–9	1½*d.*	—	—
French beans	11–22	6*d.*–11½*d.*	13¼–26¼	7¾*d.*–1*s.* 4½*d.*	20¼–25¾	1*s.* 2*d.*–1*s.* 6*d.*	23½	1*s.* 4¼*d.*
Beetroot	—	—	—	—	9¾–11	2*d.*–2¼*d.*	—	—
Brussels sprouts	1–3	<¼*d.*–½*d.*	—	—	1¼–1¾	¼*d.*–½*d.*	—	—
Black currant	½–¾	¼*d.*–½*d.*	¾–1	½*d.*	½–¾	¼*d.*–½*d.*	1–1¼	>½*d.*–1*d.*
Cabbage	1	<¼*d.*	—	—	2¾–3¼	¼*d.*	—	—
Cauliflower	3	1*d.*	—	—	1½	¾*d.*	—	—
Carrot	28–50	1¾*d.*–3*d.*	—	—	20¼–20¾	.2½*d.*	—	—
Celery (stem)	12–19½	3*d.*–5*d.*	46¼–49½	1*s.* 9¾*d.*–1*s.* 11¼*d.*	19–19¾	4¾*d.*–5*d.*	35¼	1*s.* 9*d.*
Date	58½	2*s.* 5*d.*	—	—	108½	10*s.* 6½*d.*	—	—
Grapes (S. American)	483–585	>£1	—	—	126¾–526	9*s.* 3*d.*–>£1	—	—
Grapefruit juice	3½–4	¾*d.*–1*d.*	—	—	3	¾*d.*	—	—
Seakale	3	2¼*d.*	—	—	2¾–3	2½*d.*	—	—
Curly kale	2–3	¼*d.*–½*d.*	—	—	1–3¾	¼*d.*–¾*d.*	—	—
Endive	—	—	—	—	5–18½	6*d.*–1*s.* 9½*d.*	—	—
Leek	5½–6½	1*d.*–1¼*d.*	—	—	4½–5¾	1*d.*–1¼*d.*	—	—
Gooseberry	3	½*d.*	4	1*d.*	3½–4	1¼*d.*–1½*d.*	4½	2*d.*
Lemon juice	2½–4	¼*d.*–½*d.*	—	—	1½–3	¼*d.*–¾*d.*	—	—
Liver	5	5*d.*	—	—	2	3*d.*	—	—
Lettuce	21	1*s.* 2*d.*	—	—	6¾–87¾	8*d.*–7*s.* 10½*d.*	—	—

Table 14 (*cont.*)

Fruit or vegetable	Cheap market, raw (table) oz.	Cost of that quantity	Cheap market, canned oz.	Cost of that quantity	Expensive market, raw (table) oz.	Cost of that quantity	Expensive market, canned oz.	Cost of that quantity
Mushroom	29	3*s*. 7½*d*.	—	—	17½–45¾	2*s*. 5½*d*.–4*s*. 5¼*d*.	—	—
Onion	11–11¼	¾*d*.	—	—	8–9	1*d*.	—	—
Orange juice	1–3	<¼*d*.–½*d*.	—	—	1¼–2	¼*d*.–½*d*.	—	—
Pea	6½–21	1¼*d*.–4*d*.	58½–62	11*d*.–11½*d*.	5¾–11	1¾*d*.–3½*d*.	7–7½	2¼*d*.–2½*d*.
Parsley	½–¾	½*d*.	—	—	¾–1¾	¾*d*.–1¾*d*.	—	—
Pear (cortex)	127	4*s*. 4½*d*.	—	—	87¾	4*s*. 6¾*d*.	—	—
Parsnip (old)	21–22½	1½*d*.	—	—	17¾–22½	2¼*d*.–2¾*d*.	—	—
Potato (old)	29¼–34	1¾*d*.–2*d*.	—	—	35–48	3¼*d*.–4½*d*.	—	—
Potato (new)	8¼–8½	2*d*.	—	—	8¼–10½	2¼*d*.–3*d*.	—	—
Peach	26¼–34	2*s*. 2¼*d*.–2*s*. 10*d*.	—	—	26¼–34	4*s*. 4½*d*.–5*s*. 8*d*.	—	—
Plum	108½–191½	3*s*. 4¾*d*.–5*s*. 11¾*d*.	117–176	4*s*. 1¾*d*.–6*s*. 3*d*.	276–280¾	12*s*. 11*d*.–13*s*. 3*d*.	263¼	12*s*. 0¾*d*.
Prune	25¾	9½*d*.	—	—	13¾	7*d*.	—	—
Radish	5	1½*d*.	—	—	7¾	3¾*d*.	—	—
Rhubarb	9¾–10¼	2½*d*.	—	—	11¼–12½	2¾*d*.–3*d*.	—	—
Raspberry	3¼–3½	1¼*d*.	14–17	6¾*d*.–8*d*.	3½	1¾*d*.	5¾–8	3*d*.–4½*d*.
Strawberry	2¾–3¼	1*d*.–1¼*d*.	4½	2¼*d*.	2½	1½*d*.	2½–5	1¾*d*.–3½*d*.
Spring greens	1–2	<¼*d*.	—	—	1½–2	¼*d*.	—	—
Tomato	2¾–7¼	1*d*.–2¾*d*.	—	—	6½–8¾	3¼*d*.–4½*d*.	—	—
Tomato juice	5–8½	2*d*.–3¼*d*.	—	—	6¾	3½*d*.	—	—
Swede	3½–5	½*d*	—	—	3–3½	½*d*.	—	—
Savoy cabbage	2–2¼	<¼*d*.	—	—	2½	¼*d*.	—	—
Turnip (old)	5–7½	¼*d*.–½*d*.	—	—	4¾–9¾	½*d*.–1¼*d*.	—	—
Turnip tops	—	—	—	—	1	<¼*d*.	—	—
Watercress	1½	¼*d*.	—	—	1½	¾*d*.	—	—

The costs for canned fruits are given for solid material only. As there is an approximately equal quantity of ascorbic acid in the syrup which will be used, this cost will be thereby reduced.

Table 14 emphasizes the fact that the cheaper markets are not a negligible source of vitamin C, and that when the available vitamin in any one fruit or vegetable is less in the cheaper product than the more expensive one, it may still be cheaper to obtain the daily requirement by a larger consumption of the less expensive article. In this respect, the use of more raw fruits and vegetables in the daily dietary should be advocated. The requirement of 30 mg. may be obtained from as little as half an ounce of raw parsley or black currants, or may necessitate the consumption of as much as 585 oz. of grapes, at costs varying respectively from a farthing to more than £1.

A reference to the table also shows that for the cheapest sources of ascorbic acid the cost from either market is often approximately the same, with a slightly higher cost from expensive stores. For the foods containing so little vitamin C that large quantities would be required daily to provide 30 mg., the cheap market is by far the more profitable source. In a very few instances, the average price for a food from the inexpensive market worked out fractionally higher than from the fashionable stores. As would be expected, there is a wider range of prices for commodities purchased in the latter.

There is a comparatively close correlation between the average values of a food as a source of antiscorbutic potency from whatever market it may be obtained. The citrus fruits, watercress and black currants are inexpensive and valuable preventatives of avitaminosis C.

In view of increases in market price levels under war-time conditions, and as it has been shown that foods sold on the open market are less rich in vitamin C than fresh garden produce, the use of home-grown fruits and vegetables should be encouraged. The allotment scheme now in force will doubtless benefit the health of the nation.

It appears, however, that avitaminosis occurring amongst those of limited means is due to an improper dietary, caused by poverty and ignorance, rather than to an insufficiency of ascorbic acid in the foods purchased on the open market.

SUMMARY

Values for the ascorbic acid content of a number of foods sold in diverse markets were determined by titration against 2 : 6 dichlorophenolindophenol in acid solution. The results showed that the least expensive material was not necessarily the poorest source of vitamin C and might be more valuable than expensive foods. Samples of cabbage from the cheap market contained 329 % as much vitamin C as samples from expensive sources. These results on comparison with figures recorded for fresh garden produce showed that market foods have lost some of their vitamin C content on exposure for sale, but still contain satisfactory amounts of ascorbic acid when purchased.

Results from different samples of fruits and vegetables showed wide variation. No data relating to storage before purchase were available, so limiting figures were used for each food. Mean values were calculated for purposes of comparative tabulation.

The effect of household storage after purchase was noted for foods from inexpensive and fashionable markets. The values obtained showed that the loss of ascorbic acid in foods stored in the home after a period of exposure for sale, though marked, was not as serious as has previously been indicated.

An irregular fall in the ascorbic acid content of some of the material examined was noted and investigated. Wide variations in the amount of ascorbic acid present in different parts of individual fruits and vegetables were observed. In view of experimental results it is recommended that foods be purchased and prepared for consumption immediately before use.

Canned foods from diverse markets were examined to determine their ascorbic acid content, and it was shown that the vitamin is distributed throughout solid and liquid. Although a percentage of vitamin is destroyed on heating, those fruits and vegetables initially high in ascorbic acid retained sufficient vitamin to afford a better, and frequently cheaper, source of vitamin than unheated samples with a low ascorbic acid content. Considerable quantities of vitamin C are lost when the liquid from canned vegetables is discarded. When the syrup from cans is used as well as the fruit the vitamin available to the consumer is frequently greater than the amount yielded by the same weight of raw fruit from market sources.

Raw and canned plant tissues from cheap and expensive sources were compared for their antiscorbutic value in the human diet, and for the cost of the daily requirement at ruling market prices. It was found that a day's ration of ascorbic acid could be purchased at a cost as low as a farthing to as high as a pound.

REFERENCES

Ahmad, B. (1935). Vitamin C value of some common Indian fruits, vegetables and pulses by chemical method. *Ind. J. Med. Res.* **22**, 789–99.

Archer, H. E. & Graham, G. (1936*a*). Some observations on the excretion of ascorbic acid. *Lancet*, **1**, 710–13.

—— —— (1936*b*). Subscurvy state in relation to gastric and duodenal ulcer. *Lancet*, **2**, 364–6.

Bacharach, A. L., Cook, P. M. & Smith, E. L. (1934). Ascorbic acid content of certain citrus fruits and some manufactured citrus products. *Biochem. J.* **28**, 1038–47.

Birch, T. W., Harris, L. J. & Ray, S. N. (1933). Microchemical method for determining the hexuronic acid (vitamin C) content of foodstuffs. *Biochem. J.* **27**, 590–4.

Boas Fixsen, M. A. & Roscoe, M. H. (1938). Tables of vitamin content of human and animal foods. *Nutrit. Abstr. Rev.* **7**, 823–67.

—— —— (1940). Tables of the vitamin contents of human and animal foods. *Nutrit. Abstr. Rev.* **9**, 795–861.

Bracewell, M. F., Hoyle, E. & Zilva, S. S. (1930). Antiscorbutic potency of apples. *Biochem. J.* **24**, 82–90.

Bracewell, M. F., Kidd, F., West, C. & Zilva, S. S. (1931). Antiscorbutic potency of apples. *Biochem. J.* **25**, 138–43.

Bukin, V. N., Povolotzkaya, K. L. & Onokhova, N. P. (1934). Presence of the anti-scorbutic vitamine in northern varieties of fruits, berries and vegetables. *Nutrit. Abstr. Rev.* 1935, **4**, 519.

CAMPBELL, M. E. D. & CHICK, H. (1919). The antiscorbutic and growth promoting value of canned vegetables. *Lancet*, **2**, 320–4.

DANIEL, E. P. & MUNSELL, H. E. (1937). Vitamin content of foods. *Misc. Publ. U.S. Dep. Agric.* no. 275.

DANIEL, E. P. & RUTHERFORD, M. B. (1936). Effect of home canning and storage on the ascorbic acid content of tomatoes. *Food Res.* **1**, 341–7.

EDDY, W. H., KOHMAN, E. F. & CARLSSON, V. (1926). Vitamins in canned foods. IV. Green Peas. *Industr. Engng Chem.* **18**, 85–9.

FUJITA, A. & EBIHARA, T. (1939). Über die kolorimetrische Bestimmung des Vitamins C. *Biochem. Z.* **300**, 136–47.

GARRETT, O. F., TUCKER, H. H. & BUTTON, F. C. (1938). Relation of colour and ascorbic acid to flavour in milk from individual cows. *J. Dairy Sci.* **21**, 121–6.

GOTHLIN, G. F. (1934). Human daily requirements of dietary ascorbic acid. *Nature, Lond.*, **134**, 569.

GUHA, B. C. & SEN-GUPTA, P. N. (1938). Ascorbigen in plant and animal tissues. *Nature, Lond.*, **141**, 974.

HAHN, F. V. VON & SCHEUNERT, A. Cited by Tillmans (1932). *Z. Untersuch. Lebensm.* **63**, 241.

HARRIS, L. J. (1938). *Vitamins in Theory and Practice*, 3rd ed., 242 pp., 66 figs. Camb. Univ. Press.

HARRIS, L. J. & RAY, S. N. (1933). Specificity of hexuronic (ascorbic) acid as an anti-scorbutic factor. *Biochem. J.* **27**, 580–9.

HAWKSLEY, J. C. (1939). A case of pellagra treated with nitotinic acid. *Lancet*, **1**, 944–5.

IJDO, J. B. H. (1936). The influence of fertilisers on the carotene and vitamin C content of plants. *Biochem. J.* **30**, 2307–12.

KARK, R. & LOZNER, E. (1939). Nutritional deficiency of vitamin K in man. *Lancet*, **2**, 1162–3.

KLODT, W. & STIEB, B. (1938). Über die Oxydationsgeschwindigkeit natürlichen und synthetischen C-Vitamins unter der Einwirkung der üblichen Nahrungsmittelzubereitung und Konservierung. *Arch. exp. Path. Pharmak.* **188**, 21–34.

KOBAYASHI, C. & DOI, J. (1937). Seven cases of scurvy in adults. *J. Orient Med.* **27**, 120.

KOHMAN, E. F., EDDY, W. H. & CARLSSON, V. (1925). Vitamins in canned foods. III. Canned Spinach. *Industr. Engng Chem.* **17**, 69–74.

KOHMAN, E. F., EDDY, W. H. & HALLIDAY, N. (1928). Vitamins in canned foods. Strawberries. *Industr. Engng Chem.* **20**, 202–4.

KOHMAN, E. F. & SANBORN, N. H. (1937). Vegetal reduction of dehydroascorbic acid. *Industr. Engng Chem.* **29**, 1195–9.

KRÖNER, W. & VÖLKSEN, W. (1938). Die Verteilung des vitamins C in der Kartoffel-knolle. *Vorrats. Lebensm.* **1**, 693–9.

LASSABLIÈRE, P. & UZAN, M. (1938). Vitamin C content of oranges from the Paris market. *Rev. Med. Hyg. Trop.* **30**, 109.

LAZARUS, S. (1937). Vitamin C nutrition in cases of haematemesis and malaena. *Brit. med. J.* **2**, 1011–15.

LEVERTON, R. M. (1937). Ascorbic-acid content of bananas at three stages during ripening. *Food Res.* **2**, 59–63.

LEVY, L. F. & FOX, F. W. (1935). Antiscorbutic value of some South African foodstuffs as measured by their indophenol reducing power. *S. Afr. med. J.* **9**, 181–6.

MACLINN, W. A., FELLERS, C. R. & BUCK, R. E. (1937). Tomato variety and strain differences in ascorbic acid content. *Proc. Amer. Soc. Hort. Sci.* **34**, 543–52.

MACK, G. L. (1936). The state of ascorbic acid in plant tissues. *Nature, Lond.*, **138**, 505.

MCHENRY, E. W. & GRAHAM, M. (1935*a*). Observations on estimation of ascorbic acid by titration. *Biochem. J.* **29**, 2013–9.

—— —— (1935*b*). Estimation of ascorbic acid by titration. *Nature, Lond.*, **136**, 871.

Mathiesen, E. (1939). Variations in vitamin C content of potatoes. *Nord. Med.* **1**, 42–4.

Olliver, M. (1936). The ascorbic acid content of fruits and vegetables with special reference to the effect of cooking and canning. *J. Soc. Chem. Industr.* **55**, 156.

—— (1940). Antiscorbutic values of fruits and vegetables. *Lancet*, **2**, 190–3.

Oskima, Y., Yamamoto, R. & Fukuzaki, T. (1937). Vitamin C contents of some fruits and vegetables of Formosa. *J. Soc. Trop. Agric.* **9**, 156–61.

Paech, K. (1938*a*). Die Verteilung der Ascorbinsäure in der Kartoffelknolle. *Biochem. Z.* **298**, 307–11.

—— (1938*b*). Über den vitamin C-Gehalt deutscher Äpfel. *Z. Untersuch. Lebensm.* **76**, 234–9.

Platt, R. (1936). Scurvy as the result of dietetic treatment. *Lancet*, **2**, 366–7.

Roberts, J. A. (1937). Vitamin C in citrus-juice beverages and canned grape-fruit juice. *Food Res.* **2**, 331–7.

Rudra, M. N. (1936). Distribution of vitamin C in different parts of common Indian food-stuffs. *Biochem. J.* **30**, 701–3.

Scheunert, A. & Reschke, J. (1938). Effect of method of preparation and use of cooking box on vitamin C content of some vegetables. *Vorrats. Lebensm.* **1**, 238–43.

Stone, W. (1937). Ascorbic acid oxidase and state of ascorbic acid in vegetable tissues. *Biochem. J.* **31**, 508–12.

Tauber, H. (1936). Stability of vitamin C, and absence of ascorbic acid oxidase in citrous fruits and milk. *Proc. Soc. exp. Biol., N.Y.*, **35**, 422–3.

Thornton, N. C. (1938). Extraction and determination of vitamin C in plant tissues. *Contr. Boyce Thompson Inst.* **9**, 273.

Tillmans, J., Hirsch, P. & Jackisch, J. (1932). Das Reduktionsvermögen pflanzlicher Lebensmittel und seine Beziehung zum Vitamin C. 3. Der Gehalt der verschiedenen Obst- und Gemüsearten an reduzierendem Stoff. *Z. Untersuch. Lebens.* **63**, 241–67.

Tripp, F., Satterfield, G. H. & Holmes, A. D. (1937). Varietal differences in the vitamin C (ascorbic acid) content of tomatoes. *J. Home Econ.* **29**, 258–62.

Van Eekelen, M. (1935). Estimation of ascorbic acid by titration. *Nature, Lond.*, **136**, 144.

Young, J. Bruce (1938). Adult scurvy associated with vitamin B_1 deficiency. *Lancet*, **1**, 1385–7.

Zilva, S. S., Morris, T. N. & Perry, E. O. V. (1935). The preservation of vitamin C in canning fruits and vegetables. *Rep. Food Invest. Bd for* 1934, pp. 203–5.

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