Summary and Conclusions

The losses of nutrients in the cooking and plate waste of milk, eggs, fish and meat and the losses in the storage and preparation of vegetables have been studied. Records are presented also of waste in school and other canteens.

The waste in boiling milk is about 10 per cent. Scrambling is the most wasteful method of cooking eggs. Thermostatically controlled pans would reduce the waste in cooking eggs.

The filleting of fish in shops would ensure more economic use of the whole fish.

Plate waste of meat may be as high as 30 per cent. of cooked meat. Fat should be removed from plates before vegetables are served, or it should not be served. Imported meat has a higher plate waste than home fed.

Plate waste in school canteens includes 7 per cent. of the protein and 7 per cent. of the fat served. In a college canteen the waste of protein was 11 per cent. and of fat 5 to 10 per cent. In a Government canteen 6 per cent. of protein and 3 per cent. of fat served were wasted.

The wastage of vegetables is greatly increased by wilting in storage. Marketing methods are in great need of improvement. Some system of local market gardens should be adopted so that consumers in large towns could buy their vegetables fresh. Schools and institutions should have their own gardens.

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Loss of Nutrients in Cooking

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Introduction

Scattered through the literature are many papers dealing with the losses suffered by foodstuffs during cooking. Most of these deal with the more readily estimated of the inorganic constituents and vitamins, some by analysis of one or two substances in a variety of foods, others by detailed study of one or two closely related foods. It is difficult to find, or to build up, any general view of the subject, partly because of the very great differences in chemical and anatomical structure between the various classes of foodstuffs, partly because the substances which are, or may be, lost are of such varying chemical nature, partly because of the variety of cooking methods which involve differing physico-chemical processes, partly because cooking losses may be qualitative as well as

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quantitative, and partly because it is not easy to disentangle unavoidable losses inherent in the process from those due to faulty cooking technique.

It is difficult to decide how the available data may best be considered and presented. It is not claimed that the one adopted, of considering foods in three separate classes, vegetables and fruits, meat and fish, and cereals, would be the best under all circumstances, but it does offer certain conveniences for the purpose in view. Nevertheless, it must be remembered that this arrangement may well lead to the making of statements which, though generally true, are subject to exceptions which it may not always be possible to specify. It is perhaps well, also, to utter the reminder that cooking processes may lead to gain in nutritive value, both quantitative and qualitative, as well as to losses, although it is not part of the purpose of this paper to discuss these gains.

Vegetables and Fruits

When vegetables are cooked by boiling or steaming, the changes in quantitative composition seem to be the resultant of three actions, the relative importance of which may vary widely: shrinkage due to collapse of the cell walls and extrusion of the juices, leaching by the boiling water or condensed steam, and hydration.

Many vegetables, when steamed, suffer little or no loss, whether of total weight or of water soluble constituents, and it is noteworthy that potatoes are included among these. There is, in these cases, no extrusion of juices, the amount of condensation is insufficient for appreciable leaching or hydration and, in saturated water vapour, as in boiling, there is naturally no evaporation. Other vegetables, including root vegetables such as carrots, swedes, and parsnips, lose up to 30 per cent. or thereabouts of their water, the amount depending on the temperature of the steam and the time of cooking, with an approximately equal percentage loss of their water soluble constituents. In these, shrinkage with extrusion of juices seems to be the main factor. In still others, *e.g.*, Brussels sprouts and cabbage, the losses appear to be small, but cannot readily be evaluated since the anatomical structure is such that extruded juices remain trapped in the spaces between the leaves. Since, however, these juices must be eaten with the leaves the point is only of theoretical interest.

Boiling vegetables in water obviously increases the chances of hydration overcoming the tendency to shrinkage by extrusion or diffusion from the dead cells, and, in fact, boiling results in little or no change in weight. The opportunity for leaching is, however, much greater than in steaming and, accordingly, the losses of water soluble constituents are considerable and increase with the duration of cooking as well as, to some extent, with the volume of water. Thus McCance, Widdowson and Shackleton (1938), found that potatoes, boiled in about twice their volume of distilled water for 25 minutes, suffered no appreciable loss of weight, lost only 1 or 2 per cent. of their starch and protein, but 16 per cent. of their magnesium, iron, and reducing sugars, 18 per cent. of their potassium, and 22 per cent. of their chlorine. The losses of water soluble salts from some other vegetables during the normal cooking time were much greater, for example, 70 per cent. of chlorine from runner beans, 40 per cent. of chlorine and of potassium from carrots, and, since in these cases also the total weight and the water insoluble constituents remained

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relatively unchanged, the main cause of loss appeared to be the leaching action of the water.

It may be objected that these results were obtained by boiling the vegetables in distilled water. Ordinary tap water contains small amounts of various salts and in ordinary practice it is common to add others, *e.g.*, sodium chloride and, in the case of green vegetables, sodium bicarbonate. Several early workers have claimed that sodium chloride reduces the cooking losses from various vegetables (*e.g.*, Bodinus, 1915; Griebel and Miermeister, 1926), though this was denied by others (*e.g.*, Masters, 1918; Lang, 1930; Clifford, 1931). McCance *et al.* (1938), showed that potato, cooked in 2 per cent. NaCl solution, absorbed sodium and chlorine, but lost potassium to the same extent as in distilled water, a result to be expected on the supposition that the salt losses during boiling are due to leaching and one which, they point out, results in a most useful change in the K:Na ratio from 435 : 5 to 355 : 103.

The loss of calcium during the boiling of vegetables is generally much less than that of potassium, and may be nil, because calcium so readily forms insoluble salts which are not removed by leaching. Ziegelmayer (1931) reported that whereas potatoes* lost some 25 per cent. of their calcium when boiled in distilled water, they might even gain up to 300 per cent. in very hard water. McCance *et al.* (1938), doubt whether such increases ever occur in practice, but substantial increases in the calcium content of green vegetables have been observed to occur in practice and to be reproducible by using water of a hardness found in some parts of the country (unpublished observations by the author). Similar increases in the iron content of vegetables have also been found, probably when weak acids liberated during the cooking have dissolved iron or iron salts from the cooking vessels.

Calcium salts have been shown to delay the "cooking" (*i.e.*, the softening) of vegetables (Viswanath, Row and Ayyangar, 1914–16; Ziegelmayer, 1931) and the softening of hard water may be one cause of the accelerating effect of sodium bicarbonate. Sodium bicarbonate, by raising the *p*H of the water, seems to increase somewhat the loss of water soluble salts, but this effect is not great and is almost compensated by the shortening of the cooking time (McCance *et al.*, 1938); by precipitating calcium salts and so immobilizing them it tends to decrease rather than increase the loss of this element.

Baking and frying, so far at least as potatoes are concerned, appear to result only in loss of water, the process being one of evaporation.

It is evident that cooking in air or fat must be regarded as the most conservative method of cooking vegetables so far as the inorganic constituents are concerned, that steaming ranks next and is almost equal in the case of, *e.g.*, potatoes; while boiling results in considerable losses of all water soluble constituents. Boiling with a very small volume of water is really partly boiling and partly "steaming". It is, however, worth while, as McCance *et al.* (1938) have pointed out, to consider what these losses, which seem so large when expressed as a percentage of the amounts present in the raw vegetables, really amount to in terms of actual

* Potatoes boiled with the skins intact suffer no appreciable loss, even of soluble salts.

quantities in relation to the daily intake. Table 1 shows the actual loss of various substances from 150 g. potato, 50 g. carrots and 50 g. green peas boiled for the normal time, and contrasts them with the approximate daily intake. Since these amounts represent at least the average daily consumption of vegetables, it is evident that the cooking losses cannot be regarded as dietetically important.

TABLE 1

LOSS OF CERTAIN CONSTITUENTS IN THE BOILING OF VEGETABLES COMPARED WITH THE DAILY INTAKE OF THESE CONSTITUENTS

Vegetable	Amount g.	Loss mg. Na	K	Ca	Fe	P	Carbohydrate g.
Potatoes ..	150	—	144	1·0	0·27	4·5	0·14
Carrots ..	50	30	40	3·4	0·10	2·0	0·95
Green peas ..	50	—	76	0·75	0·20	10·5	1·15
	Total	30	260	5·15	0·57	17·0	2·24
Daily intake ..		mg. 4600	mg. 3400	mg. 700	mg. 14	mg. 1400	g. 300

Though the losses of minerals, as well as of carbohydrate and protein, during the cooking of vegetables appear to be of little nutritional importance, that is merely because these foods are very minor sources of those substances of which the percentage losses are or may be considerable. The position is, especially in war time, very different with respect to certain vitamins of which vegetables form a major source of supply. A survey of the scattered literature suggests that vitamin losses during the cooking of vegetables are due to the same causes as losses of salts, *i.e.*, that they are due largely to leaching. Some of the vitamins, however, are chemically unstable and subject to destruction under the conditions of cooking, so that in these cases some part of the vitamin is actually destroyed.

The water insoluble vitamins or provitamins appear to be little affected by cooking; this at least has repeatedly been found to be true of carotene (Fraps, Meinke and Kemmerer, 1941; Oser, Melnick and Oser, 1943). Water soluble vitamins appear to be lost by soaking out and the loss of them is, so far as this cause is concerned, affected by the same factors which affect the loss of minerals, but because of the destructive effects of cooking on the less stable members of this group, losses are much more variable than in the case of salts and are affected by factors which have little effect on salt losses. There is, for example, ample evidence that the volume of cooking water has a great effect on the losses of ascorbic acid and other water soluble vitamins (Olliver, 1941; Oser *et al.*, 1943; Ireson and Eheart, 1944; Van Duyne, Chase, and Simpson, 1944). Losses are least, other things being equal, when the volume of water is kept at a minimum and therefore when steaming is substituted for boiling. For potatoes, cooking without water, *i.e.*, roasting, baking,

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or frying, gives the greatest retention of vitamin C and, when boiling is used, retention of the skin affords considerable protection against leaching (Esselen, Lyons and Fellers, 1942). Vitamin B_1 and ascorbic acid are both subject to destruction, the former being heat labile especially at high *p*H, the latter subject to oxidation catalysed by copper and by certain enzymes, this also being more rapid at *p*H above 6. Accordingly, the losses are greater if cooking is slow, and especially by the initial raising of the temperature before enzymes have been destroyed (Allen and Mapson, 1944). The destruction of ascorbic acid and vitamin B_1 appears to continue after cooking is complete and the vegetables, exposed to air, await serving. Thus Nagel and Harris (1943) found that in large scale cooking, potatoes lost 35 per cent. of their vitamin B_1 and 45 per cent. of their ascorbic acid; after standing on the hot plate these losses were increased to 70 and 75 per cent., respectively. Similarly, Kahn and Halliday (1944) found that, although potatoes steamed in their skins lost little or no ascorbic acid even after 50 minutes on the hot plate, baked potatoes lost 20 per cent. of their ascorbic acid during cooking and a further 39 per cent. after 43 minutes on the hot plate, while steamed potatoes which had lost 39 per cent. during cooking lost nearly all the remainder when mashed and allowed to stand (*cf.* Esselen *et al.*, 1942).

The seriousness of this from the nutritional point of view is shown by the following data. Analyses during April of this year showed that, given good cooking (boiling) and rapid serving, 150 g. whole potato may supply 9 to 10 mg. of ascorbic acid, and 50 g. of cabbage a like amount, a total of two-fifths of the amount suggested as a reasonable daily intake. If, however, the potatoes are mashed and the vegetables are kept hot for $\frac{3}{4}$ to 1 hour before serving, the total amount of ascorbic acid derived from them may be reduced to 2 to 3 mg.

Meat and Fish

McCance and Shipp (1933) published the results of a careful study of the water, salt, protein and fat losses incurred in cooking flesh foods. These investigators found that when heat to over 60° C. is applied to flesh foods, there is shrinkage of the fibres, which tends to be greater the higher the temperature, and expression of juices; this occurs irrespective of the mode of cooking, and is the most important single source of loss of soluble salts. When meat is boiled, there may be additional salt loss by diffusion; when it is cooked in air or fat, water loss by evaporation is so great that salts are left on or near the surface and so tend to be conserved. Protein losses are very variable and depend on many factors, the type of flesh food (the kidney, for example, loses more than muscle), mode of cooking (more being lost in boiling than in steaming, and roasting causing the least loss), duration and temperature of cooking, and so on. They are not negligible, figures of the order of 7 per cent. having been reported for boiled beef, and up to 20 per cent. for boiled or steamed kidney. Fat losses are due simply to liquefaction and consequent leakage; they are, therefore, very variable, rising to 40 per cent. or more.

It is very difficult to assess the practical importance of these losses. The amounts of soluble salts, though they appear large when expressed as percentages of the amounts present in the raw food are relatively insignificant in relation to the total daily intake. The 20 per cent. or so of iron which is lost may be more serious but there is a suggestion in Odham's (1941) studies of anaemic rats that it is partly compensated by an increased "availability" of the iron caused by cooking. The evaluation, from the nutritional standpoint, of cooking losses is further complicated by the facts that drippings from meat are partly or wholly eaten as gravies or, in the case of fat, used for other cooking purposes, while the cooking water from boiled meats is generally used for soup preparation.

The quantitative loss of protein has already been mentioned; there exists also the possibility of a qualitative loss. Although McCance and Shipp (1933) summarize the earlier literature by stating that "however it is cooked, meat has been shown to be completely digested and to lose little, if any, of its nutritive value", there is some evidence to the contrary. Kapp (1937) showed that the digestibility of meat *in vitro* was reduced from 86 per cent. to 60 to 64 per cent. by stewing, boiling or grilling, and to 51 per cent. by roasting. Morgan and Kern (1934), using both nitrogen balance and growth methods, found a decrease in the nutritive value of beef muscle protein boiled normally or at 15 lb. pressure. The known effects of dry heat on cereal proteins or milk proteins suggest that roasting or deep frying may well produce similar decreases in the nutritional value of meat protein. The information available, however, is insufficient for more than a warning that, in considering the cooking losses of flesh foods, the possibility of qualitative changes must be taken into account.

Meat is an important source of certain vitamins of the B group. Fortunately most of these substances are moderately heat stable and so, though losses occur by the same mechanism as that which brings about losses of water soluble salts, actual destruction is not very great, and a considerable part of the "lost" vitamins can be found in the drippings. It seems to be fairly generally agreed (*e.g.*, McIntire, Schweigert and Elvehjem, 1943; McIntire, Schweigert, Henderson and Elvehjem, 1943; Cover, McLaren and Pearson, 1944) that the loss of vitamin B_1 from beef, veal, pork or cured ham, ranges from 20 to 50 per cent. according to the method and duration of cooking, with a net destruction of about 20 to 25 per cent. With an average daily intake of 100 g. of meat and an average vitamin B_1 content of 100 I.U. per 100 g. raw meat there would be a maximum daily cooking loss of about 50 I.U. of vitamin B_1; this could only be serious if, owing to the exclusive use of low extraction cereals, meat were promoted from a minor to a major source of vitamin B_1.

The better known members of the vitamin B_2 complex are more resistant to heat than vitamin B_1; the losses of these substances appear, as would be expected, to be smaller. Thus, according to the workers quoted for vitamin B_1 losses, the loss of riboflavin ranges from 15 to 25 per cent. (0 to 13 per cent. if the drippings are included); that of nicotinic acid from 15 to 35 per cent. (0 to 10 per cent. including the drippings) and of pantothenic acid from 10 to 25 per cent. According to Schweigert, Nielsen, McIntire and Elvehjem (1943), 80 per cent. of the biotin of meat survives cooking. These losses do not seem very serious, and since they do not seem to be due to faulty technique, they must be regarded as the unavoidable penalty of a preference for cooked rather than raw meat.

Cereals

The ways in which cereal foods are prepared and cooked are not such as to lead to losses of inorganic constituents or of protein, fat and carbohydrate, though, as in other cases, the application of dry heat may sometimes change the nutritive value of the proteins.

Cereal foods are important sources of certain vitamins of the B group; some of these are stable to heat, but others are not and are therefore susceptible to destruction in baking. Thus riboflavin is heat stable and losses in cooking are said to be negligible (Andrews, Boyd and Terry, 1942) though, since the substance is destroyed by light, exposure of cut slices of bread may result in some loss. Vitamin B_1, on the other hand, is more readily destroyed by heat, especially at high *p*H. Dawson and Martin (1942) state that white bread, made with a vitamin rich yeast, loses about 8 per cent. of its vitamin B_1 in baking, bread from 85 per cent. extraction flour about 27 per cent., and wholemeal bread about 35 per cent.; Schultz, Atkin and Frey (1942) give the average baking loss as 20 per cent. under normal large scale conditions and add that the loss is greater in the crust than in the crumb. There is, it appears, increasing loss with increasing temperature and various workers have called attention to the extra loss in toasting bread (*e.g.*, Downs and Meckel, 1943) and in biscuit making (*e.g.*, Barackman, 1942). The effect of *p*H on loss of vitamin B_1 is shown by the greater loss involved in the use of baking powders than in that of yeast. Thus, Wilson (1942) reported that yeast bread contained 2·1 I.U. vitamin B_1 per g., whereas comparable bread made with baking powder, with cream of tartar as the acid constituent, contained only 1·3 I.U. per g. Barackman (1942) found that when "self raising" flours were used for biscuit making,with water mixing, the *p*H was 8·5 and the vitamin B_1 loss 51 per cent.; at *p*H 6·7, however, the loss was only 9 per cent. Decreased loss, with lowered *p*H, was obtainable by using milk for mixing, or by adding acid calcium phosphate to the flour. It seems that, as one would expect from the known behaviour of pure vitamin B_1, the loss in cereal cooking is minimized by preserving as low a *p*H as possible and by avoiding excessive heating. This probably applies also to certain members of the vitamin B_2 complex, the stability of which resembles that of vitamin B_1.

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Discussion

Dr. J. C. Thompson (Food Research Laboratory, Barkers (Contractors), Ltd., c/o Morris Motors, Ltd., Cowley, Oxford), opener: The problem of the loss of ascorbic acid in food is one which has aroused considerable interest in recent years, particularly with food prepared on a large scale as for industrial canteens and British Restaurants. This is because there are certain processes peculiar to large scale catering which can cause the loss of considerable amounts of ascorbic acid.

Although the emphasis is on ascorbic acid because more estimations of the ascorbic acid content of foods have been made and more is known of its properties, this is simply because it is the easiest of the readily lost vitamins to estimate. As it is one of the most readily destroyed, and as the properties which lead to its disappearance from food, *i.e.*, by being soluble in water, by being heat labile and by destruction by alkalis, are equally shared by other vitamins, particularly vitamin B_1 and members of the vitamin B_2 complex, it is safe to assume that if the ascorbic acid content of vegetables is satisfactory, the content of the other vitamins is assured. There are of course obvious exceptions to this assumption, *e.g.*, dried legumes are rich in vitamin B_1 but are devoid of ascorbic acid.

The methods of cooking vegetables so as to conserve the greatest amount of ascorbic acid have been widely advertised by the Ministry of Food. They may be summarized as follows. All vegetables should be prepared, cooked and served as quickly as possible and with the minimum physical destruction of the vegetables, *e.g.*, cabbage should be coarsely shredded with a sharp knife and potatoes should not be mashed. Expensive cooking, that is cooking involving large material waste, such as the discarding of the outer green leaves of cabbage and the peel of potatoes, or high fuel consumption because of the huge quantities of water used, produces food of inferior nutritive quality.

There are two aspects of large scale cooking I would like to mention, the use of bicarbonate of soda in the cooking of greens and the storage of food in the hot plate.