add to the palatability of soup. The next question is, does Dr. Stewart approve the recommendations of the Ministry of Food for cooking green vegetables in as little water as possible? He mentioned the question of the effect of cooking on the digestibility and nutritive value of proteins. The effect might be different with different foods since it is different with different feeding stuffs. It is necessary to heat cottonseed meal to render it non-toxic, but heating it to temperatures which make soya bean meal palatable and digestible greatly reduces the feeding value. I do not know whether any similar problem arises with regard to the proteins of human foods. On the question of the loss of vitamin B_1 in cooking, the main issue appears to be that, unless overmilled cereals and sugar are used, even with a 50 per cent. loss you would not reduce the proportion of vitamin B_1 to calories below the required level. It is the use of sugar and white bread that makes it necessary to take account of destruction of vitamin B_1.

Dr. C. P. Stewart replied: If cabbage is to provide an important part of the vitamin C supply it might be best to eat it, or part of it, raw. The losses in cooking are by oxidation and by leaching. The more quickly the cabbage is heated to boiling, *i.e.*, the greater the volume of boiling water, the less will be the loss by oxidation but the greater the loss by leaching. The best results are got by a compromise. In my experience the maximum amount of vitamin C is conserved if the pan is just the size to take the vegetable packed and covered with water.

Whether vitamin C is got from cabbage or other cooked vegetables, or salads is largely a matter of taste. It is not difficult to get 50 mg. a day, but since the requirement is probably nearer 15 mg. and potatoes can supply 15 to 20 mg. even at the worst time of year, there seems to be no reason to force people to eat either cabbage or raw salads.

A great deal more work is required on the value and digestibility of different proteins and the effect of cooking. The losses of vitamin B_1 in cooking are of no significance so long as we do not return to 70 per cent. extraction bread.

Losses of Nutrients in the Conservation of Farm Produce and of Animal Feeding Stuffs

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The preservation of foodstuffs for the use of farm stock in winter is one of the most important aspects of agriculture. The crops grown for this purpose have to be stored on the farm and can be divided into three main classes. There are the crops which are grown primarily for their seeds, such as the cereals and pulses; then come the root crops and, perhaps the most important of all, the green crops such as grassland herbage.

The practice in this country has been for the farmer to store also the foodstuffs which are used for direct human consumption and on him fall all the risks of storage of such crops.

Despite the importance of storage processes to the agricultural industry

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it is surprising what a dearth of accurate information there is on the losses which are associated with the conservation of farm crops. This does not mean that the processes are not efficient; experience has resulted in the development of sound methods, but there is still much to learn if the losses are to be kept to a minimum.

Cereals

Of the crops grown for their seeds the cereals are the most important and the problems which they present are fairly simple. In addition to the seed there is of course the straw and this looms large in the agricultural bill of fare, particularly oat straw.

The first question which is met in the storage of cereals is as yet unanswered. Should the grain be stored in the stack until it is wanted or should the crop be threshed and the grain stored in bins? The problem does not affect the grain alone, because many feeders will tell you that their cattle do better on freshly threshed straw. No reason has been put forward for this, but when one sees how the straw is broken at threshing it is conceivable that moulds are able to develop more freely on the threshed and broken straw than on the clean unbroken straw in the sheaf; old straw at any rate is more apt to be musty than when it is first threshed.

Oats are the most important grain for feeding on the farm and newly harvested oats must be fed with caution especially if the moisture content is high, since digestive troubles may often follow their use. At this time the constituents of the grain are still in process of transformation to the reserve products which are found in the mature grain. It is probable that these intermediate substances are the cause of the digestive disturbances associated with the use of new oats.

Cereal grains generally, if well ripened, are stored without much trouble. They are usually kept in shallow heaps on the granary floor and may be turned from time to time. The advent of the combine harvester has added somewhat to the troubles of storage of cereal grain on the farm. The crop is cut and threshed immediately and the grain is then, in Scotland at least, too high in moisture to be stored without drying to a safe level. This calls for a special dryer, and storage bins have to be designed so that the grain can be turned or have a current of air blown through it.

If the moisture is too high the grain will "heat", this being due to an acceleration of the respiration which is always going on in the seeds. Kellner (1915) quotes an experiment in which 50 g. samples of oats containing 2·5, 11·2, 17·0 and 17·8 per cent. of water gave out over a period of three weeks 0·2, 3·1, 24·7 and 35·1 ml. of carbon dioxide, respectively. He also points out that moist grain in bulk suffers from the further disadvantage that, as a consequence of the rise in temperature, part of the water passes off as steam and condenses on the cooler parts of the store causing moulds to form. It is said that it is therefore inadvisable to store grain in such holders if the moisture content exceeds 13 to 14 per cent. Normally when grain is kept in shallow heaps the loss due to moulds is avoided.

In the stack the grain dries slowly and if it has been harvested in good condition little trouble is to be expected when it is subsequently threshed, and storage in bulk is easier. In countries such as Canada where moisture contents at harvest are low, storage in bulk presents less difficulty.

As might be expected, respiration increases with temperature and the cooler the store the lower the losses are likely to be.

The available evidence seems to show that in the course of a year oats lose some 6·5 per cent. of the original carbon present as a result of respiration, which would mean a loss of the order of 15 to 20 per cent. of the dry matter.

Losses in crushed or ground cereal grains are likely to be much greater and the chances of insect attack also are increased considerably. The losses due to vermin and insect attack vary according to the nature of the store and no figure can be given to cover this contingency, but under bad conditions they may be very large.

The remarks made on the cereal grains apply equally well to the pulses such as beans and peas.

If stored in a dry place the straw and the other thresher residues such as chaff and cavings keep fairly well, but the last are liable to become mouldy as time goes on. The palatability of all these by-products falls with time but no data are available to show the nature of the changes which take place. Bean and, to a less extent, pea straws mould more readily, probably because the nitrogen they contain provides a better medium in which the organisms can grow.

Root Crops

The root crops such as potatoes, turnips and mangolds also undergo the process of respiration and during the storage period constant internal changes are taking place. The losses in the potato fall chiefly upon the starch of which a quantity is always being turned into sugar. At normal and higher temperatures this is not easily seen since the sugar is used up rapidly. When the tuber is frosted the respiration rate is lowered and the sugar content of the potato increases. Kellner (1915) has shown that where potatoes were kept at 0° C. the sugar rose from 0·51 g. after 3 days to 18·53 g. after 30 days, and 30·3 g. after 60 days. At 3° C. the rate of formation of sugar was much lower and at 8 to 10° C. there was no storage of sugar.

When frosted potatoes are thawed the sugar disappears rapidly and often degenerative changes supervene and rotting may set in. The precise physical effect of freezing is not known, but the permeability of the protoplasmic layer of the cells seems to be increased and micro-organisms can develop freely.

Kellner quotes mean losses after five months' storage of 8 per cent. in weight, varying from 3·8 to 20·4 per cent., to which had to be added a further loss of 4·2 per cent. due to disease. It is said that carefully stored potatoes lose 1·3 per cent. of their weight per month and when the tubers begin to sprout the losses increase considerably until by June they may have lost from 15 to 20 per cent. of their weight. Flegel (1931) found that storage in the clamp up to April resulted in a loss of 14·4 per cent. of the weight while in a cellar the loss was 22·4 per cent. By September the losses had risen to 63·5 and 76·3 per cent., respectively. Norwegian data (Isaachsen, Ulvesli and Husby, 1936) show much lower losses, potatoes stored in a cellar losing 7 per cent. of dry matter in 117 days, rising to 13 per cent. after 227 days. Kirsch and Jantzon (1932) showed that the losses in potatoes were similar whether they were stored in a clamp or a cellar. By April the potatoes had lost 11·2 and 14·8 per cent., respectively, in total weight, the values for dry matter being 4·2 and 19·1 per cent. The losses of dry matter had risen to 13·6 per cent. in the clamp and 25·8 per cent. in the cellar by June and were 45·8 and 53·0 per cent. by September. Respiration was responsible for 10·6 and 10·1 per cent. of the total losses in April, the losses due to disease being 0·6 per cent. in the clamp and 4·7 per cent. in the cellar. The losses due to this cause rose till in September, of a total loss in weight in the clamp of 53·1 per cent., 26·6 per cent. was due to disease and, in the cellar, disease accounted for 26·4 per cent. of the total loss of 54·7 per cent. Determinations of the different constituents were made and in the clamped potatoes it was found that by April 24·8 per cent. of the starch was lost; in June the figure was 40·4 per cent. and it had risen by September to 59·2 per cent.

It is clear that there is a considerable loss in weight of potatoes during storage and a relatively lower loss of dry matter, showing that the major loss is that of water, though the loss in nutrients is appreciable. The main possibility of further loss during storage is disease and there is no doubt that the control of disease in clamps would be of the greatest economic advantage to agriculture. Efforts to achieve this by disinfection are being made and every effort should be directed to the control of diseases such as "blight" during the growing period, and towards the improvement of harvesting methods. Bad harvesting results in injuries to the tubers, each of which is a focal point for attack by the soil borne organisms.

The potato has been the most valuable source of vitamin C during the present war and it is of interest to trace the fate of this factor during storage. American (Thiessen, 1936) and German (Kröner and Steinhoff, 1937) work has shown that the vitamin C content fell gradually during storage to about half of its original value, but that it then increased almost to its original value just prior to sprouting. After some months of storage there was still a considerable amount of the vitamin present.

The losses in dry matter and the possibility of marked increases in disease have led to the treatment of potatoes by different conservation processes. In East Prussia where large quantities of potatoes are grown for pig feeding it is common practice to steam the potatoes after washing and then to ensile them by filling into suitable pits, pressing them down and covering with a layer of straw or boards; weights are added, sometimes in the form of a layer of soil. A mild lactic fermentation develops and the resultant product is palatable and as digestible as the original steamed potatoes. The losses are extremely low and, if a proper pit is used, negligible. The steamed potatoes incidentally are more valuable for stock than the raw potatoes largely because of the acrid taste of the raw tubers which reduces the palatability slightly.

Dehydration is the obvious theoretical solution to the conservation of potatoes and the nutrient content is unaffected by the process so far as farm stock is concerned.

For stock feeding, turnips and mangolds are of greater importance than potatoes. Whereas the potato is usually harvested after the haulm has died down, the other roots are still growing when they are lifted and considerable changes take place during storage. In the early stages there are many translocation products present and there are troubles associated with feeding roots. High mortality in stock is reported where immature roots, principally mangolds, are fed. The cause is unknown though it is often said in the literature to be due to the presence of nitrate nitrogen (Shutt, 1901). This is said to be changed to nitrites in the stomach with fatal results, but no data exist to confirm this. Whatever may be the cause, there is no doubt that the root crops should be kept for a period before they can be fed with safety. At the latter end of the storage period diseased roots should not be fed as they must contain decomposition products which arise from the changes brought about by the organisms responsible for the diseases. These changes are often of a putrefactive nature.

The root crops, even if sound, must respire during storage and, according to Kellner (1915), the losses in mangolds due to this cause after five months totalled 8 per cent. of the dry matter. The moisture content of the root had some effect on losses, and varieties which contained a lot of water lost 9·5 per cent. of the dry matter and 9·1 per cent. of nitrogen free extractives; mangolds of lower moisture content lost only 5·8 per cent. of dry matter and 5·7 per cent. of nitrogen free extractives. Losses in Ireland (Pyne, 1927) were much higher and experiments at the Munster Institute Farm showed a loss of 27 per cent. of the dry matter during the period December to May. Miller (1900, 1902) in England reports losses of 16 per cent. of the dry matter and 20·6 per cent. of the sugar between October and July.

In practice mangolds and turnips keep well if they have been lifted in good condition and are protected from frost, and are a useful food in the latter part of the winter when succulent foods are scarce.

Turnips behave similarly to mangolds and should store as easily.

Richardson and Mayfield (1933) have investigated the storage of swede turnips and state that, under normal conditions, there appeared to be no destructive effect on vitamin B_1 or C whether the swedes were stored under cool and damp, or warm and dry, conditions.

Hay and Grass

The greater part of the winter ration of livestock on the farm, apart from pigs and poultry, is made up of the bulky foods hay and straw. The latter has been dealt with already.

Hay is the form in which the green crops are generally conserved for winter use and the magnitude of the losses is surprising, even under the best conditions.

The herbage at the time of cutting is actively respiring and this continues until the cells are killed in the drying process. Carbon assimilation ceases so that quite extensive losses may arise. Then as the material dries some of the leafy portions tend to break off and are lost, a loss which may be very heavy in the case of some plants, more particularly the legumes. Even when the hay is removed from the field, changes continue and there is always a certain amount of fermentation taking place in the stack.

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In the course of experiments extending over four years under varying weather conditions the total loss was 20 per cent. of the dry matter, 14·3 per cent. being losses in the field and the remaining 5·7 per cent. in the stack (Watson, Ferguson and Horton, 1937). Unfortunately this is not all the story since the respiration and mechanical losses in the field as well as the changes in the stack all affect the most easily soluble, and hence the more digestible, fractions.

The total loss of energy measured as starch equivalent, in the series of trials referred to, was 32·0 per cent., of which 26·7 per cent. was lost in the field. The losses of digestible protein were of a similar order. The lowest loss obtained in this series was one of 10·4 per cent. of the dry matter, with 23·0 per cent. loss of starch equivalent, and 17·0 per cent. loss of digestible protein.

These data agree well with an estimate made by Wiegner (1925) in Switzerland, who estimated the losses in haymaking during good weather at 10 to 30 per cent. of the dry matter, respiration accounting for up to 10 per cent., and mechanical losses and fermentation in the stack, each causing a further loss of 5 to 10 per cent. Where weather conditions are unsatisfactory, the losses may be very much greater than these figures indicate. In countries where good haymaking weather is not to be expected many expedients are used. The partially dried herbage is placed on pyramids, hurdles, posts or specially erected wire fences and allowed to complete its drying there. The main aim in these adaptations of the drying process is to get the herbage into such a form that rain will easily run off the mass, that air will circulate freely and that the material does not become so dry before it is handled that all the valuable leafy portions fall off. In Scandinavia and Northern Europe hay is so essential to winter feeding that these specialized methods of making hay are everyday practice.

The fermentation of hay in the stack may cause serious losses and in extreme cases the temperature developed may be such that spontaneous combustion arises with a resultant total loss. Heated hay, known by its dark colour, is often palatable to stock but the digestibility may be lowered to a very large extent.

Of all the vitamins the only one which seems to be critical so far as the ruminant is concerned is vitamin A, or more properly its precursor, carotene. This substance is present in relatively large amounts in the original fresh herbage, but under the normal conditions of haymaking its destruction is almost complete. The special methods of haymaking outlined above result in less loss of carotene, since the crop is gathered before it has been subjected for too long to the bleaching action of the sun. The quantity of carotene retained under the best of these treatments is not high, though the amount present may be very useful.

To overcome these losses the modern trend has been to develop artificial drying of grassland herbage and this has been accomplished with every success, though the economic picture is not always as satisfactory as might be desired. Artificial drying will give a product of which the digestibility is equal to that of the original grass. The losses are of a very low order since there is no time for respiration to take its toll, and the mechanical loss in the field is avoided, as is also the subsequent fermentation during storage. If drying is efficient the loss will be negligible, but it should be noted that the design of the dryer is of importance. If the material is not removed from the dryer as soon as the dehydration is completed it will be subjected to the action of the hot drying gases and the digestibility of the product and particularly of the protein may suffer. In practice this rarely occurs and is easily identified since the normal green colour of the herbage also is affected by the high temperature. Simultaneously with the loss of green colour in badly dried grass, the carotene is destroyed, whereas in properly treated material it is retained almost unchanged. During subsequent storage of the dried product there may be a loss of carotene which is related to the exposure of the material to the action of air and light. If the grass is properly stored in a cool dark place the losses can be kept to a low level.

In recent years there has been a revival of the old process of ensilage of green crops in which they undergo a controlled fermentation (Watson, 1939). The details of the process are more clearly understood today, control of the changes is more certain and the operation is everyday practice on the farm. The losses are of the order of 20 per cent. of the dry matter and fall evenly on most of the constituents. The nutrient loss is therefore of the same order and is due in the main to respiration and to a lesser extent to loss from leaching of some of the soluble nutrients, together with some breakdown of the fermentable substances by microorganisms. After the original loss there is very little change during storage if a good container has been used to ensile the green crop. The final product is equal in feeding value to the original crop and retains its carotene in a large measure.

Enough has been said to show that the conservation of foodstuffs on the farm will always entail losses, some of which can be avoided by taking the necessary precautions. More information is needed if adequate steps are to be taken to reduce the loss of feeding value of farm crops in the storage period. Until that is done we shall not make the best of our resources or produce the maximum yield of food from the land.

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Discussion

Mr. W. Holmes (Hannah Dairy Research Institute, Kirkhill, Ayr), opener: Dr. Watson has dealt very fully with conservation of home produced feeding stuffs, and I propose to discuss only a few points and

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