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DEHYDRATION OF FOODS AND THE EFFECT ON THEIR NUTRITIONAL VALUE

Morning Session: Chairman, SIR EDWARD APPLETON

Sir Edward Appleton (Department of Scientific and Industrial Research): It was a most happy decision on the part of those who arranged this joint meeting of The Nutrition Society and the Food Group to select for discussion today such an important, interesting and topical subject as the dehydration of food. The papers on this subject which are to be read and discussed will deal with work carried out as part of the programme of the Food Investigation Board of the Department of Scientific and Industrial Research. The experimental part of that programme has been conducted at the Low Temperature Research Station, Cambridge, at the Torry Research Station, Aberdeen, and also at the Dunn Nutritional Laboratory, Cambridge. It will be described by the various groups of scientific workers who have carried it out and are thus responsible for its success.

Nowadays we frequently see and hear, in print and in conversations, discussions concerning the way in which science can be used to further the nation's war effort. An analysis of the role played by science shows that the scientist can play two parts. In the first place he can devote his talents to solving some existing urgent problem for one of the fighting Services or civil departments, or, in the second place, he can look ahead and anticipate a need likely to be felt later and, in this way, have the solution ready in time. When the history of the war is written it is probable that quite a number of anticipations of this kind will be credited to scientists and that this work on the dehydration of food will be counted as not the least important of them.

When the Food (Defence Plans) Department was formed in 1937 it at once sought the assistance of the Department of Scientific and Industrial Research in solving a number of problems. Also, when war broke out, the Food Investigation Board, under the chairmanship of Sir Joseph Barcroft, whom you are to hear this afternoon and to whom I wish to pay a warm tribute for his inspiring and encouraging assistance and co-operation, decided to subordinate its own programme on the wider aspects of food processing to matters connected with our food supply in time of war. It was at once clear to the Board that one of the most important problems was to discover how best to economize transport and labour, and save waste generally, by reducing the volume and weight of foodstuffs and by making possible the storage of foodstuffs at ordinary temperature without refrigeration, and their preservation in transit. This problem had been tackled in a variety of ways with a considerable measure of success, but for war purposes the process had to be carried further. It is a striking fact that in peace time we import, according to Dr. A. J. Smith's estimate, as much as three million tons of water annually as part of our foodstuffs! Clearly the greatest possibility of economizing in storage space lay in the removal of this water which forms such a large part of all fresh foods.

The drying of foodstuffs is not, of course, new. According to Marco Polo, the Tartars dried milk in the 13th century, while the adventure stories we used to read as boys made us familiar with dried meat in the form of pemmican and biltong. Large amounts of vegetables were dried in the last war, but the process was little used in peace time. Dried milk, dried egg, dried fruits and dried salted fish are regular articles of commerce. But, of the dried foodstuffs, meat, fish, eggs and vegetables, with which we are concerned today, it is fair to say that none of them was of a quality suitable for general consumption in place of the fresh article, and that little was known of the factors influencing their palatability, nutritive value and keeping quality. While a good deal of work had been done on the design of the plant for drying, all too little was known of the effect on quality of the pre-drying treatment, of the conditions during drying and of the methods of packing. In fact, Sir William Hardy's famous dictum, that it was necessary to be clear about the biology before coming to the engineering, had not been applied.

Later speakers will tell how the work has been successfully developed as part of the war time effort. It was organized by Mr. Eric Barnard, Director of Food Investigation, and carried out, chiefly at Cambridge, under the scientific leadership of Dr. Kidd, who is to read the first paper on the programme. In this connexion special mention must be made of the friendly co-operation which the Cambridge Low Temperature Research Station has received from the Dunn Nutritional Laboratory, also in Cambridge. It was clear that no drying process could be accepted which led to a marked diminution in nutritive value and, therefore, with the kind permission of Sir Edward Mellanby, the Dunn Nutritional Laboratory joined in the work to ensure that the processes of dehydration should not be destructive of the nutritive value. At this point it is appropriate to make acknowledgment of the invaluable and constructive work of Dr. Harris and his colleagues.

Finally must be added a very warm word of thanks to the firms and

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individuals in industry who have, often at great inconvenience to themselves, given such generous help in bringing this work to its present stage of development. In all this work on food the relations with industry have been happy and, in that connexion, the presence here today is particularly welcome of Dr. Lampitt, an old friend of the Department. We shall do our best to extend and deepen those happy relations and I know industry will do the same, for the existence of these two Societies, and especially this joint conference they are holding here today, testify that we all alike recognize the primary task we share. That task is to do all that lies in our power to help the people, not only of the United Kingdom and our Allies, but, ultimately, of the whole world, to get the best food supply that knowledge and endeavour can provide. The way to success in that task is the way for which we all stand, the way of research and of the application of science in industrial practice.

The Principles and Practice of Food Dehydration

Dr. F. Kidd (Low Temperature Research Station (University of Cambridge and Department of Scientific and Industrial Research))

The two things which need to be emphasized today with regard to dried foodstuffs are the quality of the products, their palatability, appearance and nutritive value, and the saving of weight and space in transport and distribution.

The reason is simple why dried foodstuffs were not used to any extent in peace time, although resort is made to them in war; they were not good. This, as is realized today, was because it was thought that the first principle involved in the production of good dried foods, the removal of water to protect them against bacterial decay, was the only principle. Another reason may be that refrigeration, developments in transport, and canning, which itself originated in a war, have so far met all needs for preservation of foods. These processes had great advantages in avoiding waste and yielding attractive products, easy to use.

In the years before the present war new developments in refrigeration were taking place. Fish, meat, fruit and vegetables were being prepared for immediate use. They were frozen at the place of production and delivered frozen to the consumer's door. It was claimed that the consumer obtained in this way the nearest possible approach to the fresh food.

It is interesting to realize that freezing is, in fact, dehydration. Pure water is withdrawn from the foodstuff and deposited as ice crystals within it and, in thawing, is taken up again by the dry material. Drying in itself does not, therefore, necessarily damage a foodstuff. In this latest development of refrigeration it was found highly important, with vegetables and some fruits, to destroy, before freezing, the enzymes present in the tissue. This was achieved by a short heat treatment technically known as blanching or scalding, carried out before the products were frozen; otherwise chemical changes leading to the development of off flavours and destruction of vitamins took place even in the frozen condition.

It has now been found that the water frozen in foodstuffs can readily be removed without thawing. The ice is sublimed in a vacuum at about $-20°$ C. and the vapour condenses on refrigerating coils at a still lower temperature, for example $-40°$ C. Freezing can be effected by the sheer speed of evaporation, and drying periods as short as 5 hours have been achieved by Dr. A. S. McFarlane of the Lister Institute. The Department of Scientific and Industrial Research has made trials with all the principal fruits, vegetables and meats, and with milk, eggs and fish, and some of these vacuum ice dried products were, on a previous occasion, demonstrated to the Food Group of the Society of Chemical Industry. Foodstuffs dried in this way are of exceptionally high quality as regards flavour, appearance and retention of the vitamins. Blanching or scalding before drying, improves the keeping properties of the dried products.

It was decided, however, not to attempt to develop vacuum ice drying under war conditions because it seemed doubtful whether the necessary industrial plant could be developed in time to be of use, because the bulkiness of the foodstuff is not reduced and, lastly, because of the open porous structure of vacuum ice dried products. This structure renders them particularly susceptible to spoilage by atmospheric oxygen and moisture during storage.

The effect of oxygen in causing deterioration in a dried foodstuff of high quality was first thoroughly investigated by Dr. T. Moran and Dr. C. H. Lea, of the Low Temperature Research Station. They worked in collaboration with Dr. N. C. Wright and Dr. J. A. B. Smith, of The Hannah Dairy Research Institute, and with Professor H. D. Kay and Dr. S. K. Kon, of the National Institute for Research in Dairying, and with the co-operation of the industry. This work gave a firm scientific basis to the practice of packing full cream, spray dried milk in a metal box filled with an inert atmosphere so that water is excluded and oxidation prevented. By this means the palatability and nutritive value of the milk can be almost completely retained for years. These discoveries brought about a revolution by making possible the preservation of rich spring and early summer milk for winter use. The results obtained with vacuum ice dried foods and with dried milk illustrate the second, third and fourth principles of dehydration, the necessity of inactivating enzymes by heat treatment before drying, the exclusion of oxygen or the retardation of oxidative changes and, finally, the prevention of the uptake of water vapour from the air. It is vitally necessary to realize that, however good a dried product may be, it does not become stable merely as the result of drying.

Procedures to which brief reference should be made are the use of anti-oxidants in dried foods and the avoidance of contamination with metal catalysts such as copper. Anti-oxidant substances are naturally present in many foodstuffs, and a systematic effort is now being made to discover and use them to render dried foods more stable. Anti-oxidants, when present only in minute amounts, are usually effective in retarding deterioration.

Successful retention of colour and of vitamin C in dried green vegetables is due in part to the use of SO_2 in the pre-drying treatment and the presence of small quantities of SO_2 in the dried product.

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When these various precautions are observed, simple air drying procedures, such as spreading the pre-cooked or partially pre-cooked foods on wire mesh trays in a current of warm air, may be applied to fish, meat and vegetables. The products so obtained, when reconstituted and cooked, are nearly indistinguishable from the fresh foods. Their keeping qualities are good provided they are packed so that oxygen and moisture are excluded.

Further important principles in dehydration emerge from a study of these procedures. In warm air drying there is an upper limit of temperature, varying with the water content, above which the products must not be heated; otherwise over-cooked or scorched tastes are produced, protein is denatured and nutritive value may suffer (fifth principle). There is also a lower limit below which they should not be held for more than a short time, particularly when wet, if the growth of bacteria is to be avoided (sixth principle). In any case, drying should always be carried out in the shortest possible time.

While the future will no doubt see remarkable developments in engineering appliances for achieving quick drying of various products within the limits of temperature permissible, the balance of experience at present suggests that tunnel driers are the most practical for vegetables. In these the material is spread on moving perforated belts or on perforated trays on trolleys in a current of warm air.

The seventh and last principle of dehydration lays down that dried products of good quality can be obtained only if the quality of the material before drying is good and the conditions in the factories suitable as regards hygiene. You cannot make a silk purse out of a sow's ear or expect good dried milk from milk which is unfit for distribution in the liquid form. Drying plants must not be used as a convenient sink for low grade foods which have deteriorated beyond the point at which they would be acceptable in the fresh condition.

The main general points to be observed in the dehydration of foodstuffs are, therefore, firstly to remove water, in order to protect the product against bacterial decay; secondly, wherever possible to destroy enzymes in the product by a short heat treatment before the material is dried; thirdly, to exclude oxygen or retard oxidative changes by the use of anti-oxidants, and to avoid contamination with traces of metal; fourthly, during storage and distribution to maintain a low water content in the dried product by shielding it from contact with air; fifthly, to avoid too high temperatures during drying but nevertheless to dry as quickly as possible; sixthly, while the material is moist, to avoid temperatures at which bacteria flourish; and, lastly, to select at the start material of the best flavour, appearance and nutritive value, and treat it with scrupulous cleanliness during the manufacturing operations. When these principles are followed the quality of the dried foodstuffs is, in general, equal to that of foods preserved by the established processes of canning and refrigeration. There are, however, certain limitations to the forms which dried foods can take. Thus, meat and fish are in the form of mince, vegetables are in slices, whole egg is a powder which can be reconstituted to a liquid such as is obtained when fresh eggs are beaten for the preparation of omelettes or scrambled eggs.

So far, only quality has been considered, but of no less importance today are the economies that can be achieved by the use of dried foods, in labour, in shipping and storage space, in tinplate and in the avoidance of waste. This can be illustrated by taking a typical vegetable such as carrots. By supplying carrots dried instead of fresh, the same number of calories could be delivered to the consumer at one-twelfth of the weight including package, in one-twentieth of the space. If they were packed dried rather than canned, the tinplate used would be one-seventieth, and one-twenty-fifth of the weight would be carried in one-thirtieth of the space. Figures for other products are not all as dramatic as these, but food for a week consisting of flour, biscuits, cereals, potatoes, vegetables, pulses, meats, soups, fats, sugar, eggs, fish and milk, in the requisite proportions and fully packed, is reduced to a quarter of the weight and volume of the fresh products.

The reduction in volume on drying of vegetables especially, and to a less extent of other products, is largely achieved by compressing them into blocks with a specific gravity between 1 and 1·3. I am able to demonstrate the ease of reconstitution of these compressed vegetables by dropping them into water here while I am speaking.

Compression of any of these foodstuffs into blocks protects them to some extent against oxidative changes and the uptake of water from the air. It is hoped that it will be possible in the near future to provide for these blocks some sort of covering which is not a metal box but which will be impervious to oxygen and water vapour.

Dr. Isherwood, who is responsible for the work on blocking, will be able to answer any questions raised in the discussion, but I want to stress my own firm conviction that it is the height of folly to allow the original nutritive value of fresh foods correctly dried to deteriorate steadily by exposure to oxygen and atmospheric humidity, and nothing short of sheer necessity should at present force us to use anything but the strictly gas tight metal box as a package. The idea that dried foods are stable merely as the result of drying is illusory but firmly fixed in the minds of both the industry and the public.

I was asked to speak about the practice as well as the principles of dehydration. Practice in production, and experience in use, of products of the quality under consideration today are matters of the future, but manufacture, based on the principles just set forth, is now in progress in Canada, the United States, Australia and New Zealand, and has also, as far at least as vegetables are concerned, been begun in this country. It is abundantly clear that the first steps have been taken in founding a new industry of service to man.

Dried Meat and Dried Eggs

Dr. E. C. Bate-Smith and Dr. J. G. Sharp ((Low Temperature Research Station (University of Cambridge and Department of Scientific and Industrial Research)) and Dr. E. M. Cruickshank (Dunn Nutritional Laboratory, Cambridge)

It is convenient to deal with dried meat and dried eggs together since these two foods have much in common. They are of less importance

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as sources of vitamins than as sources of calories and first class protein, and possibly more important is the place they occupy in our meals on account of their palatability. In our work on the drying of these foods preservation of the palatability of the product has been our primary object but, fortunately, it has never been found necessary to sacrifice nutritive value to palatability; on the contrary, the processes yielding

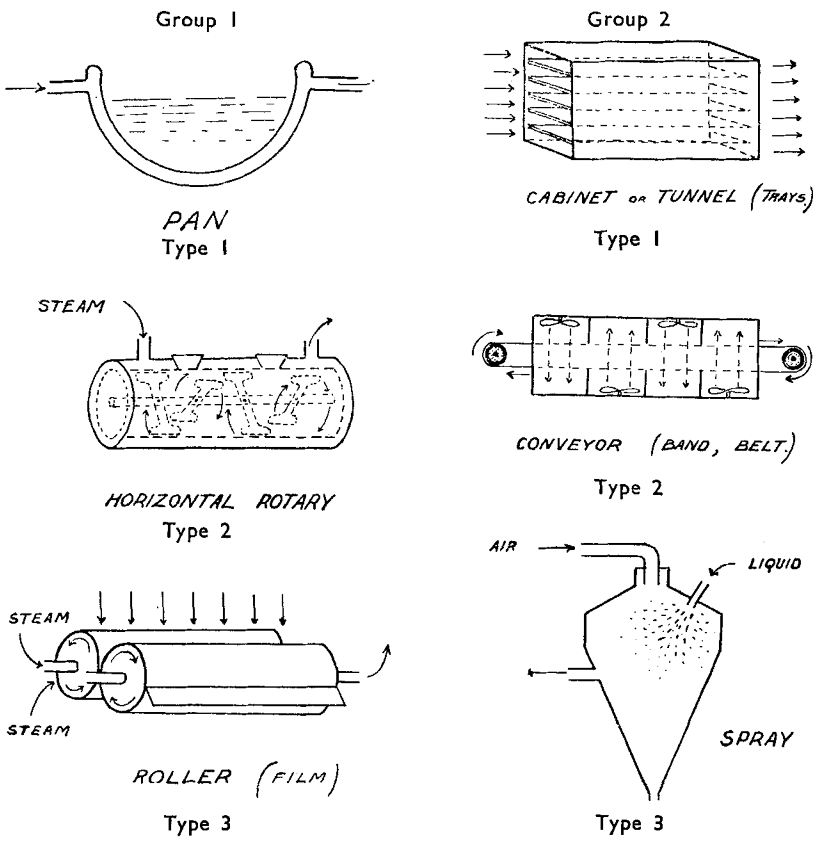

FIGURE 1. DESIGNS OF DRYING APPARATUS.

the most attractive products have always proved to be those which best preserved the nutritive value.

Before a brief summary is given of the results of the nutritional aspects of this work it is necessary to describe some of the types of drying plant in common use, which give their name to the drying processes and to the products dried by these processes.

Methods of drying can be roughly divided into two groups, those employing direct contact with a heated surface, and those employing a current of warm dry air (see Figure 1). In each group three types are

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represented. Type 1 of the first group is the simple pan, heated by a steam jacket; type 2 is a rotary drier in which the material is constantly agitated by revolving paddles; and type 3 consists of a steam heated roller or pair of rollers on to which the wet material is delivered, the dry product being peeled from the surface by a delicately adjusted knife. In group 2, type 1 is an apparatus in which the wet material is spread on trays in a cabinet, or stacked on trucks wheeled into a tunnel, through which warm dry air is passed, flowing horizontally over the material. In type 2 the material is spread on an endless belt or band; the principle is the same, but the draught of air passes through instead of over the material. In type 3 the wet material is sprayed into a large chamber into which a current of air is forced. In falling to the bottom of the chamber the droplets of spray are dried and are collected as a powder, hence the term spray dried.

The choice of method of drying is determined by one primary consideration, that the temperature reached at any stage shall not be high enough to scorch the material or injure the protein in either a physical or nutritional sense. This effect of temperature on the nutritive value of the protein may be illustrated by reference to experiments carried out in Cambridge with small scale prototypes of these drying plants.

Effect of Drying on Nutritive Value

Dried Meat

Protein. The nutritive value of the protein of dried meat was compared with that of cooked meat from the same source by means of metabolic experiments on rats. The amounts of each meat were calculated to supply 5, 10 or 15 per cent. of protein in the diet. With meat, air dried in a cabinet drier with the air at 60° C., the weight increase and nitrogen absorption were the same for the groups of animals receiving the cooked or the dried meat. The digestibility of the two kinds of meat was the same, ranging from 85 to 94 per cent.

Samples of meat dried at 70° and 80° C. in a small drum drier (Figure 1, type 2, group 1) under a slight vacuum also proved to be almost equal in value to the cooked meat as far as the protein was concerned, but meat dried without vacuum, where the temperature rose eventually to 125° C., was so injured that the weight increase of the rats eating it was 30 per cent. less than that of the controls. It appears, therefore, that meat dried at 80° C. or below retains the biological value of the protein in full. Temperatures higher than this, affect in addition the palatability of the product.

Vitamin B_1. The temperature at which meat is dried is of even greater importance in regard to the vitamin B_1 content. This was demonstrated by the losses incurred when the meat was dried at temperatures ranging from 60 to 125° C. Thus drying at 60 to 80° C. produced little or no loss; at 100° C. the loss was about 60 to 70 per cent., while at 118 to 125° C. vitamin B_1 was almost entirely destroyed. At these high temperatures the destruction of the vitamin was in the early stages of drying. Commercial samples prepared on horizontal rotary driers have been found to contain no vitamin B_1 whatever.

The vitamin B_1 content of air dried meat is less than that of the original raw meat, but this loss is almost entirely due to the preliminary cooking process. During this process the loss is from 30 to 50 per cent. Losses of this magnitude occur in any case during normal household cooking.

Nicotinic acid and riboflavin have not yet received the attention they merit, but investigation of the effect of drying at a low temperature, about 70° C., on these two constituents has been begun. No loss has been found during the actual drying process.

Dried Eggs

For almost any purpose for which the product is used it is desirable that the protein of dried egg shall be completely soluble when again wetted. This precludes the use of steam heated surfaces for drying and, in practice, nearly all dried egg is band dried or spray dried. It is not so much a question of gross damage to the nutritive properties, as of the degree to which denaturation and coagulation of the protein take place. In operating the spray drying process we have found that little damage to the protein occurs if the temperature of drying, as measured by the outlet temperature of the air, does not exceed 70° C. It is customary to operate band driers at temperatures as low as 45 to 50° C.

In the prolonged process of band drying, however, considerable destruction of vitamins may occur. In the course of drying at 50 to 55° C. in the experimental cabinet drier under conditions similar to those obtaining during band drying, vitamins A and D were much reduced and 50 per cent. of the vitamin B_1 was lost.

No loss of vitamins A and D was observed during spray drying although the vitamin B_1 content was reduced by 30 per cent. Data from America on the vitamin content of spray dried egg such as is now being imported and distributed, indicate that this food, new to the great majority of people, has a vitamin content at least as high as the equivalent fresh home produced egg.

Palatability

Up to the present palatability has been referred to as if it were a single well defined property of a particular food, but it is obvious that the term covers every aspect of the food's appeal to the senses, including flavour, texture, odour, and appearance.

Dried Meat

A true meat flavour can be secured by a variety of methods of drying, provided the temperature can be held below 80° C. Texture is, however, a very different question. The only way in which a proper meat texture can be retained in pieces of reasonable size is by drying the meat in a current of air in a tunnel or conveyer drier. Even so, the limit to the size of pieces which can be successfully dried is that of coarsely minced grains. The horizontal rotary drier, by the beating effect of the revolving paddles, breaks the meat down into meal. The roller drier produces a film which, although of excellent flavour, is too fine in texture to compare favourably with the air dried product.

The process now recommended for application to imported meat is as follows: the meat, beef, mutton, or pork, is boned, cut into slices about $\frac{1}{2}$ to 1 inch thick, and cooked until brown throughout. The partly cooked meat is minced and spread on wire mesh trays at the rate of 2 lb. per square foot. The cooking liquors, which have meanwhile been concentrated, are distributed over the minced meat, and the trays are stacked on trucks which are run into a cabinet or tunnel drier. Drying, which begins with air at 80° C. and finishes with air at 70° C., is completed in about 5 hours.

A fat content of 30 to 45 per cent. is specified as desirable. This does not represent the whole of the fat present on a carcass of ordinary fatness, but is an amount which can conveniently be included and which gives a satisfactory sensation of moistness on the palate. It is specified that all the juices of the meat must be included, thereby ensuring full meat flavour and the presence of all the mineral constituents and water soluble vitamins. Dehydrated meat is literally "meat minus moisture."

Dried Eggs

For eggs palatability is not the only factor determining quality. In addition there are the physical properties to be considered, the aerating power which is made use of in sponge cakes, the binding power so important in ordinary baking and cooking, and the moistening effect which delays the staling of cakes. All these properties have received attention, but the one on which we have concentrated is flavour, since this is of paramount importance in egg destined for ordinary household use.

The evaluation of flavour has proved to be unexpectedly simple and reproducible. A system of scoring is employed with a range of marks from 8 to 0, having the following significance:

Fresh egg flavour, 8; exceptional strength of fresh egg flavour indicated by one or more plus signs;
Very slight off flavour, 7;
Definite but not unpleasant off flavour, 6;
Unpleasant off flavour, 5;
Increasingly strong and unpleasant off flavour, 4, 3;
Repulsive to inedible flavour, 2, 1, 0.

In training a new panel of tasters standard samples scored by a trained panel are submitted for guidance. Several panels are now operating in different parts of the country and in 19 out of 20 samples scoring agrees to within half a point.

The question arises as to how scores by this system are related to the public taste. Tests have shown that at least 75 per cent. of people find a specimen with a score of $5\frac{1}{2}$ satisfactory as scrambled egg, while only 30 per cent. feel the same of a sample scoring $4\frac{1}{2}$. All the domestic egg now being distributed has been tested for flavour and passed with the borderline fixed at a score of $5\frac{1}{2}$.

Storage

Both dried meat and dried egg deteriorate if stored with free access of air, even though protected against uptake of moisture. At ordinary temperatures the deterioration is noticeable, but not as a rule serious, after two months, and dried meat may keep in a carton resistant to moisture for 6 months without undue loss in quality. Both products, however, need to be packed with exclusion of air if the initial quality is to be preserved. Dried meat of the specified composition can then be expected to keep in good condition for years, and dried egg is also very stable if the moisture content is sufficiently low.

It is, therefore, concluded that, unless alternative methods of packing can be developed on a practical scale to give equally good results, there is only one form of pack which can be fully recommended for these two products, the air tight container, with the air replaced by inert gas for dried egg.

The work described in this paper was carried out as part of the programme of the Food Investigation Board, and is published by permission of the Department of Scientific and Industrial Research, and the Medical Research Council.

The Dehydration of Fish

Dr. C. L. Cutting and Dr. G. A. Reay (Torry Research Station (Department of Scientific and Industrial Research), Aberdeen)

The preservation of fish by drying, with or without salting, has been practised for centuries all over the world, and it is still true that more fish is preserved in this way than in any other. Traditional procedures with poor control of curing conditions result, however, in much loss through spoilage and in great lack of uniformity in the final products. Drying, which is generally effected by exposure to wind and sun, is a relatively slow process, and the fish in consequence develops characteristic cured odours and flavours which find little favour with modern industrial populations. These, being accustomed to great variety of fresh, frozen and canned foods, have not been forced by circumstances to acquire a taste for the more primitive dried product. Drying, moreover, yields a product that does not re-absorb its initial content of water or revert to its original, soft, glutinous texture. The possibilities of producing, by a controlled process, an improved dried fish acceptable to the British palate have been under investigation for some time, and, it may be said at once, with very promising results.

It was considered that lean fish more than any other kind would yield a product relatively stable to oxidation, and the only fish considered are, therefore, those such as cod, haddock and whiting, which contain no more than 0·2 to 0·3 per cent. of lipoids, amounting at most to 1·5 per cent. in the dried fish.*

At the outset it was thought that drying in a high vacuum at temperatures below the freezing point would yield the best product possible. Fish dried in this way, however, either as whole fish or fillets did not reconstitute well on soaking; the flesh was bleached, spongy, and not nearly as glutinous as that of fresh fish. When tasted, the fish was inferior in palatability to fresh or frozen controls, being somewhat less full in flavour, and dry and crumbly in texture. On being soaked the fish re-absorbed up to 75 per cent. of its original water content, but much of this could be expelled again by slight pressure. Moreover, the solubility of the proteins in neutral salt (7 per cent. LiCl) was reduced by about

* Fatty fish such as herring have now been successfully dried (Cutting and Reay, 1944). (Footnote added in proof.)

55 per cent. Whilst these results showed that there was apparently little hope of drying fish without causing considerable irreversible alteration, they were, nevertheless, evidence of a great improvement on existing commercial dried products. The strong cured flavour had been eliminated and, although an entire, reconstituted fillet was unpalatable in texture as compared with a fresh fillet, it was found that the meal produced by grinding the dried fillet made very good fried fish and potato cakes. This suggested that it would be worth while to investigate simpler methods of drying at higher temperatures and at atmospheric pressure.†

Roller Drying

Minced fillets of raw cod, haddock and whiting were dried on rollers to a water content of about 10 per cent., the fish coming off the rollers in a flat sheet resembling lace work and yielding a very nice product. Although experience was gained only with a small laboratory plant, it is felt that no insuperable difficulties are likely to be encountered in full scale commercial operations.

Fish cakes made with the roller dried fish were excellent in flavour and texture. The texture was not quite the same as that of fresh fish, the artificial ribbon structure produced by rolling being still detectable. Fish cakes made with the dried fish after fine milling were considered to be too pasty in texture, and it was decided to aim in all subsequent work at retaining, as far as possible, the normal fibrous texture. Milled products would, however, be useful to provide protein fillers, as in the manufacture of fish pastes. There was some slight loss of the delicate sweet aroma of perfectly fresh fish, but the cakes, like those made from perfectly fresh fish, did not have the more pronounced fishy flavour of cakes made with stale or salt cured fish or fish essences.

Drying in Warm Air

Experiments on the air drying of fish were greatly helped by adapting for the purpose the semi-automatic horizontal kiln devised by Hardy and Cutting (1942) for the smoke curing of fish. Within the curing chamber uniform flow of air and ready control of its temperature, humidity and rate of movement could be obtained with the apparatus, which dried the full load of the kiln, 5 crans or about 6000 herrings, with great uniformity, to a predetermined loss of weight during the process of smoke curing. By substituting wire mesh trays for tenters on the kiln's two trucks, and cutting out the smoke producing arrangement the kiln was easily adapted for its new purpose.

It was found that raw, minced fillets dried more rapidly at first than whole fillets, but "case hardening" occurred subsequently and reduced considerably the rate of drying; in addition, the dried product stuck too firmly to the trays. These difficulties were completely overcome by cooking the fish before drying. Minced fillets, packed at a density of about 4½ lb. per square foot on meshed trays, were cooked for half an hour in a canner's retort in steam at a pressure of 2 to 3 lb. High pressures of steam of 8 lb. or more were found to darken the flesh and to give it a somewhat "burnt" flavour. During cooking the fish lost some 30 to

† Vacuum ice dried, cooked, minced fish has been found to reconstitute extremely well. (Footnote added in proof.)

40 per cent. of weight, the water content being reduced from 4·3 g. to 2·7 g. for every gram of solid. Such a loss of juice did not cause any appreciable alteration in the flavour of fish cakes made from the dried product, and there was, therefore, no need to concentrate the escaped juices and add them back to the fish as is necessary with meat. The losses in protein and extractive nitrogen were of the order of 2 and 30 per cent., respectively; on the other hand, there was a considerable saving in the time and cost of drying. Pressing after cooking, although it still further reduced the water content of the material to be dried, resulted in a rather tough product and is not recommended.

After being cooked the fish was minced again while still warm, and was spread evenly and lightly on the drying trays at a density not exceeding 2 lb. per square foot. Mincing before cooking may be recommended because it resulted in more even cooking and more economical packing of trays. Mincing again after cooking is strongly recommended, since it gave the fish a more open and uniform structure which facilitated even drying and uptake of water on reconstitution, and secured retention of the normal free, fibrous texture upon which palatability in large measure depends.

Tests in which cooked fish dried to various water contents was exposed for short periods of an hour or two to temperatures between 50° and 100° C. showed that the higher the temperature and the drier the fish, the greater was the degree of "scorching" as shown by both colour and flavour. The results suggested that in practice the temperature of the fish should never be allowed to exceed about 65° to 70° C. during the drying process. This, of course, excluded the use of steam jacketed driers operating at atmospheric pressure. The total drying time, being the time required to dry from a water content of about 2·7 g. per g. solid to 0·1 g. per g. solid, was found to have some influence on the quality of the final product. In general, the shorter the drying time the more tender and normally fibrous was the texture of the dried fish, and a practical limit of 4 hours is suggested.

As a result of experiments in which fish was dried at various constant air temperatures and relative humidities, in air moving at 10 feet per second, at a tray loading of 2 lb. per square foot, the following time table of drying conditions for a 4 hours' run was drawn up. For the first half of the drying time, *i.e.*, 2 hours, the dry bulb temperature of the air should be 85° C. and the relative humidity 30 per cent. (wet bulb temperature 60° C.). Thereafter the dry bulb temperature should be kept at 75° C. and the relative humidity at 25 per cent. (wet bulb temperature 50° C.), until the final half hour during which the dry bulb temperature should be lowered to 70° C., the relative humidity falling still lower. These drying conditions, which seem likely to be attainable on an economic basis, were tested and found to yield a satisfactory product, the temperature of the fish never exceeding 70° C. The time of drying could, it was found, be considerably reduced, if desired, by increasing the air speed and by reducing the density of tray loading.

Fillets of cod, haddock, whiting, hake, ling, lemon sole and plaice have been air dried in the standard manner described and, after reconstitution, the dried products were made into excellent fish cakes in which the distinctive flavours and textures of the various species could be recognized.

The texture of the air dried products is more normally fibrous to the palate than that of the roller dried ones with their artificial ribbon structure.

When the dried fish, whether air dried or roller dried, is immersed in hot or cold water, it rapidly absorbs water, maximum absorption being reached within a few minutes. Much of this water, however, is only held by capillarity and, on moderate pressure, oozes out and is immediately re-absorbed when the pressure is released. In practice, for making fish cakes and pies, about $2\frac{1}{2}$ g. of water should be added per g. of dried fish, by which the water content is restored to approximately that of the cooked fish. The addition of more water results in too wet a mixture.

Both roller dried and air dried fish, which are completely edible, contain about 75 per cent. of protein. In comparison, the original, wet white fish, such as cod or haddock, furnishes an edible portion of only 40 per cent., of which only 16 per cent. is protein. The waste portion, namely head, skin and bone, furnishes the normal raw material of the animal feeding meal industry.

When wet cod fillets are stowed in bulk very compactly, about half a ton of protein is contained in 100 cubic feet of space, without any allowance being made for packaging or dunnage. When roller dried cod is packed without compression, about four-fifths of a ton of protein occupies 100 cubic feet. With compression this figure can be raised to about 2 tons of protein in 100 cubic feet. The block, thus obtained, is fairly cohesive and suitable for packing. Air dried minced cod can be packed under hand pressure so that about 1 ton of protein occupies 100 cubic feet. Greater pressure, mechanically applied, breaks down the pieces of dried fish, destroying desirable fibrous texture and yielding a very crumbly block not suitable for handling and transport. Increased density can be obtained, however, without these disadvantages by pressing the fish when dried to a water content of about 0·25 g. per g. solid and then drying the block. In this way about $1\frac{1}{2}$ tons of protein can be compressed into 100 cubic feet in satisfactorily cohesive blocks without destruction of fibrous texture. If certain reasonable assumptions are made with regard to type of package, crate and dunnage, it can be calculated that, on the basis of the wet fish as eaten, the use of dried fish products would involve the carriage of only one-ninth to one-sixth of the weight, and of only one-tenth to one-eighth of the volume required by fresh, frozen or canned fish.

In the course of these investigations air dried and roller dried products have been stored in lever lid tins at ordinary laboratory temperature and humidity for periods up to a year. In general, the samples have shown negligible deterioration in flavour and colour, even when the period of storage has been as long as a year. In a few instances, however, gradual deterioration in flavour and colour has set in after periods of 3 to 6 months. Dried fish, therefore, appears to be a fairly stable commodity, and the whole question of storage is now being thoroughly investigated to ascertain the conditions in which stability, which is probably related to oxidative changes, can be still further increased. In the conditions of laboratory storage the water contents of the meals have always remained considerably below the equilibrium water content of 0·13 g. per g. solid.

Experiments are in progress to determine what types of package are sufficiently moisture proof in the most severe conditions likely to be encountered.

Although the fish cake has been used as the standard preparation for tests of quality, other dishes, such as fish and potato pie, kedgeree, soup, fish curry, *au gratin* dishes, and so on, have been satisfactorily made in domestic science colleges from the samples of dried fish submitted for the test. Fish cakes and pies have been most favourably received at communal school feeding centres. No doubt palatable dishes other than those mentioned could be devised. A few experiments have shown that dried fish with a pleasant smoked flavour can be prepared.

The work described in this paper was carried out at the Torry Research Station, Aberdeen, as part of the programme of the Food Investigation Board, and is published by permission of the Department of Scientific and Industrial Research.

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Discussion

Mr. N. L. Wright (New Zealand Government Offices, 415 Strand, London, W.C.2), opener: In these critical days there at last appears to be a widespread realization that shipping space is the key war factor transcending in importance every other factor. Anything, therefore, which can be done to economize in shipping weight and space will be of the highest importance as a major contribution to the war effort. That is why food dehydration is of such special significance today.

The work already described, and that to follow, reveals a remarkable story of team work and of constructive intensive effort in a field which has never before been so adequately explored. The authors of this work, and others associated with them, laid it down as a basic principle that it is unprofitable to allow tens of thousands of tons of water to take up precious shipping space.

The staff of the Food Investigation Board have done a magnificent job of work and so have Dr. Harris and his colleagues of the Dunn Nutritional Laboratory. An important contribution was made by Dr. Lampitt, whose prior work on meat dehydration was made available and greatly stimulated interest at a most opportune time. In addition, mention should be made of the Canadian work on plant design and of the notable work of Dr. Vickery and his team in Australia.

It is an achievement to have established that, from meat which offers perhaps the greatest potential saving in shipping space, an attractive product of high nutritive value, excellent palatability and good keeping qualities can be produced by drying.

The dried meat can be shipped in ordinary space, thus economizing the precious refrigerated space, and about four times as much dried compressed meat can be carried in the same space as carcass meat. The critics will no doubt emphasize the fact that the dried product is minced and a relatively poor substitute for a steak or a chop. But the mass of consumers would surely accept this product as part of their

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ration if they knew that the space saved would mean more guns, or tanks, or aeroplanes.

Those present who are doubtful about the quality of the products will surely be converted when they taste the sample dishes available today.

To bridge the gap between the laboratory stage and actual commercial production is to solve the age old problem of discovery and its translation into productive effort on the most economic and efficient basis. The meat producing countries will no doubt energetically respond to a call to produce dried meat if given a definite target, with all possible assistance as to the best type of plant and methods of processing and packaging on a large scale.

Unfortunately, there are as yet no data of large scale production available anywhere, on which to base selection of the most efficient and economical plant. It will, therefore, be necessary for those overseas to adopt and possibly modify existing designs of drying plant which, in principle, appear likely to satisfy local conditions and requirements.

In New Zealand it is hoped to obtain much valuable guidance on these problems of production from this country and particularly from America, where recent news encourages us to hope for early assistance. In this country there must be a great deal of valuable assistance which might be mobilized from engineering firms with experience in dehydration in general, and an appeal for help would probably be responded to wholeheartedly.

In addition, much is yet to be learned about the best methods of treating the meat before drying and about the most suitable methods of packaging, with due regard to the shortage of raw materials, such as tinplate.

In many countries intensive investigation is in progress on food dehydration in general. From this work no doubt important discoveries will emerge which will facilitate development and production. A strong appeal should be made to the responsible authorities in all interested countries to arrange for the full and immediate interchange of information so that each country may benefit from the pooled contributions. The process of dehydration, if actively applied and developed, can make a major contribution to the war effort.

Dr. A. S. McFarlane (Lister Institute, Chelsea Bridge Road, London, S.W.1): In freeze drying experiments water could be removed in certain conditions at the rate of $\frac{1}{2}$ lb. per square foot per hour. Material dried by this method has excellent miscibility with water, an important property for products like milk and fruit juices. Freeze dried milk when compressed or blocked to the density of spray dried milk is still freely miscible with water.

Dr. D. H. F. Clayson (Research Laboratories, J. Lyons and Co., Ltd., Cadby Hall, London, W.14): The efficiency of methods of drying is, in general, rather low in respect of the amount of fuel needed. The rotary louvres type of drier might be used in the final stages of drying when a non-adherent, particulate product containing less than 40 per cent. moisture has been obtained.

Mr. W. M. Spooner (Spooner Drying and Engineering Co., 17 The Grove, Ilkley, Yorks.): What is the lowest temperature that could be used in drying without danger of bacterial deterioration and has the use of an inert gas instead of air been considered as a means of obtaining better keeping qualities? The modern drier could be made to operate with high efficiency.

Dr. R. T. Colgate (Huntley and Palmers, Ltd., Reading): I have examined recently the power of aeration of many samples of dried eggs and found that none was as satisfactory in this respect as frozen eggs. Vacuum drying might well give a better product. The problem of drying eggs is similar to that of drying wheat gluten with which use of a high vacuum gives excellent results.

Dr. F. Kidd, in reply to *Mr. Spooner*: No experiments with inert gas have been done in Cambridge, but it has been used in South Africa.

Dr. E. C. Bate-Smith gave the following replies:

To Mr. Clayson: Much work is being done to make driers as efficient as possible. The actual cost of drying is very small for products like meat and eggs, something of the order of one halfpenny per lb. weight.

To Dr. Colgate: Though vacuum drying gives products of the highest quality, eggs so treated are inferior to fresh eggs in power of aeration. As a matter of fact, with eggs, spray drying in optimal conditions gives a product just as good as vacuum drying. When beaten at 40° C. such eggs aerate as well as fresh eggs, and even poor quality spray dried egg powder can be satisfactorily aerated if the temperature is raised to 50 or 55° C.

Afternoon Session: Chairman, Dr. H. E. Cox

The Drying of Vegetables

Dr. R. J. L. Allen and Dr. J. Barker (Low Temperature Research Station (University of Cambridge and Department of Scientific and Industrial Research)) and Dr. L. W. Mapson (Dunn Nutritional Laboratory, Cambridge)

Although vegetables have been preserved by drying since the earliest times, there is ample evidence that in the past the culinary quality and nutritive value and, especially, the antiscorbutic activity of dried vegetables have generally been poor. During the last few years there has been a considerable revival of interest in dried vegetables in many parts of the world, especially in America and Germany. Numerous papers have been published on the technological and engineering aspects of the problems involved, but there have been few on the nutritive and culinary value of the material produced. The object of the present investigations made in Cambridge at the Low Temperature Research Station and at the Dunn Nutritional Laboratory was to devise methods for the production, by ordinary hot air drying, of dried vegetables which would retain for long periods the good culinary quality and a substantial proportion of the nutritive value of the raw vegetable. Only a brief summary can be given of the main results of two years' work.

Although a variety of vegetables has been successfully dried, the discussion will be confined to consideration of cabbage, carrot and potato, the three vegetables consumed in largest quantities in this country.

Cabbage

The preservation of culinary quality and of ascorbic acid content were the principal problems with cabbage. Of the various factors that contribute to the "quality" of cabbage, colour is particularly important, and special attention was paid to the production of material in which the green portions were bright, and not olive, green and the white portions were not discoloured. Ascorbic acid is probably the most important nutritive constituent of cabbage, and, to secure its preservation, possible loss was studied at every stage of preparation from the raw material to the cooked dried product.

Preliminary Treatment

It was found necessary to scald cabbage before drying. Dried raw it generally had a poor colour, flavour and texture, usually contained little ascorbic acid and stored badly. The cabbage, trimmed and cut into shreds about a quarter of an inch wide, was scalded by immersion for 2 to 3 minutes in boiling water containing about 0·22 per cent. crystalline sodium sulphite. The presence of sulphite in the water for scalding had the effect of protecting the ascorbic acid from oxidative destruction during scalding, drying and storage, and of greatly improving the colour of the final product. During scalding the principal loss of ascorbic acid was due to leaching. Losses from this cause were kept as small as possible by using no more water than was necessary and by scalding only for long enough to inactivate the enzymes; the most substantial reduction in loss of ascorbic acid and other water soluble materials, including those responsible for flavour, was, however, effected by using the same water for scalding successive batches of cabbage, and making up the volume of water and the concentration of sulphite again after each scald. With a ratio by weight of cabbage to water of 1:1½ there was no further loss of soluble solids, including ascorbic acid, by leaching after about the sixth successive scald. Leaching losses were still further reduced by replacing the plain sulphite solution by an extract prepared by boiling waste outer leaves and cores of cabbage with dilute sodium sulphite; this extract was so rich in ascorbic acid that cabbage scalded in it lost almost no ascorbic acid by leaching. The colour of the dried cabbage prepared by this last method was, however, poor and means of counteracting this loss of colour are under investigation.

Steam Scalding

Steam scalding has been suggested as a means of reducing losses by leaching, and dried cabbage scalded in this way certainly retained a high proportion of ascorbic acid; the colour and flavour of the reconstituted and cooked product were, however, poor. Preliminary experiments in Canada and at Cambridge suggest that it may be possible to combine the advantages of steam scalding and of sulphite scalding by dipping the raw cabbage shreds in sulphite solution before steaming them.* Yet

* Steam scalding after dipping in sulphite has now (1944) been shown to be a satisfactory procedure for factory operation. (Footnote added in proof.)

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another method which has been used in Canada, apparently with success, is to spray the cabbage with sulphite solution during scalding.

Drying

In the experiments at Cambridge the cabbage was dried in a cabinet drier on wire mesh trays over which a current of hot air was circulated. The dry bulb temperature of the air was as high as 95° C. at the beginning

TABLE 1

RETENTION OF ASCORBIC ACID DURING SCALDING AND DRYING OF CABBAGE

Scalding treatment	Percentage of original ascorbic acid content of raw cabbage retained	
	Scalded cabbage	Dried cabbage
Single scald in water	49*	30*
,, ,, ,, sulphite	57*	48*
Steam scald after dip in cold sulphite ..	84*	63*
Serial scald in sulphite, scald 1	60*	50*
,, ,, ,, ,, ,, 3	70*	55*
,, ,, ,, ,, ,, 5	80*	61*
,, ,, ,, ,, ,, 8	85*	70*
Single scald in extract of outer leaves ..	89**	75**
Serial scald in extract of outer leaves, scald 1	89**	75**
,, ,, ,, ,, ,, ,, ,, ,, 5	90**	75**
,, ,, ,, ,, ,, ,, ,, ,, 8	90**	80**

* Value derived from several experiments.
** Value derived from a single experiment.

and was gradually dropped to about 60° C. as the material became dry; by using a high initial temperature the drying time was reduced and the development of bacteria prevented. Drying was continued until the water content fell to about 5 per cent. in 3 to 5 hours.

Changes in Ascorbic Acid Content

The ascorbic acid content of cabbage after being scalded in various ways and dried is given in Table 1.

Reconstitution and Cooking

There was no need to soak the dried cabbage before cooking; better results were obtained if it was cooked by plunging it into boiling water and boiling it until tender, usually for 20 to 30 minutes.

Nutritive Value of Reconstituted and Cooked Cabbage

The proportion of the ascorbic acid content of the dried cabbage which was retained by the cooked cabbage depended largely on the amount of water used in cooking. When excessive amounts of water were used, only 25 per cent. might be retained, but when only just sufficient water was used, about 60 per cent. was retained. If, therefore, the dried cabbage retained about 70 per cent. of the ascorbic acid content of the raw cabbage, the cooked cabbage retained about 35 per cent., a value which compares very favourably with that for cooked fresh cabbage. A special advantage of dried cabbage is the absence of oxidizing enzymes; destruction of ascorbic acid by careless treatment during cooking is, therefore, much less likely than with fresh cabbage.

Weight Saved by Drying

One hundred pounds of cabbage as purchased gave about 50 pounds of trimmed and cored cabbage, which gave about 3½ pounds of dried cabbage.

Storage

Dried cabbage prepared as described, and dried to a water content of about 5 per cent., has been stored at 15° C. in cans filled with nitrogen with almost complete retention of ascorbic acid content and of culinary quality for at least 18 months; in the absence of sulphite, with higher water contents or at higher temperatures the storage life was less. Cabbage dried to a water content of 5 per cent. and packed in air in air tight cans could usually be stored for 6 months under the same conditions without serious loss of culinary quality or ascorbic acid content; preliminary results suggested that if the water content was as low as 3 per cent. cabbage might be stored in air almost as well as in nitrogen. Water content, the presence of sulphite and the temperature were thus very important factors in determining storage life.

Carrot

The principal problems in the drying of carrot were the preservation of the carotene, the sugar, of which dried carrot contains about 50 per cent., and the culinary quality.

Preliminary Treatment and Drying

Carrots dried without scalding retained most of their carotene and all their sugar but were pale and tough when reconstituted and cooked, and usually had only a short storage life. Carrots dried after scalding retained at least 90 per cent. of the carotene content of the raw vegetable and were of excellent culinary quality provided undue loss of sugar and flavour was avoided by scalding the carrots whole for about 15 minutes in boiling water; in these conditions the loss of water soluble material by leaching was negligible. The scalded carrots were cut into strips about a quarter of an inch square before being dried to a water content of about 5 per cent. in conditions similar to those used for cabbage.

In the United States carrots are usually scalded in steam in order to make the leaching losses as small as possible.

Reconstitution and Cooking: Nutritive Value of the Product

The dried carrot could be satisfactorily reconstituted and cooked by either of two methods. By one it was covered with boiling water, left overnight without further heating and then simmered in the same water until tender for 20 to 40 minutes; by the other it was covered with boiling water, kept hot for an hour and then cooked as before until tender. There was no loss of carotene during reconstitution and cooking. The loss of sugars depended on the amount of water used, but it was never necessary for it to exceed that incurred during cooking of fresh carrots; with care the total loss of sugars from the raw state to that of the reconstituted and cooked carrot could be much less.

Weight Saved by Drying

One hundred pounds of carrots as purchased gave about 80 pounds of trimmed and peeled carrot, which gave about 7½ pounds of dried carrot.

Storage

Dried carrot prepared as described and dried to a water content of about 5 per cent. could be stored at 15° C. in cans filled with nitrogen with almost complete retention of carotene content and culinary quality for at least 18 months; with higher water content the storage life was reduced. Carrot could not be stored satisfactorily in air; some samples have been stored for as long as 6 months in air in cans with satisfactory preservation of carotene and culinary quality, but other comparable samples have deteriorated badly within a few weeks, losing their content of carotene and developing a strong smell of violets, showing the presence of β-ionone. The reason for such differences between batches is at present unknown.

Potato

With potato, special attention was paid to the retention during drying of ascorbic acid and of colour, and the prevention of pastiness or stickiness in the final product; a dark or greyish colour in the reconstituted and cooked potato was found to be particularly objectionable.

Preliminary Treatment

As with cabbage and carrot, scalding was necessary before drying; potato dried without scalding had a poor colour and flavour. The potatoes were peeled and trimmed and cut into strips about three-sixteenths by a quarter of an inch in cross section; they were washed in running water to remove surface starch and scalded for 2 to 3 minutes in boiling water containing 0·05 per cent. crystalline sodium sulphite. As with cabbage, leaching losses, principally of ascorbic acid and minerals, were minimized by scalding for the shortest time necessary to inactivate the enzymes in the potato, by using as little water as possible and by using the same water to scald successive batches of potato. The addition of sulphite to the scalding water protected ascorbic acid during scalding, drying and storage and helped to prevent darkening of the potato; the colour of the final product was also improved by selecting a non-darkening strain of potato such as King Edward, by avoiding all contact with bare iron, and by acidifying slightly the water used for scalding or cooking.

Drying

The potato was dried to a water content of 5 per cent., in much the same conditions as cabbage, the temperature being high in the early stages of drying and being reduced gradually to about 65° C. as the material became drier.

Nutritive Value of the Product

Potato scalded serially in nine batches retained an average of about 75 per cent. of the ascorbic acid content of the raw potato; after drying about 60 per cent. of the raw value was retained.

Reconstitution and Cooking: Nutritive Value of the Product

Dried potato was cooked by covering it with boiling water, allowing it to stand for an hour and then cooking it in the same water for about

10 minutes until tender. As with cabbage, the proportion of the ascorbic acid content of the dry potato which was retained after cooking depended largely on the amount of water needed in cooking but was usually not less than 40 per cent. If, therefore, the dried potato retained about 60 per cent. of the ascorbic acid of the raw potato, the cooked potato retained about 25 per cent.

Weight Saved by Drying

One hundred pounds of potato as purchased gave about 75 pounds of washed, peeled and trimmed potato, which gave about 11 pounds of dried potato.

Storage

Dried potato prepared as described and dried to a water content of about 5 per cent. has been stored at 15° C. in cans filled with nitrogen with almost complete retention of ascorbic acid content and culinary quality for at least a year. Information with regard to the effects of packing in air is at present scanty but it seems likely that as long as the water content is kept low, culinary quality will be as well retained as in nitrogen but ascorbic acid will be gradually destroyed.

The Use of Sulphite in Scalding

The use of sulphite in scalding has the advantage that the dried product is superior in quality, ascorbic acid content and storage life to material dried after scalding in water alone. The chief drawback of sulphite scalding is the possible destruction of vitamin B_1.

When cabbage was scalded in a 0·22 per cent. solution of sulphite it lost from 50 to 75 per cent. of its vitamin B_1 content, a substantial proportion of this loss being due to leaching; this loss was only slightly reduced by serial scalding, presumably because the destructive action of sulphite prevented accumulation of vitamin B_1 in the liquor. Raw cabbage, however, contains only small amounts of vitamin B_1, about 60μg. per 100 g., and the use of sulphite can be fully justified on the grounds of its preservation of ascorbic acid, by far the most important nutritive constituent of cabbage.

Potatoes contain important amounts of vitamin B_1; preliminary experiments suggest that 35 to 50 per cent. is lost during scalding in a 0·05 per cent. sulphite solution.

When dried vegetables containing sulphite are cooked, a considerable proportion of the sulphite escapes or is destroyed. The amount thus eliminated is variable, but a sample of dried cabbage containing 1500 p.p.m. SO_2 will contain only 50 to 100 p.p.m. when reconstituted and cooked.

Conclusions

In drying vegetables by the methods briefly described above, no fundamentally new factor has been introduced, but factors already known to give beneficial results have been used together to the best advantage.

Scalding prior to drying has been used before but the time of scalding was often too short, and losses by leaching were often serious. In the present method, the special development is the serial scald; whether this is better than steam scalding is still uncertain.

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Treatment with sulphite has been commonly applied to fruits before drying but its use in scalding cabbage appears to be new.

In the actual process of drying the principal points are avoidance of both scorching and unduly slow drying and the attainment of a low water content.

The rate of deterioration in storage is reduced by adequate scalding, a low water content, and storage in nitrogen.

Summary

1. Cabbage, carrot and potato must be scalded before being dried if satisfactory retention of nutritive value and culinary quality during drying and storage is to be obtained.

2. The addition of a small quantity of sulphite to the scalding water is beneficial with cabbage and potato, protecting ascorbic acid from oxidation and improving the colour of the dried product.

3. Losses by leaching during scalding can be minimized by scalding for as long only as is necessary to inactivate enzymes, by using as little water as possible and by scalding the material serially in batches in the same water. Carrots may be scalded whole.

4. Dried cabbage should contain about 70 per cent. of the ascorbic acid present in the raw vegetable, potato about 60 per cent. Reconstituted and cooked dried cabbage and potato should contain at least 35 and 25 per cent., respectively, of the ascorbic acid content of the raw vegetable. There is almost no loss of carotene during scalding, drying, reconstituting or cooking of carrot.

5. By drying to about 5 per cent. water content and packing in nitrogen, carrot, cabbage and potato can be stored for at least 12 to 18 months at 15° C. without significant loss of nutritive or culinary value; at higher water contents and temperatures and, with cabbage and potato, in the absence of sulphite, the storage life is reduced. As regards storage in air, the information available is scanty; it suggests that cabbage and potato can be stored for 6 months at 15° C. without serious loss of culinary quality or nutritive value, but that carrot is less stable and, until more is known of the factors governing storage life, packing in air should be avoided.

The work described in this paper was carried out as part of the programme of the Food Investigation Board, and is published by permission of the Department of Scientific and Industrial Research, and the Medical Research Council.

Discussion

Mr. V. L. S. Charley (Department of Agriculture and Horticulture, Research Station, Long Ashton, Bristol), opener: Dehydration will not only save bulk and weight but will help also in avoiding waste of vegetables during glut periods. The marked increase in the growing of green vegetables has led to local surpluses and these could be utilized, and dried vegetables made available during the 2 or 3 months when the fresh product is almost unobtainable. It is estimated that the American Army will in 1942 use 22,000 tons of dried vegetables; this represents an impressive weight of fresh produce.

The Long Ashton Station is concerned about the presence of sulphur dioxide in processed vegetables and fruit syrups, and information about factors which govern its removal from such products would be very welcome. The large losses of nutrients in trimming vegetables before drying and also in the scalding water could be reduced if trimmings and water were used for the preparation of concentrated extracts rich in vitamins. It is most important to translate results of laboratory experiments into commercial practice, and it would be of interest to know to what extent this is being done by the industry.

Mr. T. Rendle (Chivers and Sons, Ltd., Histon, Cambridge): Large scale production has been greatly helped by the use of pilot plants. The information now put before the meeting will be used before long in actual commercial production of dehydrated vegetables.

Mr. B. G. McLellan (Rowntree and Co., Ltd., York): Apart from large scale factory dehydration, arrangements should be made for the drying of domestic crops from gardens and allotments; otherwise much of such produce will find its way to the compost heap. I will gladly supply to anyone interested information about an efficient and cheaply made drier which has been successfully used for such purposes for several years.

Dr. R. T. L. Allen gave the following replies:

To Mr. Charley: With cabbage, waste consists mainly of the outer leaves and, sometimes, of the inner, white hard core. It is possible to incorporate these in the final product and in some whiter varieties the appearance is improved by the addition of the outer leaves. Nutritionally this would be of benefit. One objection to the utilization of the scalding water is that it contains sulphite.

In this country drying of vegetables on a factory scale is approaching but the demands of the Forces are so great that there is little hope of supplying the domestic consumer.

To Mr. McLellan: The suggestion of a cheap drier for domestic use is sound; the preparation, scalding, and storage of vegetables are, however, beset by practical difficulties and it would be necessary to give very detailed instructions.

Dr. L. W. Mapson also replied to the discussion:

To conserve ascorbic acid and other water soluble constituents in canned or dried vegetables, serial scalding or scalding in extracts made from outer waste leaves may be applied in the processing. The chief nutritional advantage of dried vegetables over fresh is that the former contain no ascorbic acid oxidase; there is therefore no danger of loss of ascorbic acid from bruising the vegetable or immersing it in water at temperatures below the boiling point. Dried cabbage reconstituted, cooked and kept on a hotplate loses its ascorbic acid content almost as rapidly as fresh cabbage when cooked, but it can be cooked so easily that the use of the hotplate in canteens can be avoided.

The Utilization of Desiccated Foods

Sir Joseph Barcroft (Physiological Laboratory, Cambridge)

It is the influence of the desiccation of foods on the trends of national life and policy, rather than on the details of culinary practice, that will be here discussed, and quality is the aspect which will first receive attention.

It may seem strange not to emphasize first the saving of space in storage and of weight in transport which makes these products an attractive proposition in peace and even more so in war. True, these are the qualities which have given the present impetus to research, but they seem small matters when compared with the ideal that the nation should be fed with food of the highest quality produced, and that such food should be available to the whole population. In considering quality, a number of issues immediately arise.

The Location of the Desiccation Plant

In general it may be taken that food does not gain in quality during the time of its passage from the producer to the consumer and, therefore, if it is to be desiccated and its quality maintained, the sooner that is done the better.

Fish, for instance, should be desiccated within seven days of being put in ice. If fish from the Icelandic fishing grounds is to be desiccated the drying would, therefore, have to be accomplished in Iceland because the bulk of the fish from there takes more than seven days to reach this country. The amount of fish, however, which would be saved from deterioration would be enormous and, of course, when it was carried across the Atlantic there would be only 2000 tons of dry material to be transported for each 10,000 tons of fish, to say nothing of the saving of the transport of ice.

Clearly the men who fish immediately around the coasts in Great Britain have nothing to fear from the desiccation of ganoids in Iceland for they land their fish fresh and, in any case, their catch includes many more choice sorts of fish. The only menace that desiccation could present to the trade in home caught fish would be to those dealers who allow it to deteriorate before it reaches the consumer.

The above considerations help to clarify the general principle that desiccation promises to help the producer of high quality food, though the same cannot be said of the producer of inferior material.

It is self evident that meat, if desiccated, must be desiccated on the spot, and this truth is of general application; desiccation must take place where the food is produced. For many of the foods that we eat in this country, this means that the drying will take place overseas, and the food will be imported from producer countries in the dry condition. This country would reap the benefit in the increase of food of good quality, and it might be hoped that with the saving of wastage and the reduced cost of transport there would be a saving in price.

If it is possible to maintain the quality of dried products under commercial conditions there should be a big future for the process, and if this big future eventuates, it would be coupled with a considerable alteration in the whole organization of the locus of production and transport. This has to be mentioned because the problem is one which must be faced fairly and squarely by the various interests concerned in this country. We have agreed that the desiccation must take place in the producer countries, and if we are not prepared to fall in with its implications, and yet are unable to prevent it, we shall lose the benefits which might accrue, and our markets after the war will be flooded with food on which we shall lose the profit at every point. It is well worth facing this problem now because it would be much more easily dealt with when industries, largely wrecked, could be reconstituted on new lines, than when normal industries would have to be remodelled at considerable loss. For instance, it may be taken for granted that much of our refrigerated tonnage is lost; if the desiccation of food reduces the demands for refrigerated tonnage it would be easier to meet the changed demand when new ships are being built in any case, than by the scrapping or disuse of expensive machinery in normal times.

The Relation to Agriculture

Among the industries which have been much affected by the war and which, in any case, must not be allowed to slip back into their pre-war condition is agriculture. No thought can be wasted which deals with the possibilities of desiccation in improving the outlook for the agriculturist for, here again, if desiccation has come to stay the agriculturists of this country will be faced with the alternative of taking advantage of it or suffering; they cannot neglect it.

The help which desiccation can give to the dairy farmer in this country depends ultimately on the quality of the milk produced. If the farmer has herds and pasture capable of producing the very best milk and if, at the same time, the drying industry can give both the dairy farmer and the public the assurance that the milk produced in summer can be served up in winter without loss of quality or flavour, it would seem that the dairy farmer's position is strengthened rather than weakened, because he would be more free to produce milk at whatever season of the year the natural order of things dictated.

The principle which was beginning to take shape when fish was discussed has now flashed out clearly, namely that the grower of good food or the producer of high grade milk has everything to gain from desiccation, whilst the grower of poor food or the producer of indifferent milk may rightly regard it as somewhat of a menace because his produce will have to face the possibility of competition with desiccated materials of higher quality.

The concept of a "glut" must next be considered. The word appears to be used in two senses, in one of which it designates little more than is meant by a good crop at a definite season, while in the other it is used to mean something quite abnormal in quantity occurring at an unforeseeable time and place. In the latter sense, it might be used of a vast catch of herrings, occurring one does not know when or where. The public conscience has come to rebel against the throwing away of large quantities of wholesome food in one place, while people are starving in another. It seems beyond the possibility of anything we can foresee that desiccation should be able to make the saving of such food an economic process or indeed that anything could. The most that could be asked of desiccation at present is to inquire of it whether it could make the salvage of such gluts less uneconomic and, if such food is to be saved, reduce the burden that would have to be borne by the more economic processes of food production.

In dealing with gluts in the sense of large seasonal productions of high grade and perishable commodities, there seems to be a field in which desiccation should be able to help the grower very materially. After all, it is only an expansion of the problem confronting those who make jam and otherwise deal with the seasonal fruits of the earth as at present. It is clear that anything which could at once convert fruit or vegetable harvests quickly to a form in which they would keep and be reconstituted would go far to prevent the fall in price incident on excessive production. It would be along these lines, therefore, that agriculture should consider what can be most profitably grown in this country to take full advantage of the possibilities of storage in the desiccated form, and there is this consideration in addition, that, with milk for instance, the hoped for general rise in the nutrition of a great proportion of the population should bring about an increase in the demand for perishable foods grown in this country which would, in fact, be grown not for immediate consumption, but for processing.

One more point should be made about quality. The foods shown by Dr. Kidd are not only of high grade, but they are ascertainedly so, and their quality could be certified just as the quality of the civilian respirator is certified. Should the public wish to be protected against rubbishy products, there is no reason why this should not be done with desiccated foods.

Use in Canteens and Kitchens

The question of the utilization of desiccated foods has been dealt with as it seems to affect future policy; the no less difficult question must now be considered of the ways in which desiccation of food may influence our habits as a nation. The whole question of communal feeding is one which will present a big problem in the near future, and it is clear that the reduction of bulk in the transit and storage of food, coupled with an indefinite increase in its keeping capacity, must simplify the solution very much.

Many tributes have been paid by canteen caterers to the Low Temperature Station for the value of its desiccated foods. The soup powders are an outstanding contribution to solve the problems of emergency feeding, particularly in London where a large stock, requiring elaborate arrangements for turnover, is necessary.

To what extent the simplification of communal catering will really tip the scales in favour of communal feeding it is difficult to say, because the same general considerations may act even more strongly in the direction of reducing the disability of the domestic kitchen.

An enormous amount of work is expended, and time and fuel are required for the production of a meal, so much so, that it is difficult for many householders, who are themselves engaged in daily avocations outside their kitchens or homes, to produce the sort of meal that they would like to set before their families. At present the solution is that they live to a large extent on tins, which provide a meal, but a rather indifferent one. The hope for desiccated foods, especially if their variety can be greatly increased, is that from a very much smaller, more accessible and more easily cooked amount of cupboard contents, the housewife will be able to produce a vastly more attractive dinner than she can do from the present tins, with very little support from fresh materials. It may even be that these considerations will go far to reinstate the domestic kitchen and with it the home.

Discussion

Squadron Leader T. F. Macrae, R.A.F.V.R. (R.A.F. Institute of Pathology and Tropical Medicine), opener: For the feeding of troops dried foodstuffs have several obvious advantages:

(1) They are concentrated and therefore more easily transported.

(2) They keep in good condition for long periods and, therefore, in parts of the world where supplies of fresh foodstuffs are difficult to obtain, they make the dietaries more nutritious and, giving variety, more attractive.

(3) They are much more easily prepared for the plate than the fresh products.

In cooking in the field the importance of this last point is obvious.

In the R.A.F. Institute of Pathology and Tropical Medicine, and in the R.A.F. School of Cookery many tests have been carried out on dried cabbage, carrots, potatoes, meat, fish, soups and eggs; all products were found to be of high quality, and cooks and caterers were well satisfied.

In an interesting experiment comparison was made of the nutritive value and palatability of cooked cabbage made from the dried, and from the fresh, vegetable. Fresh cabbage cooked by the method usually employed in large scale cooking gave in a single helping about 10 mg. of ascorbic acid, whereas the dried product when cooked yielded about twice this amount. The reason for this is that large scale cooking leads to destruction of ascorbic acid in fresh cabbage, mainly through the ascorbic acid oxidase. Dried cabbage, which contains none of this enzyme, loses less ascorbic acid on large scale cooking. It is in a sense "cookproof." To compare the palatability of these products, the airmen in a mess were divided into two groups, one half being served with the cooked dried cabbage and the other with the cooked fresh. The former proved the more acceptable; 100 men left on their plates about 2½ lb. of cooked fresh cabbage and a similar number of men left only about ½ lb. of the cooked dried cabbage. The reason for this is simple; cooked fresh cabbage prepared under large scale conditions always contains some coarse outside leaves to which many object. In the dried product, if coarse outside leaves are included, they are shredded and are not found unpalatable.

The attitude in the R.A.F. towards dried foodstuffs is not one of worry as to whether available supplies can be used, but rather it is felt unlikely that as much will be obtainable as would be liked.

Dr. J. Hammond (School of Agriculture, Cambridge): How will the use of dehydrated foods affect in the future the 3 phases through which food

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passes, production, distribution, consumption? It will help the producer to clear off gluts. These occur with vegetables regularly at certain seasons of the year and also sporadically in certain years with favourable climatic conditions. With eggs, planning for sufficiency in November leads to surplus in March. When it comes to meat, dehydration will open for production inaccessible areas such as Rhodesia and northern Australia where it is difficult to apply cold storage methods.

In distribution, the saving of shipping space will reduce costs. The process will be of great use for the supply of meat to southern and eastern Europe and to other countries where little cold storage place is available.

The consumer also will benefit, for dehydration will meet the growing domestic demand for partly prepared foods, the cost of high quality foods will be reduced especially during the winter months at a time when malnutrition is most likely to occur. In the past only the wealthy could afford the heavy cost of out of season foods; dehydration will make many of these foods available to those of moderate means.