RECENT ADVANCES IN SOME ASPECTS OF FOOD TECHNOLOGY

by

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ABSTRACT

Food technology is the application of science and engineering to the production, processing, packaging, distribution, preparation and utilisation of foods. The scope of this definition is very wide and with the rapid strides that technology has made during the present century it is difficult to deal with all the aspects in a single attempt. This article will be concerned primarily with some of the recent techniques standardized for dehydration and sterilisation of foodstuffs including vegetables, meat, fish and dairy products. It will also record briefly the packaging improvements achieved during the last few years.

Introduction

Although very expensive this is being most actively studied in the United States (1,2,3,4,5,6). There are two stages in the process (*a*) the ice is evaporated from the frozen mass and (*b*) the remaining moisture is removed by warming to about 35-40°C. By keeping the material frozen, shrinkage and migration of the dissolved materials is avoided thus inhibiting chemical reaction. The low temperature maintained minimises loss of volatile constituents. The foodstuff is either pre-frozen by any conventional freezing equipment or by evaporative cooling after putting the material under vacuum (7). Evaporative freezing is known to produce sufficient case hardening in the unfrozen state which ultimately gives a low rate of drying and reconstitution. This is particularly true in case of meat (8).

Freeze-drying is optimum when the pressure inside the vacuum chamber is about $\frac{1}{2}$—$\frac{1}{4}$ of the vapour pressure of ice in the frozen material e.g., if temperature of the frozen material is 0°C, the (2) pressure can be of the range of 1,000 μ (1mm. of Hg.); for temperature — 20°C the corresponding pressure will be 100 μ (8). Mechanical vacuum pumps or steam jet ejectors are employed to produce vacuum. For the measurement of pressure of this order Campbell et al (9) have used a modification of the *Mcleod gauge*. The water is removed either by direct pumping in which case the load on the pump is very heavy or by condensation ahead of the pump or by chemical absorption over some dessicants (10) or by physical absorption (11). For chemical absorption various glycols and ethanol amines are being currently tried. Physical absorbents, however, are more economical than chemical dessicants as regards regeneration and capacity to hold water vapour.

During the first stage of drying when an efficient means of removal of water vapour is available, the controlling factor for rapid evaporation is the speed at which heat can be carried to the icy surface through the poorly conducting frozen foodstuff. Actually this heat transfer can be effected through various ways. It is this phase of equipment design that offers the best possibilities of improving the economics of the process. The heat is supplied either through direct conduction heating by circulation of water of the desired temperature or by radiant heating through infra-red radiation (12) or by dielectric heating. The drying rate usually maintained is 1mm. depth per hour at —18°C and 250 microns pressure. Under these conditions the rate of drying is constant during the first stage *i.e.*, until all the ice is evaporated. This removes about 95% of the total water in the material. During the second stage the final moisture content of 0·5% is achieved. The method has been examined on a small pilot plant scale as regards freeze-dried beef, lamb, chicken, pork, fish and some fruit juices. Burton (13) describes a batch dryer in which the juice is sprayed on to the walls of a warm water-jacketed tank under the influence of vaccum of 500—700 microns. The thickness of the layer is adjusted for a six hour drying cycle. The dried product is scraped with blades which are permanently installed. In large scale industrial production, however, continuous operation is considered to be the ultimate goal. A continuous drying equipment has been reported by Sender and Coworkers (14) where the product is sprayed on continuously moving drum or belts. Morse (15) has described bellows-type and grease-type seals for continuous machines.

The product is a very porous solid identical in volume with the initial material. The reconstitution is very good and rehydration time is just five minutes in some cases. The reconstituted product approximates closely to the texture and flavour of the starting material. Further, freeze-dried foods are valued specialities since refrigerated storage is unnecessary in these cases. In spite of all these inherent advantages, however, it is doubtful at the moment if freeze dried products can compete economically with other dehydrated products due to the relatively higher costs of this method.

Vacuum Contact Plate Method

Distillation of water at reduced pressure is accompanied by loss of latent heat and ultimately freezing. For continuous drying either the vacuum should be increased to such an extent that the ice formed will sublime or the latent (14) heat loss must be compensated by some external heat source. The former i.e., vac-ice drying is expensive. In the latter case the undried material is placed in contact with a source of heat. The region in immediate contact with the heating source has its latent heat loss compensated for and dries rapidly with a honey-comb like texture which is a very poor conductor of heat and prevents heat passing to the undried regions. If the material is heated from both above and below, this partly overcomes the difficulty and by gradually bringing together the two heating surfaces at a rate such that the honey-comb region is always collapsed before becoming brittle. so bringing the wet-region into close contact with the heating surface, the material may be dried through out. This process is referred to as vacuum contact plate dehydration method (16). Though of recent origin, the process is already proving very useful in case of vegetables and meat due to the fact that the temperature maintained here is considerably lower for most of the drying period than in case of normal hot air drying methods. Although the economics of the vac-contact drying as compared with air drying process have not been fully worked out, the reduction in packaging costs in the former case is expected to go a long way towards off setting the higher capacital cost of the vacuum plant. It has already been successfully applied to potatoes (17) & (18), cabbage (19), fish and meat (18 & 20).

The foodstuff is laid on sheet aluminium trays covered with a similar lid and fed between the heating plates. Water at 15°C is circulated through these plates; the cabinet is evacuated by water ejectors to a pressure of 70 mm. of Hg. and then to 3-4 mm. by steam ejectors. During the first hour of the process the material cools and eventually freezes because of the evaporation of water and the rate of evaporation now will depend on the rate at which heat is supplied to compensate the loss of latent heat. The temperature of the circulating water is now gradually raised and the rate of bringing heating surfaces closer is so controlled that it is neither too quick to avoid squeezing out of juice nor too slow so as to allow the product to become brittle and consequent lengthening of drying time. 4-6 per cent moisture content is achieved in 4 to 8 hours depending on the material and density of loading. It is claimed that the vacuum dried materials had longer storage life in tropical climates. In case of cabbage the slight compression given during dehydration forms products into thin flat slabs instead of loose shreds and results in a doubling of the packing density. At the beginning of the process when evaporation is most rapid, the temperature and pressure are so manipulated that steam channels can be induced within the portion of vegetables (21) so that on reconstitution dehydrated materials of this type will absorb water more rapidly than the corresponding hot-air dried vegetables. It is believed that the differences are largely due to the method of water removal. In air drying the outer most layer of cells dries (6) and their contents become concentrated and hygroscopic, They then absorb water from the layer of cells beneath only to lose it to the hot external air. There is, thus, a diffusion gradient from wet inner cells to outer drier cells and so to the outer hot air. The product is leathery, shrunken and dense. In the vacuum contact dehydration the moisture is distilled from the outer most layer of cells leaving a honey-comb structure. This is collapsed under pressure but sufficient channels are left for the vacuum to effect distillation of water from next layer of frozen cells when heat reaches them from the heating plates. The process gives a crisp, porus product. Matheson (91) has reported that although the quality of bacon dehydrated by vacuum contact plate method is good, the storage characteristics are not very saisfactory. More recently the technique of accelerated freeze drying as described by Hanson (92) has superseded the vacuum contact plate method and has proved advantageous as regards the storage life, reconstitution and acceptability of bacon & gammon treated by this new technique.

Fat Vacuum Method

This is also known as "ZIMMERMANN'S" method (22). Here the vegetables, meat products or dairy products are dehydrated in a fat or oil bath under high vacuum at low temperature. The moisture regaining capacity of the food is preserved by the entry of the fat into the inter cellular spaces of the tissues during the drying process. This method was developed for the German Army during the last two years of the war and is now again being revived (23, 24, 25, 26, 27).

During the first stage of drying when an efficient means of removal of water vapour is available, the controlling factor for rapid evaporation is the speed at which heat can be carried to the icy surface through the poorly conducting frozen foodstuff. Actually this heat transfer can be effected through various ways. It is this phase of equipment design that offers the best possibilities of improving the economics of the process. The heat is supplied either through direct conduction heating by circulation of water of the desired temperature or by radiant heating through infra-red radiation (12) or by dielectric heating. The drying rate usually maintained is 1mm. depth per hour at —18°C and 250 microns pressure. Under these conditions the rate of drying is constant during the first stage *i.e.*, until all the ice is evaporated. This removes about 95% of the total water in the material. During the second stage the final moisture content of 0·5% is achieved. The method has been examined on a small pilot plant scale as regards freeze-dried beef, lamb, chicken, pork, fish and some fruit juices. Burton (13) describes a batch dryer in which the juice is sprayed on to the walls of a warm water-jacketed tank under the influence of vaccum of 500—700 microns. The thickness of the layer is adjusted for a six hour drying cycle. The dried product is scraped with blades which are permanently installed. In large scale industrial production, however, continuous operation is considered to be the ultimate goal. A continuous drying equipment has been reported by Sender and Coworkers (14) where the product is sprayed on continuously moving drum or belts. Morse (15) has described bellows-type and grease-type seals for continuous machines.

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It has been employed in Newzealand solely for the dehydration of meat. Trimmed (7) boneless meat is fed into molten fat contained in the dehydrator, which is a horizontally rotating water jacketted steel vessel maintained at 200°F. The molten fat conducts the heat to the meat and drying is effected at a pressure of one inch of mercury in about 4-5 hours. The molten fat which permeates the meat is removed in a hydro-extracter. The products are reported to rehydrate very nicely.

Dehydro-Freezing

Another process that has been engaging the attention of food technologists is the dehydro-freezing of fruits and vegetables (28). In the investigations carried out upto date the quality of products has proved encouraging, whereas uniform continuous drying has been found difficult with some products. In the drying step, prior to freezing, the extent of dehydration required is adequate before the temperature of the pieces rises to a point where it causes changes characteristic of ordinary dried products—such as dried apples or dried peas. That is adequate moisture is removed before the pieces cease to be moist. Extensive research into this method has been carried out at Western Utilization Research Laboratories, California, and it is hoped that the new method will result in substantial savings in container, shipping, storage and handling costs. Thorough research has been conducted to determine the maximum reduction in weight and volume that can be achieved through dehydration with retention of quality level of conventionally frozen foods. In the pilot rotary dryer developed, air is delivered through the bed of the material by four separate air ducts each with its own blower and steam coils. Partially dried apple slices obtained by using a wet bulb temperature of 130°F and dry bulb temperature of 200°F, were of very good quality, natural creamy white in colour with clean sharp cut edges and surface free from mechanical abrasion. Commercial adoption of this method in the United States is getting under way.

Dried Fish Fillets

Upto the end of second World War, dehydrated fish products were prepared only from minced fish and could, therefore, be only used in compound dishes. Jackson et al (28) have reported some results on the dehydration of whole fish fillets by the vacuum contact plate process. Water uptake by these samples was almost 100 per cent of the original water content of the tissue after 125 minutes. The freeze-dried sample retained the typical spindle-shaped spaces induced by the formation of ice crystals even after reconstitution.

Radiation Pasteurization of Foods

Experiments on gamma irradiation of food with waste fission products from nuclear reactors have been reported recently (29). The observations include the effects on storage life, taste and quality of a wide variety of foods such as meat, fruits, potatoes, onions, cabbage, coffee, cake and bread flours. Designs for commercial irradiation facilities for the above have been studied and are believed to be feasible representing commercial applications of the fission products. A report published by the Engineering Research Institute of the University of Michigan, U.S.A. (30) records the improvement in shelf life and flavour changes of gamma ray pasteurized fresh vegetables. Studies on prolonging the storage life of ground raw pork and beef and oranges and reports of experiments on the use of low dosage gamma irradiation to prevent sprouting of potatoes and onions with subsequent storage at 50°F and approximately 50 per cent relative humidity are also described. Packaging materials used in these experiments were polythene, kraft paper bags and mesh bags. It is claimed that the gamma ray pasteurized raw ground beef can be stored at 40°F for eight days without spoilage and very possibly for ten days without noticeable flavour and odour changes. In case of potatoes the control samples stored at 50°F and 50 per cent relative humidity started sprouting after three weeks while the irradiated products were still in excellent condition after four months.

If the radiation dosage is sufficient it is possible to achieve almost complete sterilisation of foods. But before the process can be applied for commercial production it should be clearly demonstrated that no toxins i.e., induced radioactivity toxic radiation degradation products or corcinegens are produced by the required dose of irradiation and that no dietary deficiencies are caused by component degradation. It is reported that the degree of pasteurization is a function of the dosage and also depends on container material and storage temperature (31). If it is possible to pasteurize at lower doses the chances of manifestation of toxic effects will recede proportionately. Whether or not radiation pasteurization is economically feasible is still a moot point.

Antibiotics as Food Preservatives

The use of antibiotics as food preservatives has hitherto been somewhat speculative. Much research effort has been concentrated in this aspect and of late results obtained show that some of the antibiotics are extremely effective in extending the storage life of certain foodstuffs.

Tetracyclines are perhaps the most effective for poultry preservation with aureomycin having the maximum preservative power. The food grade of aureomycin is sold under the name of "Acronize" and condtions governing its use for poultry are very strict (33, 34) in USA. The aureomycin treatment has always to be combined with good hygiene and refrigeration in order to safeguard against some of the resistant forms of staphylococci and Salmonella species.

Tarr (35) and Farber (36) have found that aureomycin is also useful in extending the storage life of fish. It has been reported that the storage life of shrimps may be increased by dipping in iced water containing aureomycin and subsequent refrigeration.

U.S. Department of Agriculture is now conducting some experiments on treatment of meat with aureomycin by spraying the latter on heavily contaminated parts of the carcase and then refrigerating (32). Some of the meat packers, however, point out that notwithstanding the use of aureomycin they usually get a surface growth of some aureomycin-fast moulds after about two weeks storage at 34-36°F. Deatherage (37) has suggested the preservation of meat at room temperature by infusion of the carcase at slaughter or infection of the antibiotic several hours before slaughter. Encouraging results have been obtained both with terramycin and aureomycin but there are many uncontrolled variables in these experiments such as the condition of the animal at the time of slaughter. Antibiotics are also being tested in minced/meat and ham and bacon curing.

Nisin and subtilin are the other two antibiotics which proved quite effective in the canning field by helping to reduce the extent of heat treatment. The use of subtilin has given good results in controlling the flat sour spoilage of tomato juice (38). Nisin also is being used quite extensively in the manufacture of cheese and for the preservation of vegetables and fruits (39).

Inspite of these developments enough data are not yet available on the emergence of an antibiotic-resistant flora in a food processing plant. Furthermore although aureomycin is proved to be non-toxic when taken orally for long periods (40); its use can only be sanctioned when a complete destruction on cooking can be demonstrated. This has proved to be difficult particularly in case of meat where active residues have been detected in fried chops (1). The demonstration of the absence of active residues in Indian dishes may not be as serious a problem since Indian meat preparations are boiled and cooked for a much longer time than the corresponding European dishes.

Control of browning in processed Foods

The browning of dried foodstuffs when stored at relatively high temperatures has long been a problem. The formation of brown pigments occurs due to the interaction between amino acids and reducings sugars and results in bad appearance and liberation of off-flavours. These reactions are initiated much more readily at tropical temperatures. The badly discoloured pieces do not reconstitute properly. Browning may also occur during the drying process. Davis et al (41) have reported that one of the greatest difficulties in dehydrating potatoes is the danger of discoloration near the end of the drying period. Cruess and Frier (42) observed discoloration when potatoes were dried at high humidities, held too long at 60°C and when they were dried at high finishing temperatures. Browning has been found to be most severe with potatoes of high reducing sugar content and is very slight if the reducing sugar content is low (43, 44). The rate of discoloration is also affected by moisture content and storage temperature (45, 46, 47, 48). The browning reaction can also be inhibited by sulfiting (46, 49, 50, 51, 52). Packaging in inert atmospheres has little or no effect on the rate of browning. The effects of sulfiting, low reducing sugar contents, and of attainment of low moisture contents are additive in the sense that a combination of any two methods is more effective than either alone and a triple combination is the most effective (53).

Antioxidants as Preservatives

A number of constituents of food, including unsaturated lipids and lipid and water-soluble vitamins, pigments and flavouring substances are able to react with atmospheric oxygen, either directly or in coupled or catalysed reactions during the interval between preparation and consumption. In the living tissue of plant or animal these processes are kept under control by the complicated enzymic oxidation-reduction mechanisms of the cell but in the dead tissues and foods processed from them the degradative process can occur and may even be accelerated by some of the fragments of the shattered cell machinery, such as hæmitin pigments and certain oxidases.

Considerable emphasis has been laid in recent years on the importance of keeping edible fats palatable and wholesome especially when storage is necessary. This has been accomplished by several means such as choice of raw materials, hydrogenation, proper packaging, deodorization and taking other precautions during processing to avoid unnecessary exposure to heat and light or contamination with pro-oxidants (54). Due to some of the inherent limitations of these methods antioxidants are utlimately relied upon for the stabilisation of fats. Many compounds have been found to possess antioxidant properties, the more common being gum guaiac, gallic acid, catachol and hydroquinone. Lunberg (55) has compiled a list of antioxidants which are in current use or which have been proposed for use in stablizing edible fats, lecihin, cephalin, tocopherols and products obtained from cereals, yeasts, sugars and other food substances have also been proposed. The criteria for establishing the usefulness of a chemical as an antioxidant are that it should be fat soluble and impart no foreign colour, odour or flavour to the fat even on long storage. It should be unchanged when heated and should possess the ability of retarding rancidity in baked foods prepared from fats treated with the antioxidant. The carry over properties of the comparatively newly investigated butylated hydroxy anisoles in various fat containing foods are reported to be quite encouraging to warrant their use in edible fats (56).

Packaging

Several new packaging materials ranging from plastic films to lacquers and impregnating agents used to improve the properties of paper and metal containers have been introduced during the past decade or so. Silicone polymers, one of the newest synthetic products are highly water repellent and have got potential applications for the internal coating of glass bottles and jars to enable products such as sauces and ketchups to be poured out more quickly (59). Silicone coatings or wrapping papers make them more resistant to moisture and non-adherent to sticky products.

Two entirely new films one a nylon type (polyamide) and the other that of polyvinyl chloride (p.v.c.)—have been introduced in the packaging industry (58). The nylon film is odourless, non-toxic and entirely free from plasticisers. It is tough and pliable over an exceptionally wide temperature range (—20°C to 150°C) is resistant to both animal and vegetable oils and greases, and will not support mould growth. It is available in an oriented or "prestretched" form giving a greater tear resistance in the direction of web (59).

The new p.v.c. film does not contain any additives likely to leach out and contaminate the food products. It is completely odourless, tasteless and nontoxic. This unplasticized p.v.c. film is very suitable for the fabrication of vacuum packs due to its low gas permeability factor and is available in various colours and opaque shades.

Aluminium foil is another material which has been exploited very advantageously as packaging material during the past few years. The new aluminium foil laminate specially designed for dried soups (60) consists of a layer of paper sandwiched between two layers of foil, one side of which is coated with a heat sealing medium. The heat seal coating and the laminatants which bond the foil are highly resistant to moisture. Aluminium foil is also being used for the production of rigid squared up packs (61) used for cheese, sea foods, meat loaf and other delicacies.

As regards developments in the canning field, collapsible tubes are being used fairly extensively. A collapsible tube made from transparent polythene is already in production (62) for the packaging of concentrated fruit juices.

Effect of processing on the nutritive value of foods :

The technical processing of foods although it permits prolonged storage and distant transportation is invariably accompanied by some ecomomic losses suffered by comparatively sensitive nutrients either due to elevated temperatures employed during dehydration or through the agency of electrolytic dissociations so common in canned materials.

It has been reported that the processing of milk adversely effects its vitamin content and nutritive value of its proteins. This is particularly true of highly heated milk products like sterilized milk, condensed milk and roller dried milk solids. Sterilized milk is known to undergo significant losses of vitamin A, vitamin E (63) and pyridoxine (64); vitamin C is completely destroyed (65) and the nutritive value of protein is also reduced (66, 67, 68). Supersonic wave treatment to sterilise milk destroys up to 46% of vitamin C and 67% of vitamin B_2; B_1, however, is reported uneffected (69).

Canned goods, unless properly handled during the process, always undergo considerable loss of vitamins like vitamin B_6, earotene vitamin C, thiamine riboflavin and niacin (70).

The nutritive value of bread—one of the major sources of calorie intake as regards its vitamin, protein and mineral content—is influenced by the methods of flour production (71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82). Vitamin B_1 content of an "80 per cent" flour is 50—80 per cent of the natural content of the whole wheat; in a "70 per cent" flour it is only 12—40 per cent; the corresponding values for vitamin B_2 are 30—70 per cent and 23—50 per cent; and for nicotinic acid 15—50 per cent and 10—35 per cent; respectively (71,84). Calcium, iron, vit. E and B_6 are also similarly effected (71, 84). Chemical treatment of flour particularly bleaching also partially destroys vitamins (85, 86).

A considerable loss of vitamins always occurs in canned goods unless proper precautions are taken against such losses during the canning process (87). This was shown in reports on losses of nutritive value which have been observed in the preparation and storage of "Combat-rations" for the U.S. Army (88, 89). The newer methods of dehydration however, by the use of comparatively lower temperature safeguard these losses and assure the provision of wholesome nutritive foods everywhere and anywhere.

The processing of food does not, of course, produce only harmful effects. The utilisation of carotene in the vegetables containing it is much improved by pre-cooking (90). In some cases the proper utilisation of protein follows only after preheating (90).

Inspite of some of the above shortcomings food processing is a necessity because world food supplies at the moment are not so surplus—nor are they likely to become so in the near future—that we can afford to waste even small quantities of food if such wastage can be prevented. It also helps in easing out the seasonal glut of certain commodities in certain areas and the bottlenecks involved in the transport of them.

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