For economy of operation, within reasonable limits of compression ratio, it is recommended that ice cream plants use multi-stage compression. For freezing ice cream, producing frozen suckers and refrigerating an ice cream hardening room to −20 F, one or more booster compressors might be used at the same suction pressure, discharging into second stage compressors which also handle the mix cooling and ingredient cold storage room loads. If a hardening tunnel is used at temperature of −40 F or below at least two booster compressors should be used, one operating at the suction pressure required for the tunnel and the other operating at a higher suction pressure required for the ice cream freezers and ice cream storage room, with both discharging into the second stage compressor system. For plants with hardening tunnels arranged for large volume, an analysis of operating costs may indicate economy in using three stage compression with the low temperature booster used for the tunnel, discharging into the second stage booster used for freezers and storage, and the second stage booster discharging into the third stage compressor system.

The high temperature loads in an ice cream plant will usually consist of refrigeration for cooling and holding cream, cooling ice cream mix after pasteurization, cooling for mix holding tanks and refrigeration for the ingredient cold storage room. If direct expansion cooling is used for the high temperature loads then compressor selection can be made at about 20 F saturated suction temperature and combined with compressor capacity required to handle the booster discharge. About the same high suction temperature can be estimated if ice cream mix and mix holding tanks are cooled by chilled water from a flash type water chilling system, as described in the Milk Plant section, Chapter 32. If an ice bank chills water used for cooling pasteurized ice cream mix, it may be desirable to provide a separate compressor to handle this ice bank refrigerating load.

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CHAPTER 44

PRECOOKED AND PREPARED FROZEN FOODS

Physical and Chemical Changes, Types of Precooked Frozen Foods, Foods Served Hot, Foods Served at Room Temperature, Foods Eaten Frozen, Importance of Uniformly Low Storage Temperature

TODAY most frozen food packers are freezing one or more prepared frozen foods. Canners, packers of fish, meat and poultry, large restaurant chains, and caterers have entered the field. Leaders in the grocery products field and large dairies and bakeries are producing and marketing precooked frozen foods.

Many precooked foods are altered by freezing, storage, and reheating for use. Cooked foods may be grouped into four categories: (1) those which may be frozen, stored, and thawed without marked change—such as applesauce, clear soups, winter squash, baked breads, rolls, cookies and most cakes, and various pies; (2) those altered by freezing, storage and reheating, but which with certain changes in production or formula can be suitably modified for freezing—includes most creamed products, sauces, and gravies; (3) those of excellent initial quality but which deteriorate rapidly at ordinary storage temperatures and must be held at −20 F or lower, such as fatty fish, shellfish, and most turkey dishes; (4) those so changed by freezing and reheating as to be difficult or impossible to improve, as: custards, cooked egg whites, and salad type vegetables.

PHYSICAL AND CHEMICAL CHANGES

Changes occurring when cooked foods are frozen are most often the result of both physical and chemical action. The curdling of custards is partly caused by crystallization of water as ice and partly by a continuing denaturation of egg proteins. Gravies and thickened sauces may curdle for much the same reasons. Marked temperature fluctuations and high storage temperatures cause a greater liquid separation from sauces, when other factors remain the same. The importance of uniformly low storage temperatures is confirmed by these reactions.

Liquid separation in frozen, stored sauces and gravies has been extensively studied. The use of amylopectin flours and starches minimizes curdling. These starches, in contrast to some waxy cereal starches, have a long paste character and only certain flours appear useful. Hanson found waxy rice flour to be superior to waxy corn or sorghum flours. When sauces and gravies made from waxy corn or waxy rice flours are compared only in the reheated stage, then both yield an equally acceptable product.

Changes in proteins, resulting in coagulation and toughening, occur in many high protein foods. Raw egg white is not markedly affected by freezing and thawing. Freezing the cooked product makes it tough and rubbery. The water in the elastic gel of the cooked egg white (denatured protein) migrates to increase the size of crystals where nuclei are present. The crystals grow and penetrate the gel. This separates the structure, releasing a part of the elastic tension. The gel contracts due to the migration of the water from within the structure, plus the force exerted by the growth of ice crystals and the release of elastic tension by mechanical cleavage. This contraction is largely irreversible as demonstrated by the liquid-filled spaces remaining after thawing. The remaining structure is tougher, since it contains a considerably higher proportion of protein than the original gel.

This same denaturation of protein probably plays a part in the loss of gas from batters during freezing. This loss may also be caused by the separation of ice and the concentration of carbon dioxide in the liquid phase to such a degree that it will not stay in solution. The reaction of the carbonate of soda and acid in the more concentrated aqueous solution produced by the separation of water as nearly pure ice, also plays a part in the escape of the leavening gas during freezing and thawing. All of these reactions, except the one involving baking powder ingredients, will cause some loss of gas in yeast doughs. The yeast cells gradually lose their viability over prolonged storage periods. The longer dough is held, the longer it will take to rise after it has thawed and warmed.

Chemical changes of oxidation that bring on rancidity may occur during the freezing and storage of some fatty cooked foods. Rancidity in creamed turkey has been detected as soon as it was prepared. The rancidity increased in frozen storage. Many workers have shown that adding edible antioxidants during the cooking of fatty foods rather than just before packaging increases the effectiveness of the antioxidant in retarding oxidative rancidity.

The assumption that cooked meat fat, especially pork, turned rancid more quickly than raw fat was disproved. It was found that *pH* had no effect in rancidification of precooked ground pork. And except at the upper limits of the normal *pH* range of fresh pork, the precooked product kept better.

The cooking process inactivates peroxidizing enzyme or enzymes and so rancidity usually develops more slowly in the precooked product. The rate of all chemical reactions that cause precooked products to deteriorate is reduced by lowering storage temperatures.

The storage periods as given by Tressler and Evers (Vol. II) are roughly equivalent:

3 months at 15 F	12 months at 0 F
6 months at 10 F	24 months at −10 F
9 months at 5 F	36 months at −20 F

Factors other than temperature may influence the rate of deterioration. The type of packaging used is of great importance. Most precooked foods (fish sticks, poultry, precooked meals) have sufficient air space in the package so that fluctuating temperatures tend to dehydrate the product, causing quality loss at a rate usually greater than that for the mean temperature. At lower temperatures, the rate of the deterioration of most precooked frozen foods is about the same at a given uniformly maintained temperature and at the same mean temperature under fluctuating conditions—provided the maximum temperature is not high enough to partially thaw the product. Widely fluctuating temperatures cause the crystal size to grow during storage. This is objectionable in ice