

PROCESSED, PRECOOKED, AND PREPARED FOODS

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ALTHOUGH there are many categories of processed, precooked and prepared foods, this chapter covers primarily main dishes, meals, fruits, vegetables, and potato production from the perspective of the refrigeration and air-conditioning concerns of facilities producing these categories of food.

To ensure the safety of food products, the Hazard Analysis and Critical Control Point (HACCP) system is now accepted by food manufacturers and regulators. It is a preventive system that builds safety control features into the food product's design and the process by which it is produced. The HACCP system is used to manage physical and chemical hazards as well as biological hazards.

Each food manufacturing site should have an HACCP team to develop and implement its HACCP plan. HVAC&R practitioners are a part of that team. Areas of concern include HVAC&R equipment and the associated air distribution system, sanitation equipment and procedures, and processing (automation, heating, cooling, temperature control). [Chapter 11](#) includes additional information on HACCP.

Each plant should be equipped with HVAC systems that provide clean, filtered fresh air in quantities to offset any plant process exhaust systems. Negative plant air pressure should be avoided. In addition, HVAC systems should direct air flows and pressures from finished product areas toward initial processing areas to minimize aerosol bacteriological contamination.

MAIN DISHES, MEALS

Main dishes constitute the largest category of processed, precooked and prepared foods. They are primarily frozen products, but many are also refrigerated. Most of these dishes can be prepared in a conventional or microwave oven. Many contain sauces and/or gravies. Consequently, sauce and/or gravy kitchens are an integral part of these production facilities. A principal characteristic of main dishes is the requirement for a substantial number of ingredients, several unit operations, an assembly-type packaging line, and subsequent cooling or freezing in individual cartons or cases. Examples of these products include

- Soups and chowders
- Main dishes of meat, poultry, fish, and pasta items
- Complete dinners, each with a main dish (usually with sauce and/or gravies), a vegetable, and dessert
- Lunches and breakfasts
- Ethnic main dishes and dinners, particularly Italian, Mexican, and Asian styles
- Diet versions of many of the above
- Snack foods such as pizza, fish sticks, and breaded items

The preparation of this chapter is assigned to TC 10.9, Refrigeration Application for Foods and Beverages.

General Plant Characteristics

The plant facilities for preparing, processing, packaging, cooling, freezing, casing, and storing these products vary widely. Since the variety of products is diverse, and it is beyond the scope of this chapter to cover all the operations involved in all the products, product formulations, food chemistry, and process details are not discussed. This chapter also does not cover the basic process details for preparing meat, poultry, and fishery products. For information on these subjects, refer to [Chapters 16, 17, and 18](#), respectively.

A prepared foods plant has production areas and/or rooms for the following: receiving; storage for packaging materials and supplies; storage for ambient, refrigerated, and frozen ingredients; thawing and defrosting; refrigerated in-process storage; mixing, cutting, chopping, and assembly; sauce and/or gravy kitchens; cooking and cooling rice, pasta and/or other starches; unit operations for preparing main dishes such as meat patties, ethnic foods, and poultry items; dough manufacturing for pies and pizzas; assembly, filling, and packaging; cooling and freezing facilities; casing and palletizing operations; finished goods storage for refrigerated and frozen products; and shipping of outbound finished goods by truck or rail.

In addition, these operations have support and utilities areas for equipment and utensil sanitation; personnel facilities; and areas for utilities such as refrigeration, steam, water, wastewater disposal, electric power, natural gas, air, and vacuum.

Plants and equipment for the production of prepared foods should be constructed and operated to provide for minimum bacteriological contamination and ease of cleanup and sanitation. Sound sanitary practices should be followed at all stages of production, not only to protect the end user but also to provide wholesome, healthy products. In the United States, all meat and poultry plants, and hence most prepared food plants, operate under U.S. Department of Agriculture (USDA) regulations. For detailed information and guidelines, refer to *Agricultural Handbook* No. 570 from the USDA, Food Safety Inspection Service.

Preparation, Processing, Unit Operations

The initial steps in the production of prepared foods involve the preparation, processing, and unit manufacture of items for assembly and filling on the packaging line. These generally include scheduling ingredients; thawing or defrosting frozen ingredients, where applicable; manufacturing sauces and gravies; cooking and cooling rice, pasta and/or other starches; unit operations for manufacturing meat patties and ethnic foods, such as burritos; mixing vegetables and/or vegetables and rice, pasta or other starches; manufacturing dough; and cooling, storage, and transport operations prior to packaging.

The previously mentioned processes require refrigeration for controlled tempering in refrigerated rooms; plate heat exchangers or swept surface heat exchangers using chilled water or propylene glycol for preparation of sauces and gravies in processors; chilled water for cooling rice, pasta and/or other starches; refrigerated

preparation rooms for meat and poultry products; in-line coolers or freezers for meat patties, burritos, etc.; ice for dough manufacture; and cooler rooms for in-process storage and inventory control.

The refrigeration loads for each of these categories should be calculated individually using the methods described in [Chapter 12](#). In addition, the loads should be tabulated by time of day and classified by evaporator temperature, chilled water, ice, and propylene glycol requirements. An assessment should be made whether an ice builder is appropriate for chilled water requirements to reduce refrigeration compressor capacity.

The refrigerated rooms should be amply sized, be capable of maintaining temperatures from 0 to 10°C as required for the specific application, have power-operated doors equipped with infiltration reduction devices, and have evaporators that are easily sanitized. Evaporators for use in rooms where personnel are working should be equipped with gentle airflow to minimize drafts. Rooms with temperature maintained at 3°C or below should have evaporators equipped for automatic coil defrost. Temperature controls for such rooms should be tamperproof.

Proper safeguards and good manufacturing practices during preparation and processing minimize bacteriological contamination and growth. This involves use of clean raw materials, clean water and air, sanitary handling of product throughout, proper temperature control, and thorough sanitizing of all product contact surfaces during clean-up periods. Sauces, gravies, and cooked products must be cooled quickly to prevent conditions favorable for microbial growth. Refer to [Chapter 11](#) for further information on control of microorganisms, cleaning, and sanitation.

Assembly, Filling, and Packaging

These activities cover transporting the components to packaging lines; preparing and depositing doughs for pies, ethnic dishes, and pizzas; filling or placing components into containers; placing containers into packages; closing and checking the packages; and transporting the packages to cooling and freezing equipment.

Items that are pumpable, such as gravies and sauces, are usually pumped to a hopper or tank adjacent to the packaging lines. Items such as free-flowing individually quick frozen (IQF) vegetables may be transported to the lines in bulk boxes via lift truck directly from cold storage facilities. For example, mixes of vegetables, rice, pasta and/or other starches that have been prepared at the plant may be wheeled to the packaging lines in portable tanks or vats. Tempered, prefrozen meat or poultry rolls may be placed on special carts and wheeled to the packaging lines.

A typical packaging line for a meals product consists of a timed conveyor system with equipment for dispensing containers; a filler or fillers for components that can be filled volumetrically; volumetric timed dispensers for sauces, gravies, and desserts; net weight filler systems for components and mixes that cannot be placed volumetrically; slicing and dispensing apparatus for placing components such as tempered meat or poultry rolls and similarly configured items; line space for personnel to place components that must be placed manually; liquid dispensers for placing spices and flavorings; and a sealing mechanism for placing a sealed plastic sheet over the containers. This system may be two or three compartments wide for high-volume production.

The timed conveyor system is followed by a single filer to align the containers in single file prior to indexing into a cartoner. The containers are automatically inserted into cartons, after which they are coded and sealed. After leaving the cartoner, the filled cartons are automatically checked for underweights and tramp metal, and then conveyed to cooling or freezing equipment. Other types of packaging lines may include some or all of the mentioned apparatus; they are usually specific for the prepared food items being filled and packaged.

Comments regarding product and equipment safeguards, good manufacturing practices, and actions to minimize microbial growth apply to packaging activities as well.

It is good practice to air condition filling and packaging areas, particularly when these areas are subject to ambient temperatures and humidities that can affect product quality and significantly increase potential bacteriological exposure. In addition, workers are more productive in air-conditioned areas. Packaging area air conditioning is usually supplied through air-handling units that also provide ventilation, heat, and positive pressure to the area. Some applications use separate refrigeration systems; others use chilled water or propylene glycol available from systems installed for product chilling. Generally, no other significant refrigeration is required for filling and packaging areas.

Cooling, Freezing, Casing

The cartons from packaging are cooled or frozen in different ways depending on package sizes and shapes, speed of production, cooling or freezing time, inlet temperatures, plant configuration, available refrigeration systems, and labor costs relative to production requirements. Refer to [Chapter 15](#) for additional information.

In small plants, stationary air-blast or push-through trolley freezers are used when flexibility is required for a variety of products. In these cases, fully mechanized in-line freezers are not economically justified. In larger plants with high production rates, mechanized freezers such as automatic plate freezers, carrier freezers, and spiral belt freezers are used extensively. These freezers significantly reduce labor costs and provide for in-line freezing.

The prepared foods business has many line extension additions and changes. Each product change results in component differences that may change the freezing load and/or freezing time due to inlet temperatures, latent heat of freezing, and/or package size (particularly depth). Each product should be checked to ensure that production rates for the line extension or different products match the current freezing capacity.

Over time, experience and advances in packing line technology tend to make packaging lines more efficient and capable of higher production rates. These advances often occur with existing cooling or freezing capacity, which is relatively constant. This may result in freezer exit temperatures above -18°C if reserve freezing capacity is not available or cannot be physically added because of space limitations. For new or expanded plants, allow space and/or reserve freezer capacity. Increases in packaging line speed and efficiency of 25 to 50% are reasonable to expect. Each case should be individually evaluated.

Casing the cartoned product follows freezing with in-line production of meals and main dishes. Manual casing is used in small plants and/or with low production rates. High-speed production lines use semiautomatic and automatic casing methods to attain high productivity and to lower labor costs. Inspection at this point is necessary to ensure that freezing has been satisfactory and that the cartons are properly sealed and not disfigured. It is also important to ensure that cartons do not become defrosted due to conveyor hangups or line stoppages.

Product palletizing follows product casing. Manual palletizing is used for small plants and/or low production rates, and automatic palletizers are used for higher production rates. Most palletizing is done adjacent to or near cold storage facilities and the pallets are transported to the cold storage rooms via lift truck. Some manual palletizing occurs inside cold storage rooms, particularly for slow production lines, to prevent product warm-up, but it is more costly as labor rates are higher for workers in cold storage rooms.

Some plants are equipped with air-blast freezing cells to augment in-line freezing capacity. These are used primarily for cased products when existing in-line freezers are overloaded and to reduce temperatures of products that have been frozen through the latent zone but have not been sufficiently pulled down for placement in the

cold storage rooms. These products are usually loosely stacked on pallets with sufficient air space around the sides of the cases to achieve rapid pulldown to -18°C or lower.

Finished Goods Storage and Shipping

Larger prepared foods operations usually have sufficient cold storage space to store the necessary refrigerated and frozen ingredients and at least 72 h of finished goods production. This volume of space allows proper inventory control, adequate scheduling of ingredients for production, and sufficient control of finished goods to ensure that the product is -18°C or lower before shipment and that it meets the criteria established for product quality and bacteriological counts.

The refrigeration loads for these production warehouses are calculated as suggested in [Chapters 12 and 13](#). Special attention, however, should be given to product pulldown loads and infiltration. Liberal allowances should be made for product pulldown, as freezing problems do occur, and some plants are under negative pressure at times during the year because more air is exhausted than supplied through ventilation. This can result in infiltration by direct inflow, which is a serious refrigeration load (see [Chapter 12](#)) that should be corrected. This problem is not only costly in energy use, but it also makes it difficult to maintain proper storage temperatures.

Refrigerated trucks and/or rail cars are generally used for shipping. Shipping areas are usually refrigerated to 2 to 7°C , and the truck loading doors are equipped with cushion-closure seals to reduce infiltration of outside air. Refer to [Chapter 13](#) for additional information on refrigerated docks. Where refrigerated docks are not provided, special care should be taken to ensure that the frozen product is rapidly handled to prevent undue warming.

Refrigeration Loads

Refrigeration loads cover a wide range of evaporator temperatures and different types of equipment. Most plants cover these with two or three basic saturated suction temperatures. Where two suction temperatures are provided, they are usually at -37 to -43°C for freezing and cold storage and -12 to -7°C for cooling loads. Where provided, a third suction temperature is usually from -29 to -23°C for frozen product storage rooms and other medium-low temperature loads. The third suction temperature is advantageous with relatively large frozen product storage loads to reduce energy costs.

Refrigeration loads should be tabulated by time of day, season of year, evaporator temperature, and equipment type or function. This record should be made periodically for existing operations; it is essential for new or expanded plants. These tabulations reveal the diversity of the loadings and provide guidance for existing operations and for equipment sizing for added capacity or new plants.

In addition, loads should be tabulated for off-shift production, weekends, and holidays to provide proper equipment sizing and for economic operation for these relatively small loads. Refer to [Chapter 12](#) for information on load calculation procedures.

Refrigeration Systems

Most refrigeration systems for prepared foods use ammonia as the refrigerant. Two-stage compression systems are dominant, because compression ratios are high when freezing is involved and energy savings warrant the added expense and complexity. Evaporative condensers are extensively used for condensing the refrigerant. Evaporators are designed for full-flooded or liquid overfeed operation, depending on the equipment or application. Direct-expansion evaporators are not used extensively.

New plant designs limit the exposure of plant employees to large quantities of ammonia. This can be accomplished by locating evaporators, such as propylene glycol chillers, water chillers, and ice builders, in or near machine rooms and away from production

employees. Freezers can be located in isolated clusters near machine rooms so that the low-pressure receivers are also in or near the machine room. These practices limit exposure and provide a means for close supervision by trained, competent operators.

Some plants use glycol chillers to circulate propylene glycol to evaporators located in production areas. This results in an energy penalty because of the secondary heat transfer, but it is deemed affordable because of less potential exposure to employees and product in the event of an ammonia spill.

Other plants have a major portion of the ammonia main lines installed on the roof to reduce exposure to personnel and product and to provide accessibility. These mains require close monitoring and inspection, as an ammonia spill can still result in an injury to personnel both inside and outside the plant as well as damage to products.

Machine room equipment not only should be sized for the full refrigeration loads imposed, but also should be able to handle the relatively small off-shift and weekend loads without using large compressors and components at low capacity levels.

Many plants take advantage of energy-saving measures, such as floating head pressure controls with oversized evaporative condensers coupled with two-speed fans, single-stage refrigeration for small areas and loads; variable-speed pumps for glycol chiller systems; ice builders to compensate for peak loads; door infiltration protection devices; added insulation; and computer-based control systems for monitoring and controlling the system. These measures should be considered for existing plants that are not so equipped and should be included in the design of plant expansions and new plants.

All refrigeration systems for prepared food plants should comply with applicable codes and standards (see [Chapter 50](#)).

Plant Internal Environment

HVAC systems that provide proper ventilation and positive plant pressure relationships are very important in processed and prepared food plants to prevent condensation on building and equipment components and to minimize potential bacteriological cross-contamination between raw and cooked products. New plants and expansions should be so equipped initially, and existing plants should correct conditions that result in condensation and negative plant air pressure.

VEGETABLES

Frozen vegetables are prepared foods in that they are essentially precooked and require minimal preparation. [Chapters 14 and 23](#) have further information on handling, cooling, and storing fresh vegetables. Most vegetables to be frozen are received directly from harvest. Some are cooled and stored to smooth out production and others are processed directly. They are cleaned, washed, and graded; cut, trimmed, or chopped (if necessary); and then blanched, cooled, and inspected prior to freezing. At this point some vegetables are filled or packed into cartons prior to freezing, whereas others are frozen and then filled into packages, bags, cases, or bulk bins.

Products cartoned before freezing generally can only be manually packed and/or have to be check-weighed before closing the cartons. Examples include broccoli spears, asparagus spears, leaf spinach, French cut green beans, okra, cauliflower florets, and some volumetrically machine-filled vegetables such as peas, cut corn, and cut green beans. Products that are cartoned prior to freezing are usually frozen in manual plate freezers, automatic plate freezers, stationary airblast tunnels, and push-through trolley freezers.

Products that are frozen before packaging are included in the free-flowing or individually quick frozen (IQF) categories. These include true IQF products such as peas, cut corn, cut green beans, diced carrots, and lima beans, as well as products that are more difficult to IQF such as broccoli florets, cauliflower florets, sliced carrots, sliced squash, and chopped onions.

Products that are easy to IQF are usually frozen in straight belt freezers, fluidized bed freezers, or fluidized belt freezers. The more difficult products to IQF are usually frozen in fluidized bed freezers and fluidized belt freezers. Cryomechanical freezers are sometimes used where high-value, sticky products are frozen. Hydrocooling these products to temperatures of 7 to 16°C prior to freezing reduces the freezing load and overall energy requirements.

Products from IQF freezers are packed either directly into cartons or polyethylene bags, into cases for bulk shipment, or into tote bins for repacking at a later date or shipment to other customers for repack or use in prepared foods. The products packed into tote bins for repacking into cartons or polyethylene bags are used for single products, products of various vegetable mixes, and products with butter or cheese sauces. Repacking operations rather than direct in-season packing are preferred for most companies, as they allow the packer to produce directly for orders, which saves buying finished goods packaging material until required.

Products in tote bins for repacking are placed in dumpers in a cold storage room adjacent to the packaging lines. The products are metered onto a conveyor in proportion to the end mix required and pneumatically or mechanically conveyed to the filler hopper for volumetrically filled mixes or single products. Products and product mixes that require weighing are generally conveyed to net weight filler systems. After packaging, the products are usually cased semi-automatically or automatically and returned to cold storage immediately. The products are rapidly handled to minimize warm-up and clustering.

Corn on the cob is prepared in the same manner as other vegetables, but because of its bulk and to retain quality, it is usually cooled with refrigerated water. After cooling, the product is either packaged in polyethylene bags and frozen in stationary blast cells, push-through trolleys, or manual plate freezers; or frozen bare in this same equipment or in straight belt freezers or multipass straight belt freezers, and packed into cases for institutional use or tote bins for repacking throughout the year.

Raw, whole onions for French fried onion rings are cleaned, sliced, and prepared before being coated in breading machines; after this, they are fried in an oil fryer, cooled, and frozen. Almost all production is IQF for the restaurant and food service markets. The product is frozen in various types of belt freezers. Refrigerated precoolers or precooler sections coupled with the IQF freezers are common. Product handling must be gentle, and the product should not be cooled below -15°C prior to discharge from the freezer because it can become brittle and fractured, resulting in some product downgrading.

Changes in the Prepared Vegetable Industry

Several significant changes have occurred in the prepared vegetable industry that affect refrigeration and production in the United States. These include a shift in production of certain vegetables to Mexico and Central and South America and an increased use of vegetables in other prepared foods and in the food service markets. The produce being processed in Mexico and Central America and exported to the United States include asparagus, broccoli, cauliflower, Brussels sprouts, okra, and fruits, such as strawberries.

The freezing equipment used for these products is primarily operated manually; automation cannot be financially justified except for some types of belt freezers. Most of the production is delivered in tote bins and packaged in the consuming country.

The principal products involved are those with a short season of production in the United States (e.g., peas, green beans, corn). If an entire year's estimated requirement is based on one short harvest season, it must be stored in freezer warehouses at considerable expense. On the other hand, if a portion of the estimated requirements is produced approximately six months later, the storage costs

can be reduced significantly, and the requirements can be estimated more accurately.

The significance of frozen vegetables for retail prepared foods and food service applications is increasing. All the production is in bulk, either in cases or in tote bins. Some products are used frozen as a main vegetable or as part of a mix. In the case of mixes, some are used frozen and others are defrosted to mix with additional items prior to becoming a portion of a meal. The unit operations to include vegetables as a part of prepared foods products need to be performed in a sanitary and efficient manner to preserve product quality.

Refrigeration Loads and Systems

The principal refrigeration loads for vegetable operations are raw product cooling and storage, product cooling after blanching, freezing, process equipment located in freezer storage facilities, and freezer storage warehouses. Not all vegetable operations have all of these loads; each plant has unique conditions. Raw product cooling and storage are covered in [Chapters 14 and 23](#).

Cooling after blanching is done with fresh water, with refrigerated water, and with evaporation cooling. Fresh water is usually well water at 13 to 16°C that is reused once or twice prior to blanching for product washing, cleaning, or waste product transfer. Refrigerated water is often used in combination with well or municipal water. Refrigerated water at 2 to 4°C reduces freezing loads and, for some products (e.g., cut green beans) enhances quality.

Freezing loads and corresponding freezing capacity vary widely between different vegetables depending on the initial product temperature and the latent heat of fusion. Special attention must be paid to the variety and size of the particular vegetables to be frozen. A belt freezer designed to freeze 4500 kg/h of lima beans may only freeze 3400 kg/h of 25 mm cut green beans. In addition, the freezing time will be approximately twice as long for cut green beans due to the differences in shape and bulk. Specific and latent heats of fusion for vegetables are listed in [Chapter 8](#).

Freezer warehouse loads are calculated as suggested in [Chapters 12 and 13](#). Freezer storages located at vegetable processing plants have three additional potential loads to consider: (1) the extra capacity reserve needed for product pulldown during peak processing; (2) the negative pressure almost all vegetable facilities are under, which can substantially increase infiltration by direct flow-through; and (3) the process machinery load (particularly pneumatic conveyors) associated with repack operations.

Almost all vegetable freezing operations use ammonia as the refrigerant. Two-stage compression systems are in general use, even in those with short peak seasons. The product cooling load is done at the intermediate suction pressure. Freezing and freezer warehouse loads use the first-stage suction. Design saturated suction temperatures vary from -36 to -40°C in the first stage to -12 to -7°C in the second stage. Design saturated condensing temperatures vary from 29 to 35°C.

A unique feature of vegetable facility refrigeration is a lack of spare equipment and redundancy for those that operate for short periods at peak capacity (usually 1500 to 2500 h/year). In these applications spare capacity cannot be justified financially. Extra care and maintenance are usually provided before peak season to ensure that full capacity is available and to minimize downtime.

Flooded evaporators are often used for product cooling and cold storage facilities. Liquid overfeed systems are used for freezing apparatus and for cold storage facilities and product cooling. Direct-expansion evaporators are rarely used.

Condensing is usually done with evaporative condensers. Some older plants use shell-and-tube condensers with once-through water usage. The warmed water is reused for product washing and cleaning prior to blanching. This method provides some risk if ammonia leaks into the water stream and should not be used in new installations.

FRUITS

Frozen fruits are processed foods that are thawed prior to serving, except for specialties such as fruit pies, which are cooked. This section covers fruits that can be successfully frozen. [Chapters 14, 21, and 22](#) have further information on handling, cooling, and storing fruits prior to processing.

Most fruits to be frozen are received directly from harvest. Some are cooled and stored to smooth out production, and others are processed directly. Fruits are typically cleaned, washed, and graded; cut, trimmed, or sliced (if required); and then inspected prior to freezing. At this point some fruits are packaged into containers with sugar or syrup before freezing, whereas others are frozen and then filled into polyethylene bags, cases, and bulk bins.

Usually no special step is taken to kill pathogens in processed fruit. Hence, it is imperative that strict sanitary practices and standards be imposed to minimize the presence of pathogenic organisms. The acidity of most fruits is a bacteriological deterrent, but it is not a guarantee of bacteriological safety.

Products cartoned prior to freezing include products such as sliced strawberries mixed with sugar in a 4 to 1 ratio and whole strawberries, other berries, mixed fruits, and melon balls in a sugar syrup. The cartons and containers are liquid-tight to prevent spillage. These products are usually frozen in manual or automatic plate freezers, stationary air-blast tunnels, and push-through trolley freezers. These types of products are losing market share to other forms such as fresh fruit.

Products that are frozen before packaging are usually included in the free-flowing or IQF categories. These include whole fruits such as strawberries, cherries and grapes; and pieces (slices, dices, halves, balls) of fruits such as apples, peaches, melons, pineapples, and citrus.

The products for IQF are usually frozen in straight belt freezers, fluidized belt freezers, fluidized bed freezers, and cryomechanical freezers. Many fruits and fruit pieces are sticky, fragile, and have a relatively high latent heat value. There is a trend toward using cryomechanical freezers for those applications both in new installations and in retrofits, as they often provide a superior IQF product at a reasonable cost. [Chapter 15](#) has further information regarding freezers. The products from IQF freezers are packed and handled in a similar manner as described under the Vegetables section.

Fruit pies are a specialty pack. The IQF or fresh fruits are deposited in a dough shell and a top dough sheet is added on an assembly, filling, and packaging line as described in the section on Main Dishes, Meals. Fruit pies are usually frozen in automatic plate freezers or spiral belt freezers.

Refrigeration Loads and Systems

The principal refrigeration load calculations for fruits are similar to those as described under the Vegetables section except there is no cooling after blanching. The Vegetables section commentary on freezing, freezer warehouse loads, and refrigeration systems applies to fruits as well. Fruits do, however, respond better to a lower storage temperature (-24°C versus -18°C) due to their higher sugar content.

POTATO PRODUCTS

The primary frozen potato products include various types of French fried potatoes for fast food restaurant, regular restaurant, and institutional uses. They include regular, shoestring, crinkle cut, and curly fries. Potato sales for retail consumption are far less than those for institutional use. Other potato products include potato puffs, tots, and wedges, which are a coproduct or made from waste-stream potatoes and rejected fries. Specialty potato products include hash browns, twice-baked potatoes, and refrigerated French fries. The refrigerated product has a relatively short shelf life and requires close control of handling, shipping, and storage.

French Fries

French fried potatoes and coproducts are processed almost year-round. In the northern United States, product is received in bulk directly from the field for 1 1/2 to 2 months in the fall and thereafter from storage. Storing fresh potatoes for processing is covered in [Chapter 23](#).

French fried potato lines are usually of large capacity, often with a raw potato capacity of 23 000 kg/h with a finished capacity of 11 000 kg/h plus 900 kg/h of coproduct.

The bulk potatoes are metered into the processing lines, after which they are conveyed through a destoner to provide initial washing and to remove stones and other debris. They are then graded, and small potatoes are diverted to the coproduct line. Some processors also grade out large potatoes to be sold fresh as baking potatoes. The potatoes for French fries are then steam peeled and trimmed to remove blemishes. (French fries made with skins are not peeled.) Whole potatoes are cut into the desired fry shapes, and the slivers are automatically graded out and diverted to the coproduct line.

The fry shapes are then processed in one of two ways. The first method is to blanch, cool, blanch, mini-dry, and oil fry the potatoes, producing a product of approximately 28 to 30% solids. This product has a high moisture content and is more difficult to freeze because of its higher latent heat of fusion. The second method is to blanch, process the product through a two- or three-stage drier, and then oil fry the potatoes, which produces a product of approximately 34 to 36% solids, a so-called “dry fry.”

After frying, the French fries are frozen on a straight belt freezer system that has three separate conveyors. In the first section, filtered ambient air or refrigerated air cools the product from 82 to 93°C to approximately 21°C to drain and/or congeal the excess fryer oil on the surface of the fries. The refrigerated air is provided either by a direct flooded ammonia evaporator, by an ammonia thermosyphon system, or by water coils where plant water is heated for reuse in processing. The second and third sections, which are two mesh conveyors in series, function as a two-stage belt freezer. The second section is used for precooling and/or crust freezing to condition the fries before total freezing and sensible cooling in the third section. French fries are usually only frozen to -15 to -12°C , as they become brittle below those temperatures and may be damaged in subsequent handling.

After freezing, the fries are size graded with the longest lengths slated for institutional markets, the shorter lengths for retail, and the slivers and pieces relegated for use as cattle feed. The grading occurs in an area usually maintained at -9°C . The product from the graders is collected in tote bins for subsequent packaging, with some of the totes going directly to the packaging operation and the balance to freezer storage.

The filling of fries is accomplished with net weight fillers. The containers used include retail cartons, retail poly bags, and institutional polyethylene bags. The institutional volume is dominant. The packaging area is usually air conditioned to minimize product warm-up and clustering.

Potato Coproducts

Puffs, tots, and wedges are the coproducts manufactured from small whole potatoes that were graded out before peeling, and slivers that were graded out after cutting the whole potatoes into shapes from the French fry line. The graded-out product is about 7% of the French fried potato production. If more coproducts are desired, small whole potatoes are used.

The graded-out product and/or whole potatoes that have been steam-peeled or diced are inspected to remove blemishes and are then blanched. The product is then conveyed to a retrograde cooler, where the product temperature is reduced to approximately 2°C , and the product is partially dehydrated. From the cooler, the potatoes are conveyed to other equipment where they are chopped into

small pieces, mixed with flavorings and condiments, and formed into the desired shapes. From the formers, the product is conveyed to the oil fryers and then to the freezer.

These products are usually frozen on spiral belt freezers, as the freezing time is relatively long due to the bulky shape and the high product inlet temperature of approximately 80°C. These products are usually not cooled in a refrigerated cooler before entering the spiral freezer.

The products can be packaged directly from the freezer or stored in bins for later packaging. They are distributed in both retail and institutional markets and primarily packaged in polyethylene bags.

Hash Brown Potatoes

Hash browns are manufactured from steam-peeled whole potatoes that are too small for French fries. They are then blanched and cooled conventionally or by retrograde cooling in bins, after which they are conveyed to a slicer and sliced into strips.

They are placed on a conveyor belt and formed into shapes that are scored and pulled apart to make discrete groupings of patties. They are conveyed to a straight line belt freezer and frozen to -18°C or below. The product is generally packed into polyethylene bags for either retail or institutional distribution.

Other Potato Products

This category includes twice-baked potatoes, potato skins, and boiled potatoes with or without skins for frozen meals or main dishes.

Refrigeration Loads and Systems

The refrigeration loads result primarily from cooling and freezing products and the associated freezer storage for in-process and finished goods storage. As noted previously, the production rates and total capacity of these plants are high, to take advantage of the economics of scale.

Belt freezer refrigeration loads are the major component, and a careful analysis should be made to ensure that adequate performance is achieved to meet the capacity requirements of the various product forms to be frozen. Refrigeration loads and capacity levels for the same freezing apparatus change significantly because of differences in latent heats of fusion, inlet and outlet temperatures, specific heats, and the size and shape of individual product pieces. Additional information on freezing times and refrigeration loads for specific foods may be found in [Chapters 8](#) and [9](#).

Freezer warehouse loads are calculated as suggested in [Chapters 12](#) and [13](#). Freezer storage located at potato processing plants has additional refrigeration requirements due to product pull-down loads. French fries are often discharged from belt freezers at -15 to -12°C to reduce or eliminate product breakage due to brittleness at lower temperatures. This discharge temperature coupled with subsequent packaging can result in product inlet temperature to the freezer warehouse of -9°C. The product temperature should be lowered promptly in the freezer storage to -18°C or below before shipping. Product quantities for a typical plant can be several hundred thousand kilograms per day. Also, some freezer warehouses may be attached to plants under negative pressure, which can substantially increase infiltration. This should be corrected, as it is very difficult and costly to offset with refrigeration and infiltration reduction devices.

Potato freezing plants primarily use ammonia as a refrigerant. Two-stage compression systems are in general use, but some single-stage plants are in operation, particularly in the western United States. In two-stage systems, the product cooling is done at the intermediate pressure. Freezing and freezer warehouse loads use the first stage. Design saturated suction temperatures vary from -36 to 40°C in the first stage and -12 to -7°C in the second stage. Design saturated condensing temperatures vary from 29 to 35°C.

In single-stage systems, separate compressors are used for the -12 to -7°C product cooling and liquid refrigerant precooling. Separate compressors are used for freezing and freezer storage with design saturated suction temperatures of -33 to -36°C. The higher design suction temperature is achieved with more evaporator surface. Design saturated condensing temperatures are usually 30°C in the low wet-bulb design temperature areas where these plants are located. As the wet-bulb temperatures are even lower during the early production months in the fall, winter, and spring, the compression ratios are tolerable. Some firms find inadequate or borderline financial justification in electric power savings for the extra capital associated with two-stage systems.

Single-stage systems are simple and have a low first cost. Most of these plants are in rural areas, and it is easier and usually more satisfactory to train operators and mechanics for single-stage systems.

Condensing is usually done with evaporative condensers. New plants are often designed for 30°C condensing temperature with floating condensing pressures for lower wet-bulb temperatures and partial loads.

Potato processing plants have heavy refrigeration loads and operate for 6000 to 7000 h per year. Some spare machine room equipment may be needed, but it is not generally provided. Major maintenance is performed during periods of lower production as well as during downtime periods of 4 to 6 weeks per year.

French fried potato freezers function under heavy loads and severe duty. Features include modular, rugged construction for ease of installation, evaporators of aluminum or hot-dipped galvanized tubing with variable fin spacing, axial or centrifugal fans with updraft airflow, noncorrosive materials for product contact parts, regular or sequential water defrost, belt washing apparatus, catwalks for access, and insulated panel housings with interiors constructed to withstand periodic washdown. A few of these freezers are designed to operate continuously to provide full capacity at all times. Most are designed to be defrosted every 7 to 7.5 h, between shifts, to maintain capacity. In the latter case, the freezer should provide full capacity at the end of the shift. Spiral freezers for coproducts and straight belt freezers for hash browns are similar to those described in [Chapter 15](#).

OTHER PREPARED FOODS

Several other types of prepared foods, including appetizers, sandwiches, breads, rolls, cakes, cookies, fruit pies, toppings, ice creams, sherbets, yogurts, and frozen novelties are covered in other chapters. Bakery products are covered in [Chapter 27](#), and ice cream products are covered in [Chapter 19](#).

LONG-TERM STORAGE

Most prepared foods are not produced with long-term frozen storage as an objective. Inventories are closely supervised, and production and sales are closely linked to minimize inventory. Profitability is reduced by having finished goods in storage and in the distribution chain.

One exception is some vegetables and fruits that can be processed and frozen only during the harvest season. Even here, steps are usually taken to maximize in-process storage of bulk products and to package them as required by sale orders and projections.

Some components and ingredients for prepared foods, however, must withstand long-term frozen storage if they are only produced annually or infrequently. These products require close monitoring to ensure that the quality still meets standards when used.

Regardless of the length of storage, it is important that ingredients, components, and finished goods are stored at -18°C or below with minimal temperature fluctuations.