CHAPTER 27

PROCESSED, PRECOOKED, AND PREPARED FOODS

THERE are many categories of prepared foods. This chapter covers prepared meals, fruits, vegetables, and potato products and gives an overview of the HVAC&R requirements of facilities that process these products.

Processed, precooked, and prepared foods all come under the regulations of the Food and Drug Administration (FDA) 21CFR, and facilities using meat products also come under regulation by the U.S. Department of Agriculture (USDA).

The FDA has also implemented bioterrorism regulations for processors of fruits, vegetables, and potato products. Records must identify previous sources and initial recipients of food products, including its packaging.

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

Each food manufacturing site should develop, implement, and maintain its HACCP plan. 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 12 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 airflows 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 can be prepared in a conventional or microwave oven. Many contain sauces and/or gravies, so sauce and/or gravy kitchens may be an integral part of 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, or pasta
- 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
- Low-calorie or diet versions of many of the above
- Snack foods such as pizza, fish sticks, and breaded items

General Plant Characteristics

Plant facilities for preparing, processing, packaging, cooling, freezing, casing, and storing products vary widely. The variety of products is diverse, and it is beyond the scope of this section to cover all the operations involved in all product formulations, food chemistry, and process details of prepared foods. 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 17, 18, and 19, 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 support 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 producing prepared foods should be constructed and operated to provide for minimum bacteriological contamination and easy cleanup and sanitation. Sound sanitary practices should be followed at all stages of production. This is of particular concern in prepared food plants where the finished product may not receive a kill step (in which harmful microorganisms are inactivated by high temperature, high pressure, electrical fields, etc.) before or after packaging. (See the section on Destruction of Organisms for more information.) All U.S. meat and poultry plants, and hence many prepared food plants, operate under USDA regulations. Finished and raw product paths are controlled to prevent cross contamination, and sanitary standards are strictly followed.

Preparation, Processing, Unit Operations

Initial steps in production of prepared foods involve 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 before packaging.

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These 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.

Refrigeration loads for each of these categories should be calculated individually using the methods described in Chapter 13. In addition, 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.

Refrigerated rooms should be amply sized, be able to maintain temperatures from 31 to 49°F as required for the specific application, have power-operated doors equipped with infiltration reduction devices, and have evaporators that are easily sanitized. Evaporators for rooms where personnel are working should be equipped with gentle airflow to minimize drafts. Rooms with temperature maintained at 38°F 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 using clean raw materials, clean water and air, sanitary handling of product throughout, proper temperature control, and thorough sanitizing of all product contact surfaces during cleanup. Sauces, gravies, and cooked products must be cooled quickly to prevent conditions favorable for microbial growth. Refer to Chapter 12 for further information on control of microorganisms, cleaning, and sanitation.

Assembly, Filling, and Packaging

These activities include transporting components to packaging lines; preparing and depositing doughs for pies, ethnic dishes, and pizzas; filling or placing components into containers; placing containers into packages; coding, closing, and checking the packages; and transporting 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 by lift truck directly from cold storage. 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 meals 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 containers in single file before indexing into a cartoner. The containers are automatically inserted into cartons, after which they are coded and sealed. After leaving the cartoner, 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. Also, 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 from systems installed for product chilling. Generally, no other significant refrigeration is required for filling and packaging areas.

Cooling, Freezing, Casing

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 16 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 (e.g., automatic plate, belt, spiral belt) 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 time because of 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 are implemented with existing cooling or freezing capacity, which is relatively constant. This may result in freezer exit temperatures above 0°F 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 instance 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 increase productivity and 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 defrost during 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 with a 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 because 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 cold storage. These products are usually loosely stacked on pallets with enough air space around the sides of the cases to achieve rapid pulldown to 0°F or lower.

Finished Goods Storage and Shipping

Larger prepared foods operations usually have enough 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 0°F or lower before shipment and that it meets the criteria established for product quality and bacteriological counts.

Refrigeration loads for these production warehouses are calculated as suggested in Chapters 13 and 14. Special attention, however, should be given to product pulldown loads and infiltration. Liberal allowances should be made for product pulldown, because freezing problems do occur, and some plants or sections of plants are under negative pressure at times because more air is exhausted than supplied through ventilation, almost always caused by the need to remove an undesirable component (e.g., steam, heat, dust) without commensurate mechanical air supply to offset the exhaust. This can result in infiltration by direct inflow, which is a serious refrigeration load (see Chapter 13) 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 35 to 45°F, and the truck loading doors are equipped with cushion-closure seals to reduce infiltration of outside air. See Chapter 14 for additional information on refrigerated docks. Where refrigerated docks are not provided, take special care 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 –35 to –45°F for freezing and cold storage and 10 to 20°F for cooling loads. Where provided, a third suction temperature is usually from –20 to –10°F for frozen product storage rooms and other medium- to 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, 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 loading diversity 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. See Chapter 13 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 plant employees' exposure 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 install most of the ammonia main lines on the roof to reduce exposure to personnel and product and to provide accessibility. These mains require close monitoring and inspection, because an ammonia spill can still injure personnel both inside and outside the plant, as well as damage products.

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

Many plants use 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 computerized 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 49).

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 15 and 24 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 before freezing. At this point, some vegetables are packed into cartons before 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 and 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. These products 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 and cauliflower florets, sliced carrots or squash, and chopped onions.

Products that are easy to IQF are usually frozen in straight belt freezers, fluidized bed freezers, or fluidized belt freezers. 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 45 to 60°F before freezing reduces the freezing load and overall energy requirements if the product can be adequately drained before freezing. Sliced vegetables with large, flat surfaces are particularly difficult to drain.

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 rather than direct in-season packing is preferred by most companies, because it allows 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. 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, products are usually cased semiautomatically 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, it 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 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; then, they are fried in an oil fryer, cooled, and frozen. Almost all production is IQF for restaurants and food service. The product is frozen in various types of belt freezers. Refrigerated precoolers or precooler sections coupled with IQF freezers are common. Handling must be gentle, and product should not be cooled below 5°F before discharge from the freezer because it can become brittle and fractured, resulting in some product downgrading.

International Production

U.S. production of some frozen vegetables, mainly those that require large amounts of hand labor for harvesting and processing or those that have a short production season in the United States, has largely moved to Mexico and Central and South America. This is coupled with an increased demand for these products and other prepared foods for both retail and food service markets.

Products requiring large amounts of hand labor include asparagus, broccoli, cauliflower, Brussels sprouts, okra, and strawberries. These products are packaged for retail distribution in the United States, or packaged in bulk containers for further processing elsewhere as single items or as part of prepared foods. Freezing equipment for these products is primarily manually operated, because automation cannot be financially justified (except for some types of belt freezers).

Short-season products include peas, Lima beans, green beans, and sweet corn. The incentive for producing these products outside the United States is savings in inventory, cold-storage costs, and ability to determine yearly supply more accurately. If an entire year's estimated requirement is based on one short processing season, it must be stored in freezer warehouses at considerable expense. On the other hand, if some of the estimated requirement is produced approximately six months later in another location, storage requirements can be reduced substantially, and the requirements can be estimated more accurately.

Vegetables in Other Prepared Foods

Inclusion of frozen vegetables in other prepared foods has increased as the variety and type of frozen dishes and meals have proliferated for both retail and food service markets. This is driven not only by increased prepared foods sales volume but also by the importance health authorities place on increased vegetable consumption as part of a healthy diet. Vegetable production is in bulk, either in cases or tote bins. Some products are used frozen as a main vegetable or as part of a mix. In mixes, some are used frozen; others are defrosted to mix with additional items before becoming a portion of a meal.

The emphasis on vegetables as part of a healthy diet has also greatly increased production of prepackaged fresh, refrigerated vegetables, either as single items or as combinations of products and salad items. These products have substantially displaced frozen vegetables as a product in areas of the United States where vegetables can be grown for most of the year. Thus, the movement of frozen vegetable production to countries outside the United States has not had a negative economic effect.

Unit operations need to be sanitary and efficient, to preserve product quality. This is especially important for products that have not had a process step to inactivate microorganisms (kill step) before packaging.

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 15 and 24.

Cooling after blanching is done with fresh water, with refrigerated water, or with evaporation cooling. Fresh water is usually well water at 55 to 60°F that is used once or twice before blanching for product washing, cleaning, or waste product transfer. Refrigerated water is often used in combination with well or municipal water. Refrigerated water at 35 to 40°F 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 10,000 lb/h of lima beans may only freeze 7500 lb/h of 1 in. cut green beans. In addition, freezing time is approximately twice as long for cut green beans because of differences in shape and bulk. Specific and latent heats of fusion for vegetables are listed in Chapter 9.

Freezer warehouse loads are calculated as suggested in Chapters 13 and 14. Freezer storages in 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 –32 to –40°F in the first stage to 10 to 20°F in the second stage. Design saturated condensing temperatures vary from 85 to 95°F.

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 before 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 before serving, except for specialties such as fruit pies, which are cooked. This section covers fruits that can be successfully frozen. Chapters 15, 22, and 23 have further information on handling, cooling, and storing fruits before processing.

Most fruits to be frozen are received directly from harvest. Some are cooled and stored to even out production, and others are processed directly. Fruits are typically cleaned, washed, and graded; cut, trimmed, or sliced (if required); and then inspected before freezing. At this point, some fruits are packaged 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 before freezing include 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 liquidtight to prevent spills. 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 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.

IQF products 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, because they often provide a superior IQF product at a reasonable cost. Chapter 16 has further information on freezers. Products from IQF freezers are packed and handled 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 described under the Vegetables section, except there is no cooling after blanching. The Vegetables section discussion of freezing, freezer warehouse loads, and refrigeration systems applies to fruits, as well. Fruits do, however, respond better to a lower storage temperature (–10°F versus 0°F) because of 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 formed product made from waste-stream potatoes and rejected raw strips. Specialty potato products include hash browns, twice-baked potatoes, refrigerated French fries, potato skins, and boiled potatoes (with or without skins). The refrigerated product has a relatively short shelf life and requires close control of handling, shipping, and storage.

French Fries

French fried potatoes and formed product are processed 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 discussed in Chapter 24.

French fried potato lines are usually designed to produce large volumes, often more than 50,000 to 100,000 lb of raw product per hour. This results in a finished rate of 25,000 to 50,000 lb/h of frozen French fries, depending upon final product solids and oil content. Many plants also produce an additional 5000 to 10,000 lb/h of formed or dehydrated products from the small potatoes and the shorts and slivers produced in the process.

Bulk potatoes are metered into the processing lines, after which they are conveyed through a destoner to provide initial washing and to remove stones, vines, and other debris. They are then graded, and small potatoes are pulled for animal feed, starch production, manufacturing into other products, or the formed product line. Some processors also grade out large potatoes to be sold fresh as baking potatoes. The potatoes for French fries are then washed, steam-peeled (unless the end product should have its skin), inspected for foreign material, and sometimes preheated whole to minimize fracturing during cutting. Whole peeled potatoes are cut into the desired fry shapes, and the slivers and nubbins (short strips) are automatically graded out and diverted to the formed product line. The remaining strips are then electronically scanned, and those with defects are sorted out and the imperfections automatically removed.

The fry shapes are then processed in one of two ways. The first method is to blanch, cool, blanch, minidry, and fry the potatoes, producing a product of approximately 28 to 34% 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 fry the potatoes, which produces a product of approximately 34 to 36% solids, a “high-solids fry.” Many French fries are now battered before frying. Battering improves the shelf life of fried product at the fast food restaurant and provides opportunities for flavor addition to the strip surface.

Just before freezing, excess oil is removed from the par-fried strips, which are then cooled from 200°F to 70 to 80°F. Filtered ambient air, direct-flooded ammonia evaporator coils, ammonia thermosiphon system, or water coils (where plant water is heated for reuse in processing) provide the necessary cooling air. The freeze tunnel is a straight belt freezer system using ammonia recirculation evaporator coils and operating at 0 psig or less suction pressure. It is usually composed of two belts, so that product just starting to surface-freeze discharges from the first belt onto the second and breaks up any product clusters that have formed. Final product temperature at the tunnel discharge is kept at 5 to 10°F, because the strips are very fragile below these temperatures and may be broken in subsequent handling. Once packaged and in cold storage, product is cooled to 0 to –10°F.

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 15°F. Product from the graders goes directly to packaging and off-grade product to totes and storage for packaging under a different label.

Fries are packaged using net-weight fillers. Institutional product is packaged into 5 to 6 lb kraft/poly bags, and retail product into poly bags. The packaged product is automatically loaded into cases, palletized and on to 0 to –10°F cold storage.

Formed Potato Products

Puffs, tots, and wedges are manufactured from small whole potatoes that were graded out before peeling, and slivers and nubbins 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 formed products 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 is reduced to approximately 35°F and 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, because the freezing time is relatively long because of the bulky shape and high product inlet temperature of approximately 180°F or more, depending upon the amount of ambient cooling available. These products are usually not cooled in a refrigerated cooler before entering the spiral freezer.

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 very thin 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 0°F or below. The product is generally packed into polyethylene bags for either retail or institutional distribution.

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 performance meets 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 9 and 10.

Freezer warehouse loads are calculated as suggested in Chapters 13 and 14. Freezer storage in potato processing plants has additional refrigeration requirements because of product pull-down loads. French fries are often discharged from belt freezers at 5 to 10°F to reduce or eliminate product breakage from brittleness at lower temperatures. This discharge temperature, coupled with subsequent packaging, can result in product inlet temperature to the freezer warehouse of 15°F. Product temperature should be lowered promptly in the freezer to 0°F or below before shipping. Product quantities for a typical plant can be several million pounds per day. Also, some freezer warehouses may be attached to plants under negative pressure, which can substantially increase infiltration. This should be corrected, because 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, product cooling is done at the intermediate pressure. Freezing and freezer warehouse loads use the first stage. Design saturated suction temperatures vary from –32 to –40°F in the first stage and 10 to 20°F in the second stage. Design saturated condensing temperatures vary from 85 to 95°F.

In single-stage systems, separate compressors are used for the 10 to 20°F product cooling and liquid refrigerant precooling. Separate compressors are used for freezing and freezer storage, with design saturated suction temperatures of –28 to –32°F. The higher design suction temperature is achieved with more evaporator surface. Design saturated condensing temperatures are usually 85°F in the low-wet-bulb design temperature areas where these plants are located. Because 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 85°F 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 totaling 4 to 6 weeks per year.

French fried potato freezers function under heavy loads and severe duty. Features include modular, rugged construction for easy 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 formed product and straight belt freezers for hash browns are similar to those described in Chapter 16.

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 28, and ice cream products are covered in Chapter 20.

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 0°F or below with minimal temperature fluctuations.

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