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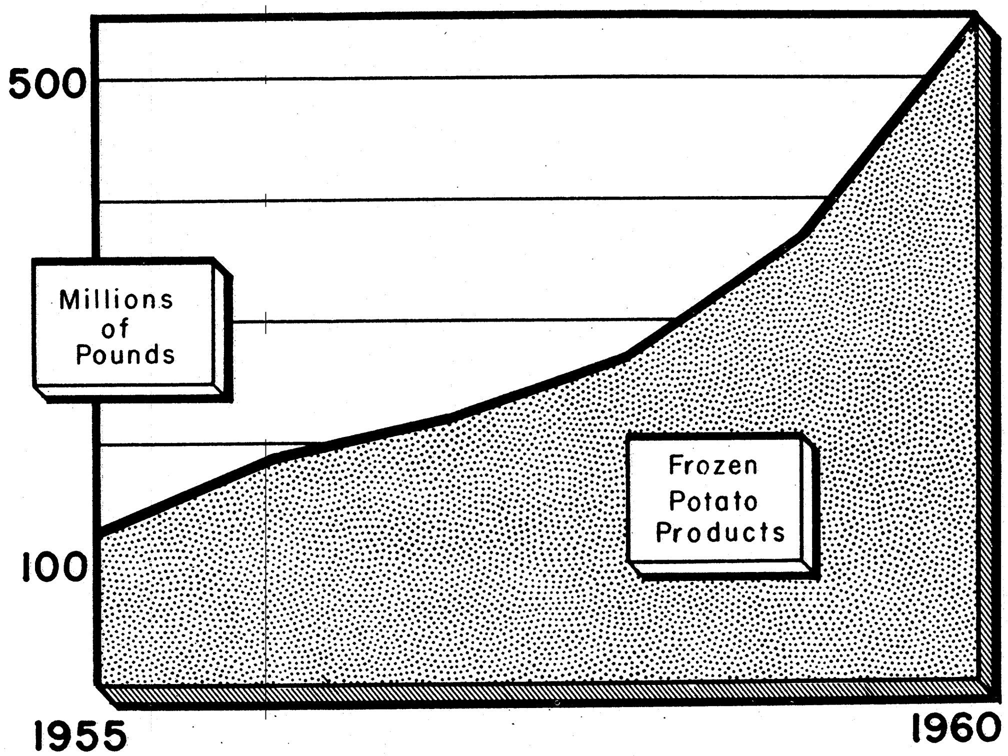
PROCESSING OF

FROZEN FRENCH FRIED POTATOES

AND OTHER FROZEN POTATO PRODUCTS



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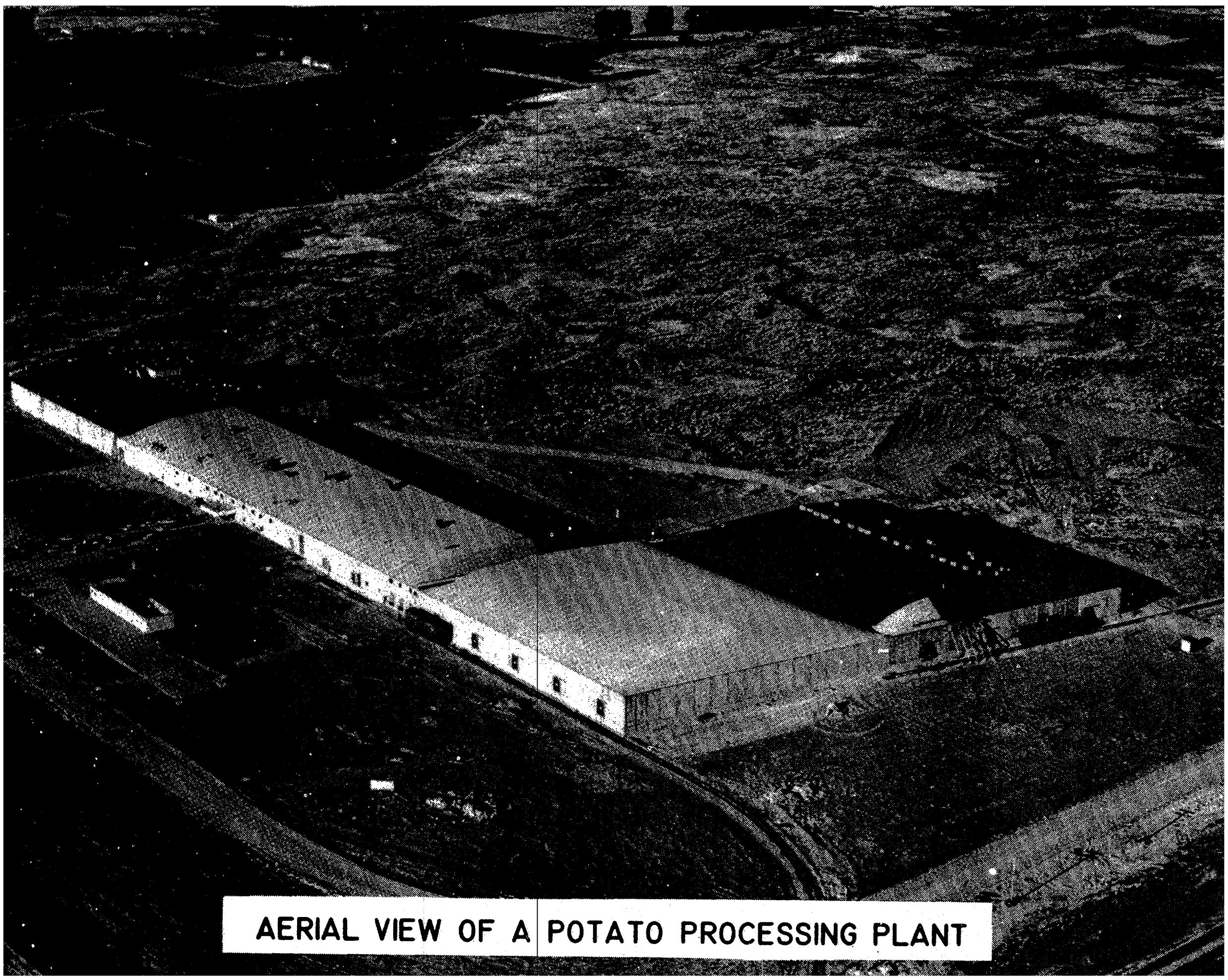

AERIAL VIEW OF A POTATO PROCESSING PLANT

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Copies of this report, prepared by the Western Utilization Research and Development Division, Agricultural Research Service, USDA, are available on request from the Western Regional Research Laboratory, Albany 10, Calif., headquarters of the Division.

May 1963

PROCESSING OF FROZEN FRENCH FRIED POTATOES AND OTHER FROZEN POTATO PRODUCTS

Commercial production of frozen French fries began in 1945 with a volume of about 3-1/2 million pounds (3). Output has steadily increased to the record of over 488 million pounds in 1960 or nearly 140 times the 1945 volume. The pack of all frozen potato products for 1960 (about 88 percent frozen French fries) was over 551 million pounds according to estimates of the National Association of Frozen Food Packers (32). This is nearly 50 percent greater than the 1959 pack (see table 1). Although production of frozen French fries dropped slightly in 1961, the total of over 579 million pounds for all frozen potato products exceeded all previous packs. Some frozen products other than French fries are listed in table 2.

This industry now utilizes well over 12 million hundredweights of potatoes per year and is expected to become an increasingly important outlet for potatoes. Frozen products presently account for about 21 percent of all potatoes processed for food, including chips and dehydrated and canned products. Processing plants for frozen potato products are widely scattered throughout the United States as indicated in figure 1. However, processing is most heavily concentrated in the potato growing areas of the Pacific Northwest and the Northeast. Idaho processes considerably more than all other States combined.

Table 1.--Pack of frozen potato products[1/]
(in pounds)

Product	1958	1959	1960	1961
French fried	232,912,478	322,294,141	488,204,712	465,935,326
Whipped & diced	4,361,341	4,347,051	2,861,414	3,209,306
Other[2/]	32,187,735	44,406,712	60,325,727	110,017,784
Total	269,461,554	371,047,904	551,391,853	579,162,416

1/ From figures compiled by the National Association of Frozen Food Packers (32).
2/ Includes patties, hash brown, puffs, shredded, rissole, etc.

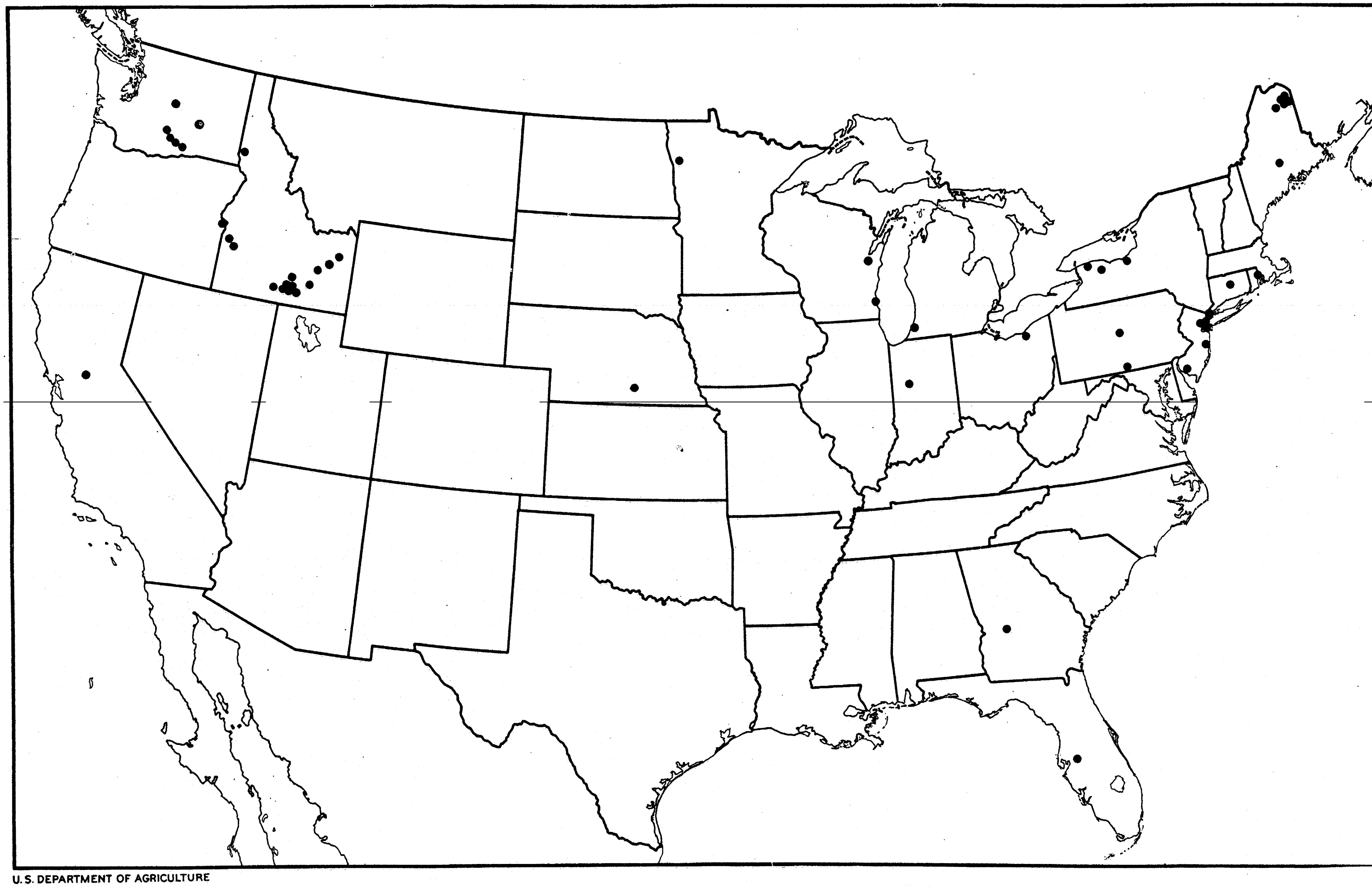


Figure 1.--Locations of producers of frozen potato products.

Table 2.--Frozen potato products
(packed individually and/or as ingredients of precooked frozen dinners)

French fries	Au gratin
Regular and crinkle cut	
Par-fries (institutional)	Delmonico
Patties	Dutch potato salad
Regular and onion-flavored	
	Boiled
Hash brown	Roasted
Shredded (extruded)	Dumplings or pirogen
Mashed or whipped	Knishes
Cuts for mashing	Blintzes
Diced	Pancakes
Regular and onion-flavored	
Puffs	Hashed in cream
Baked stuffed	Cream of potato soup
Cottage fried	Potatoes and peas in cream sauce
Whole potatoes (small)	Dehydrofrozen dice and slices
Rissole	Mashed
	Stew mix

Production of frozen potato products was about evenly divided between eastern and western sections of the United States as recently as 1955. Since then, a far more rapid expansion has taken place in the West. The latter accounted for 76 percent of the total pack in 1961. However, the volumes processed for retail were approximately the same in each producing region. Western expansion is accounted for in large part by increases in production of institutional and bulk packs (32).

Recent years have seen a spectacular increase in the institutional use of frozen potato products. In 1953, for example, only about 5 percent of the pack went to restaurants and other institutional users. Two years later the percentage rose to about 27 and by 1958 the major part (52 percent) was in the bulk and institutional category. In 1960 almost two-thirds went to the institutional trade (32).

The per capita consumption of fresh potatoes has declined steadily during the past 40 or 50 years. The inconveniences of home storage, peeling, and cooking have undoubtedly contributed to this decline, particularly in the current trend toward ready-to-serve foods. During recent years, when processed products became available in significant volume, the total per capita consumption of potatoes has remained essentially constant. In other words, increasing consumption of processed products has offset the decline in consumption of fresh potatoes. Possibly total per capita consumption may even be increased through further increases in consumption of processed products.

An important factor favoring consumer acceptance of frozen products is uniform quality from one season to another. Fresh potatoes vary and when purchased by the housewife may or may not be well suited for her purpose, such as frying, mashing, boiling, or baking.

The processor has distinct advantages over the housewife or restaurant operator in the preparation of products. First, he is usually located in the heart of a potato-growing area. This aids him in obtaining raw material best suited for his product. Second, he can process large volumes from relatively uniform lots and his products are then available when fresh market potatoes are low in quality, high in price, or possibly unavailable. Third, elimination of peeling and trimming waste and other reductions in weight effect savings in cost of shipping to consuming centers.

SUITABLE VARIETIES FOR PROCESSING

Each variety has characteristics of shape, size, color, skin texture and configuration of eyes which distinguish it from others. Characteristics of special concern to the processor of frozen French fries which are not readily apparent include specific gravity of dry matter content, texture of the cooked potato (mealy or waxy), and content of reducing sugars (14,20,22). The dry matter content is important in relation to yield, oil absorption during frying, and texture of the fried product. Starch content, cell structure, and related properties also influence the textural and eating qualities of the French fries. Reducing sugars affect the formation of the desired golden brown color during frying (20).

Kirkpatrick and coworkers (26) showed that potatoes of high specific gravity (high solids content) produced French fries that were more crisp, more mealy, and less oily than potatoes of low specific gravity as judged by taste panels. Flavor scores were also higher in some instances with higher specific gravity. Tenderness as measured by a shear test, however, was less with higher specific gravity. When the mean scores for color, uniformity of coloring, lack of oiliness, tenderness, crispness, mealiness, and flavor, collectively referred to as "palatability," were averaged for 4 potato varieties from different areas (Chippewa, Katahdin, and Irish Cobbler from Maine, Irish Cobbler from North Dakota, Katahdin from Colorado, and Russet Burbank from Washington) it was observed that palatability increased as specific gravity increased.

Suitability of potatoes for French fries varies not only according to variety but also with growing conditions (climate, soil type, fertilizer use, water availability), degree of maturity at harvest, handling procedures, and storage conditions. Specific gravity, for example, increases with maturity but decreases with excessive fertilizer and water. Excessively high temperatures and lack of sunshine tend to make potatoes low in solids content. Exposure of potatoes to low temperatures, either in the soil before harvest or in subsequent storage, causes an undesirable build-up in reducing sugar content (42).

Entirely adequate standards of suitability of potatoes for processing into frozen products have not been established and much must be left to the experience of the processor in selecting his raw material. As already indicated, a variety will vary in quality from one area to another and even from field to field in the same area. Variations from season to season can also be expected. Determinations of specific gravity and reducing-sugar content and frying tests made at harvest time and at intervals during storage are relied upon as guides. Experience has shown that the selection of a variety already proved as to its overall suitability is a prime requisite for success in producing a high quality product.

RAW MATERIAL PROCUREMENT

Processing must usually be spread over periods of 9 or 10 months for economical operation of a plant. Therefore, careful attention must be given to selection and procurement not only at harvest but also later in the processing season, since quality is subject to change during prolonged periods of storage. Most processors suspend operations during the summer when late-crop potatoes from the preceding year are no longer in dependable supply or do not have satisfactory qualities.

Open-market purchases have been widely used in the past and offer some advantages to both buyer and seller. The buyer can inspect the various lots, take samples, test for solids, and arrange to have specified amounts shipped at regular intervals. At harvest or shortly thereafter, there is a large reservoir of raw material to select from, and the experienced buyer can usually purchase to advantage the raw material that is best suited for his needs. Some growers may prefer to store all or most of their crop and sell later when higher prices may prevail.

During periods of short supply, processors may have difficulty in obtaining suitable potatoes at satisfactory prices. Consequently, contracting with growers in advance provides the best assurance of adequate supply. The purchaser can predetermine his raw material cost and also have more complete control over seed used, growing and harvest practices, and conditions of storage. If the processor is unable to make long-range procurement arrangements and to specify conditions of storage by the grower, he must provide or arrange for other storage and related facilities with capacity adequate to meet his processing schedule. Local procurement is advantageous because it enables the processor to obtain sample lots for examination and testing prior to purchase.

Potatoes used for frozen products vary in grade and quality from culls to those meeting U.S. No. 1 standards for shipment to fresh market. Thus a plant may use either graded potatoes, field run, or potatoes rejected from packing sheds as culls because they are misshapen, over- or under-sized, or broken or cut. Any food processor buying rejects or culls must be assured that the lots he obtains are sound and will keep satisfactorily in storage before processing. Field-run potatoes are often used in preference to any particular grade, since these can usually be procured at a lower cost than graded potatoes. However, unit cost of raw material should not be used as the sole basis for purchase of either graded, field-run, or cull potatoes. Poor grades purchased at a low price, for example, may involve disproportionately high peeling and trimming costs and may, in addition, give low yields of acceptable product. In some instances, potatoes that are lower in quality than U.S. No. 2 cannot be processed for food products (except canning) because of marketing agreements.

Size classification of potatoes is also important. Use of large potatoes normally results in lower peeling losses and provides greater yields of long French-fry cuts that are especially desirable for restaurant use.

STORING AND CONDITIONING

Proper storage and conditioning facilities are needed to reduce loss and to provide suitable raw material over an extended period. Storage consists of three stages: (a) initial curing, (b) dormancy, and (c) warming or conditioning.

To promote healing of cuts and injuries that have occurred during harvest, and to reduce shrinkage, potatoes should be held under high humidity at temperatures of 55° to 60°F. for the first two or three weeks. Daytime weather conditions at harvest in most late-producing states approximate these requirements. After curing, the temperature should be lowered to 38° to 40°F. (43). This permits the potatoes to be held dormant up to four or five months. Proper temperatures can usually be maintained in well designed pits, cellars, or storage houses with controlled ventilation in the northern growing districts. If the potatoes are to be kept longer (6 to 8 months) or held for seed stock, in which case any sprouting is undesirable, the temperature should be somewhat lower. However, a temperature as low as 32°F. is not necessary and may be detrimental. Potatoes with 22 percent solids freeze at slightly below 29°F. The most favorable storage conditions require circulation of air having a relative humidity of 80 to 90 percent, and the exclusion of light.

Potatoes stored under these conditions should not decrease in weight more than 5 percent throughout the winter. Under poor conditions, however, the loss may be 20 percent or more. Additional losses may occur due to net necrosis, internal discoloration, mahogany browning, hollow heart, black spot, and other disorders. Rough handling will result in increased losses. After sprouting begins, as may occur during late spring, shrinkage losses increase at a progressive rate (35,46).

Potatoes used for frozen French fries are usually suitable for processing immediately after harvest but the build-up of reducing sugars during prolonged low-temperature storage may render them undesirable for processing. If potatoes are to be used within a few months after harvest, continued storage at 50° to 60°F. should enable production of the highest quality of French-fried product. French fries from potatoes stored 2 or 3 months at these temperatures have been shown to have better texture, flavor, and color than those made from potatoes stored below 50°F. (46).

When potatoes are stored at 40°F. or lower, or are subjected to low temperatures prior to harvest, excessive concentrations of reducing sugars may develop. A high content of reducing sugars causes French fries to be too dark. In some cases, the potatoes must be "conditioned," that is, held at 70°F. or higher for 1 to 3 weeks just prior to use (3). This treatment lowers the sugar content. In other cases, suitable frozen French fries may be produced by appropriate adjustments in blanching conditions prior to frying. Some varieties, however, accumulate such high concentrations of sugar that they cannot be conditioned or processed satisfactorily while others give variable responses to conditioning (24). It has also been observed that some potatoes make poor products after conditioning even though the reducing sugar drops to a relatively low level (33). It is generally recognized that a reducing sugar content above 2 or 3 percent of the potato solids is undesirable.

SPROUT INHIBITION

Potatoes usually retain their good processing qualities when stored at 50°F. or higher; however, it is not advisable to store potatoes at this temperature for prolonged periods because of tendency to sprout. Chemicals that inhibit sprouting show promise of solving this problem. Their application permits fall potatoes to be held well into the summer season, when ordinarily potatoes would no longer be suitable for either processing or fresh marketing.

The methyl ester of naphthalene acetic acid (MENA) was the first chemical sprout inhibitor used to any great extent in the United States. It can be applied in the form of a wax emulsion or water solution to potatoes going into storage or market channels, or as a vapor to potatoes in storage. Another compound, isopropyl N-(3-chlorophenyl) carbamate (CIPC) holds considerable promise for widespread use. It can be applied as a dust, spray, or aerosol and is extremely effective. Quantities ranging from 1/4 to 1 gram per bushel of potatoes are adequate. Tetrachloronitrobenzene (TCNB) is relatively much less effective and has been widely used for potatoes grown under contract for processors.

Care must be taken in applying MENA, CIPC, and TCNB to potatoes going into storage to make sure that the skins are well set with a minimum of bruising. Otherwise treatment should be delayed until after normal wound healing, because these chemicals inhibit wound periderm formation and thus may cause rotting. However, inhibitors that can be applied as gases or vapors have important advantages over others, in that application can be delayed until a definite need for sprout inhibition is indicated. Also, the effects will be longer lasting than if the same treatment were made at harvest. Many storage buildings may require a re-design of their air circulating or ventilating systems in order to effect a more uniform and efficient application of the sprout inhibitor.

Irradiation has received much attention as a means of inhibiting sprouting. Limited dosages are very effective but practical application is subject to question because of relative cost and other considerations. Irradiation has been reported to increase the incidence of blackspots, storage rot, and darkening after cooking (39).

The subject of sprout inhibition has been discussed in detail by Talburt and Smith (45).

PREPARATION FOR PROCESSING

Potatoes to be processed are delivered to the plant by truck or rail. Two general methods are used for conveying raw potatoes from bulk storage at the plant to the preparation line: belt conveying and fluming. Various combinations of belts and fluming are also widely used. Fluming conveys potatoes with minimal cutting and bruising and also softens adhering soil. It also has an advantage of lower costs for labor, equipment, maintenance, and power, except possibly where the distances involved are relatively short (19). Because of the large volume required, fluming water should be recirculated. Flumes are usually recessed in the floor and provided with removable covers, thereby permitting storage of potatoes in practically the entire area. Portable belt conveyors are frequently used within the storage area. These are quickly accessible to various locations in the cellar.

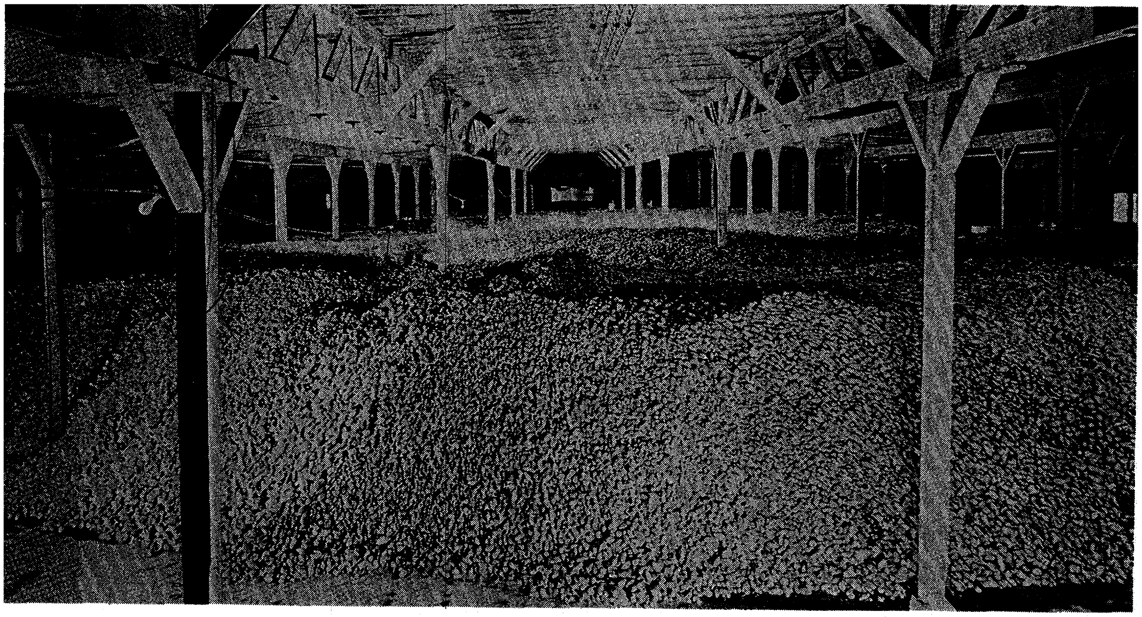


Figure 2.--Bulk storage of potatoes for processing.

Figure 3.--Washing potatoes from bulk storage into a flume.

The first processing step is usually removal of dirt and other foreign material. Fluming serves as a preliminary washing step. The potatoes are commonly passed through a destoner and trash remover and are then thoroughly washed with water sprays or other means, since adhering soil particles are objectionable in the peeling operation. If a continuous steam peeler is used, for example, dirt or grit particles may interfere with operation of valves and shorten gasket life due to abrasion. In lye peeling, dirt contaminates the lye solution and necessitates frequent change. A detergent can be used to enhance the action of the lye.

Potatoes can be graded by size either before or after washing or after peeling. Size grading permits better use, especially of field-run potatoes. The larger tubers can be cut into French-fry strips and the smaller used for patties, hash brown, or mashed potatoes. Small potatoes are not well suited for French fries, because they yield a high proportion of short cuts and slivers which must be separated from the final product. In some cases, potatoes of a special size or quality, such as bakers, are removed for sale on the fresh market when market conditions warrant. Pre-peeling inspection removes most of the defective potatoes (greened, rotted, or bruised).

Potatoes can be peeled by steam, lye or abrasive action (45). In plants processing large quantities, continuous equipment is generally preferred over batch peelers because savings in labor costs more than offset the higher initial capital investments required for continuous equipment.

Some processors prefer steam peelers, while others believe that lye peeling does a better job and results in less difficulty in adjusting conditions for different potatoes. Advantages or disadvantages as they apply in a given situation require consideration. For example, if local conditions render disposal of spent lye solutions difficult, it may be inadvisable to use a lye peeler. Initial investment may be a factor, since a continuous steam peeler is generally more costly than a continuous lye peeler of equivalent capacity. Peeling losses may be somewhat higher with lye than with steam but much depends upon control in each case. Laboratory control is needed to maintain proper concentration of lye in the peeler. Peelings from lye-peeled potatoes are not suitable for stock feed unless given considerable washing. Peeling losses from the abrasive method in large-scale operations are usually so high as to make this method uneconomical.

Preheating

Preheating before peeling is common. This insures a hot washing of the potatoes, which is particularly important to the proper functioning of the valve system of a continuous steam peeler. Dirt contamination of lye solution is reduced by a preheater. Peeler efficiency is increased through lowering the heat load. Losses are reduced by pre-softening the skins. Another advantage is that lye consumption is decreased. Preheating also allows flexibility in adjusting subsequent processing conditions by acting as a "surge" in the process, a factor of importance when time-temperature variations must be made in peeling to adjust to variations in characteristics of the raw material.

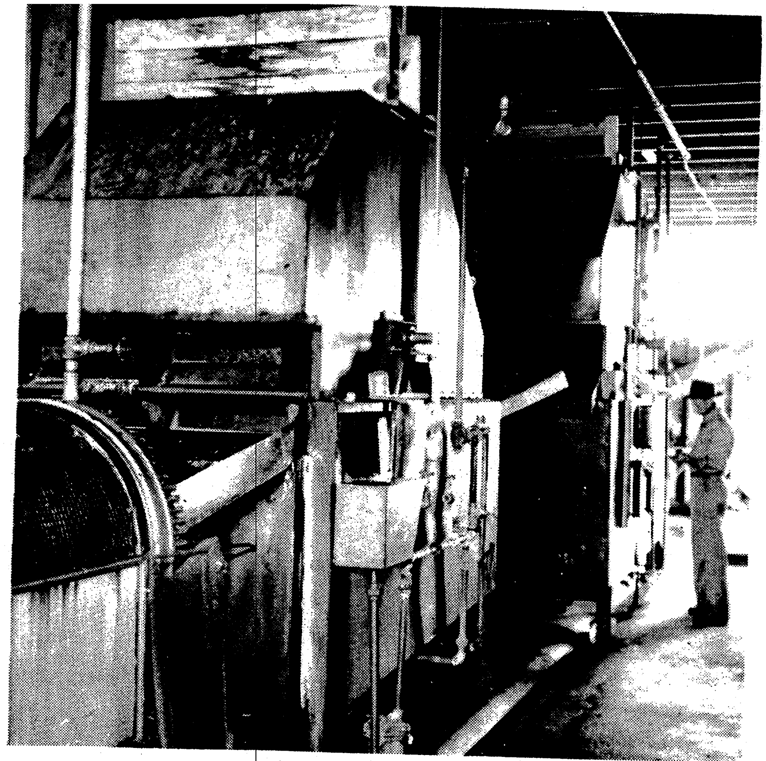


Figure 4.--Rotary preheater and lye peeler (rotary washer, lower left).

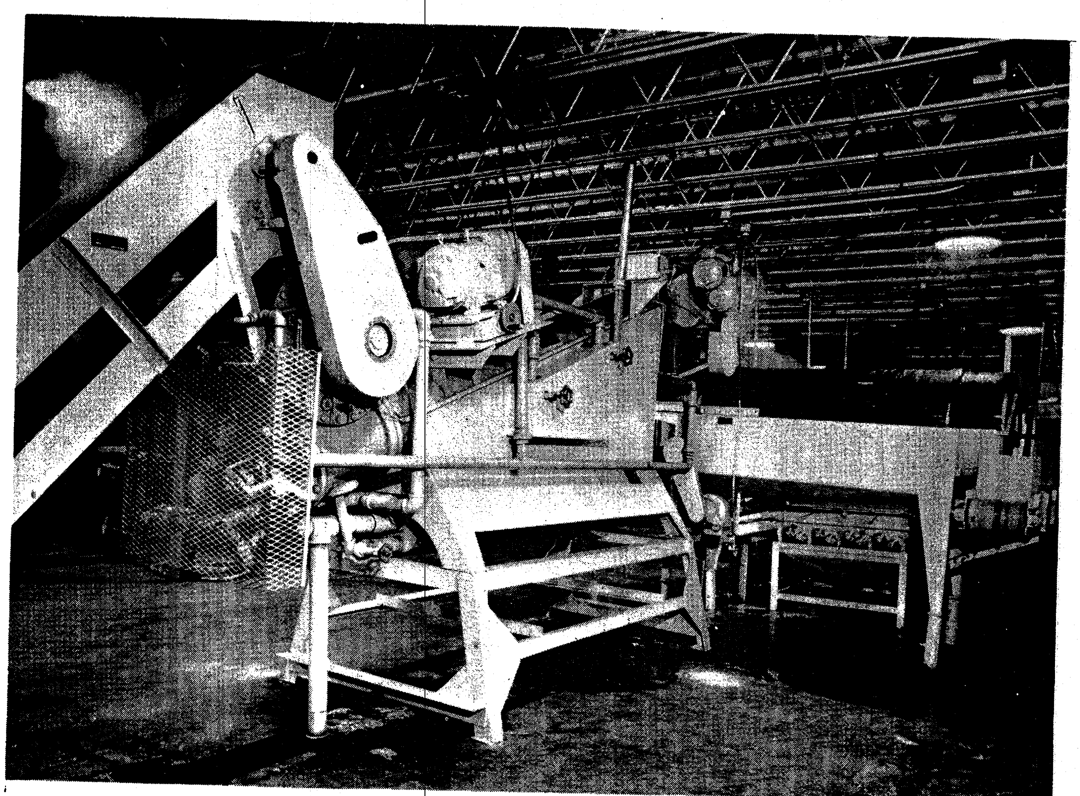


Figure 5.--Continuous steam peeler (rotary washer, right center).

The preheater is usually a rotary type, similar in construction to a rotary lye peeler but without a steam-coil section. The water is heated by direct steam injection. Draper-belt preheaters are also used with success but require more floor space than the rotary type. In some plants, the potatoes are merely washed with cold water before entering the peeler.

Lye Peeling

A lye peeler uses both chemical attack and thermal shock to loosen skins. Loosened skins and lye-affected tissue are removed by high-pressure sprays of water. Lye peelers are designed for continuous operation and are commonly the rotary or mill-wheel type as shown in figure 4 (47). Draper and rotary screw types may also be used. In this equipment, potatoes are conveyed through a hot lye solution at a controlled rate. Optimum operating conditions for lye peeling must be determined by test. In general, complete submersion of the tubers in a 15 to 20 percent caustic soda solution for a period of 2 to 5 minutes at temperatures in the range of 170° to 205°F. will usually be found satisfactory. The selection of optimum time and temperature conditions in relation to effectiveness of peeling and peeling losses will depend upon variety and age of the potatoes being peeled and also upon concentration of the lye. High-temperature lye peeling is more effective than low-temperature peeling in penetrating and removing heavily blemished or diseased areas on tubers. Lye consumption generally ranges from 20 to 30 pounds per ton of potatoes. Lye can be purchased in either solid form or a 50 percent solution. A lye make-up tank is used for diluting the 50 percent solution to operating strength, or can be used for dissolving solid lye.

The sludge formed in the lye peeler as a result of the chemical action on the potato tissue is removed periodically in order to extend the useful life of the solution. This removal is accomplished by allowing the sludge to settle and drawing it off from the bottom of the peeler or by pumping the solution through an externally located filtering device.

Potatoes that have passed through the lye peeler go directly to a washer where the peel is removed. A rotating barrel or reel-type washer in which sprays of water under high pressure impinge on the potatoes while being tumbled as they move forward through the washer serves effectively for removal of all residual caustic as well as peel. Peeling losses may vary from below 10 to over 30 percent, depending on the variety, age, and condition of the tubers at the time of processing, as well as on the peeling method used.

Steam Peeling

Both batch and continuous equipment are used for steam peeling. The high-temperature steam loosens the potato skins, which are subsequently removed with the aid of high-pressure jets of water and the tumbling or rubbing action of the washer as in lye peeling.

Batch steam peelers may hold as much as a ton of potatoes in a single charge. Typical treatment of Russet Burbank potatoes in such a peeler is 2 to 3 minutes at about 80 to 100 pounds of steam pressure. Continuous steam peelers in which a relatively small charge is present at any one time, require between

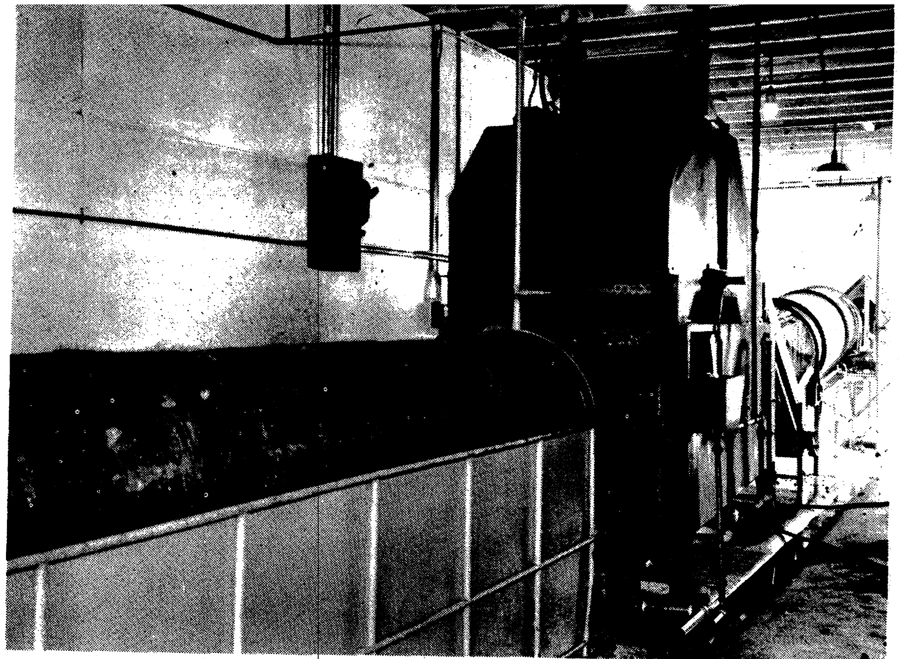


Figure 6.--Washing and removing peel after lye peeling.

Figure 7.--Trimming and sorting potatoes after peeling and washing.

35 and 45 seconds of retention time. This type of equipment may use steam pressure in excess of 100 pounds. A continuous steam peeler consists essentially of an inclined tubular steam pressure chamber containing a screw conveyor that moves the potatoes from the lower inlet end to the upper discharge end. Each end is equipped with a rotating valve which permits charging and discharging potatoes while under pressure.

Retention time in a steam peeler can be easily and quickly adjusted to meet requirements of different lots of potatoes. A few seconds of added time in the peeler, for example, increases the peel and tissue removed and thereby reduces trimming. Care should be taken, however, to avoid cooking to excessive depth, since this increases peeling losses.

Combination Lye and Steam Peeling

A comparatively new peeling method consisting of pretreating the potatoes with hot dilute caustic followed by steam peeling has been described by Adams, Hickey, and Willard (1). Optimum peeling conditions are reported to be immersion of potatoes in a 5 percent lye solution for 5-1/2 minutes and then subjecting them to a steam pressure of 75 pounds per square inch for 45 seconds. Cost analysis indicated this method to be more economical with respect to lower peeling losses and more effective use of lye than peeling by either lye or steam alone.

Abrasion Peeling

This method, which consists of a rasping action of a rapidly moving carborundum surface in contact with potatoes, is used to a very limited extent by processors of frozen potato products. The peeling losses for large-scale operations are usually so high as to make this method uneconomical.

PROCESSING

Trimming and Sorting

Peeled potatoes are conveyed over trimming and inspection belts in preparation for further processing. Unpeeled portions, bruises, or blackspots, etc., must be removed by trimming. Sun- or wind-burned potatoes and those with serious defects are diverted from the processing lines. In some plants, the largest potatoes (4 inches or over in thickness) are cut in half lengthwise to facilitate cutting into French-fry strips (53). Potatoes less than 1-1/4 inch in size are usually removed from the French-fry line for processing as potato patties, hash brown, shredded products, mashed potatoes or other by-products (25).

Trimmed and sized potatoes are conveyed to a holding tank or surge hopper to regulate their flow to the strip cutters. The surge hopper is filled with water in which the potatoes are submerged for the purpose of reducing surface oxidation or discoloration.

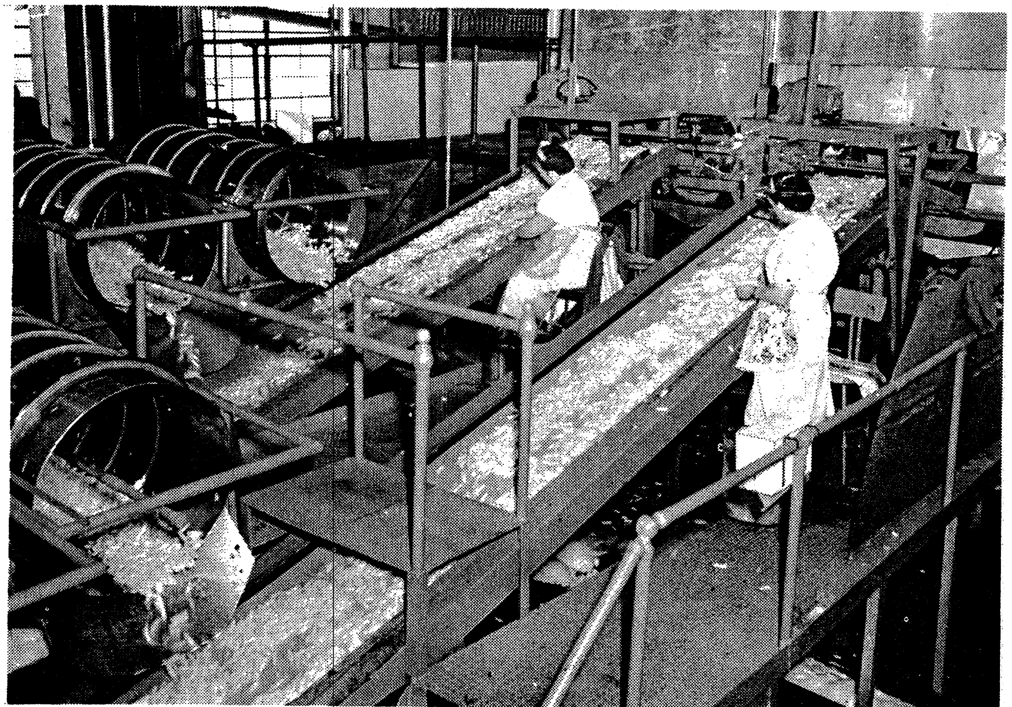


Figure 8.--Removing small pieces from French-fry cuts by reel graders.

Figure 9.--Removing slivers and nubbins from French-fry cuts by a walking-beam grader.

Strip Cutting

Equipment used for cutting potatoes into French-fry strips is designed to orient the potatoes along the long axis, or as nearly so as possible, in order to obtain the greatest yield of long cuts. A number of different sizes of French-fry strips from 5/32 to 1/2 inch square in cross section can be produced by proper selection or adjustment of equipment. Strips 3/8 or 1/2 inch square have proved to be the most popular sizes. Cuts of other sizes are produced for special orders. A new type has been described by Livingston (29). With this equipment, potatoes are squared and shot lengthwise through a so-called "water gun." This forces the potatoes through a tubular cutter under tremendous hydraulic pressure. Extra long cuts that are uniform in cross section from end to end are produced.

Crinkle or corrugated cuts are being produced in increasing volumes to meet popular demand. French-fry products destined for the institutional trade are predominantly composed of long cuts and the largest sizes of potatoes should be used for this purpose. Smaller potatoes are generally used for the short cuts that are processed for retail packaging.

Sliver and Nubbin Separation

Slivers (thin slices) and nubbins (short or broken pieces) must be separated from the product following cutting into French-fry strips. As defined by the National Association of Frozen Food Packers, a short piece is less than 1 inch in length (13). The equipment usually used consists either of a rotating reel or a shaker screen having slots through which the slivers fall as they pass through the reel or over the screen bed. Converted bean graders are also used to eliminate slivers. Nubbins may be separated by a vibrating screen after the slivers are removed. In this case, the diameter of the holes in the screen correspond to the length of the short pieces to be separated. Some processors use a walking-beam grader for separating the undersizes from those of suitable dimensions. This equipment consists of a series of inclined cam-operated steps which align the strips across the length of each step. The slivers are first removed by adjusting the clearance between the steps and the nubbins are then eliminated by a series of adjustable slots built into each step. Separating the slivers from the nubbins is therefore possible and both operations can be carried out in the same unit. The pieces not intended for frying are diverted to the co-product processing lines. Following the elimination of slivers and nubbins, some operators convey the strips to the blanchers on a short inspection belt where any remaining small pieces and discolored or otherwise defective strips are removed.

Blanching

French-fry strips are blanched in water prior to frying. Advantages claimed for blanching include (a) more uniform color, (b) reduction of fat absorption due to gelatinization of the surface layer of starch, (c) reduced frying time since the potato is partially cooked by blanching, and (d) improved texture.

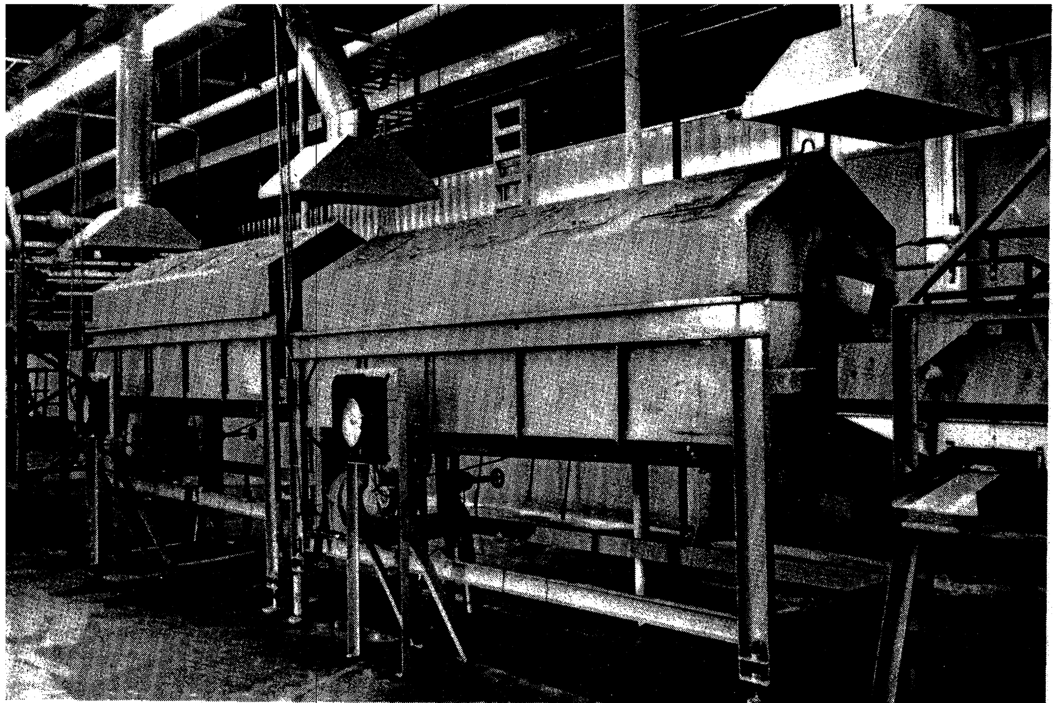


Figure 10.--Blanchers in series used for French-fry cuts.

Figure 11.--French-fry cuts entering the fryer.

Blanching serves an important function in relation to color of the fried product by its leaching effect on reducing sugars contained at or near the surfaces of the strips. Some areas of raw potato surface are higher in sugar content than others and these become correspondingly darker during frying. This results in a mottled and undesirable appearance in the finished product. Blanching levels out the differences in surface sugar concentrations and thereby improves uniformity of color. Blanching also reduces the overall reducing-sugar concentration if this is high, as may be expected in potatoes that have been held at low temperatures for a prolonged period. However, blanching does not eliminate the need for conditioning when sugar content has reached excessively high levels. Variations can be made in either time or temperature of blanching, or both, as a means of equalizing the frying characteristics of lots of potatoes. Even though processors procure potatoes that are suitable for processing, variations in frying characteristics of raw material should be expected. Experience provides the best basis for adjustment of blanching conditions to compensate for raw material variation.

Two blanchers, operating in series, are commonly used for greater flexibility and to obtain maximum control of color. The first, for example, may exert both a leaching and an equalizing effect on sugar concentrations. The second may contain a dilute sugar solution and be used to adjust the surface concentration to a desirable level for best and most uniform color development during frying. For some lots it may be desirable to use both blanchers for leaching.

Blanching is also regarded as an aid to the control of texture of frozen fries and to obtaining a more uniformly mealy internal structure. Reeve (34) observed that preheating potatoes in water at 75°C. (167°F.) and at 90°C. (194°F.) before complete cooking effected significant changes in physical properties of the starch and textural characteristics of White Rose and Russet Burbank potatoes. Subsequent investigations by Cording and coworkers (17) demonstrated that heating potatoes in water or steam in the range of 140° to 180°F. for 10 minutes or longer prior to complete cooking at 212°F. resulted in a more mealy texture of potato flakes. Precooking treatments were particularly effective with potatoes of low solids content. Gould (20) pointed out the need for careful control of both blanching and frying conditions to obtain optimum quality.

As much moisture as possible should be removed from the blanched strips to reduce the load on the fryer and to minimize the rate of hydrolytic breakdown of the fat. The lower the moisture, the less time will be required for frying, and consequently the lower the oil absorption by the product (15). Surface moisture tends to soften the potatoes if there is a delay before frying, as may be the case if inspection follows blanching.

The blanched strips are first passed over a dewatering screen, and then further dried with hot or warm air blown over or around the strips. Jones (25) described a specially designed unit for drying. This unit consists essentially of three superimposed horizontal belts. The strips cascade downward from the first belt to the second and finally to the third while high-velocity warm air is blown through the mass of strips.

Frying

Frying conditions must be carefully controlled to obtain a product that has the desired surface color and internal texture. The margin of time betwee underfrying and overfrying is very narrow. For this reason constant supervisi and strict control of moisture content of the strips, surface sugar concentrat frying time and temperature, and related factors are required for uniformity o texture and color in the finished product. Oil absorption during frying enhan flavor but an excessive content gives the product an undesirable oily surface.

Variations in degree of frying are made by the processor to meet requir ments of consumers. Restaurants, for example, desire French fries that can be prepared as needed by finish frying in deep fat to develop color and crispness To meet this need, the processor produces "par-fried" or "oil-blanched" product Par-fries require minimal frying at the processing plant.

The home user frequently does not have a deep-fat fryer and must depend upon a hot oven or a broiler. This accomplishes some browning and crisping as well as heating. Products destined for the home consumer are usually fried more completely by the processor than are the par-fries.

Equipment and operation.--Frying can be accomplished in one fryer or in two fryers operating in series. These methods are known as the single-stage a the two-stage systems. Both are used successfully by industry and proponents of each claim certain advantages.

Single-stage fryers are so designed and operated as to give the necessa control of frying. Uniformity of color is achieved by turning or agitating th strips while they are being conveyed through the fryer. An endless wire-mesh belt operated at variable speeds is commonly used to convey the potato strips through the fryer.

In the two-stage system, the blanched strips pass through the first fryer and are then conveyed to the second, which is similar in design to the first. This system increases the rate of throughput and is thought by some processors to permit more even color development and to give greater flexibili of operation. In the transfer from the first to the second fryer, the strips are turned over, which insures even color development and prevents light areas caused by two or more pieces sticking together throughout the frying process.

The frying fat is heated by heat exchangers using either high-pressure steam or high-boiling-point liquids. Some processors use direct heat obtained from gas-fired burners. The use of gas-fired heat exchangers through which fa is circulated at high velocity is becoming more popular. In any system, heat should be transmitted uniformly to the fat so as to avoid localized overheatin or hot spots.

Contamination of the frying fat with metals such as iron and copper mus be avoided, since the metallic compounds formed with the free fatty acids contained in the fat act as catalysts and cause fat breakdown. For this reason, stainless steel is considered the most desirable material for construction of the fryer pan and other parts coming in contact with the fat, although mild steel is frequently used because of its lower cost.

Constituents of fat which are volatilized during frying should be carried off through an exhaust system designed to prevent "drip-back" into the fat. These constituents, if allowed to re-enter the system, not only cause off-odors and off-flavors, but also accelerate fat deterioration.

Particles of potato left in the fryer must be removed periodically; otherwise they char and adversely affect the quality of the fat. Periodic or continuous removal is accomplished by passing the fat through centrifuges or filters. Equipment also becomes coated with gums or other material during frying and must be cleaned frequently to prevent accumulation.

Frying temperatures usually fall within the range of 350° to 375°F. The temperature should not be allowed to exceed 390°F. because fat breakdown is greatly accelerated at this temperature and higher. Frying time is usually about 1 minute or less for institutional par-fries and up to 2 minutes for retail French fries.

Frying fat.--Hydrogenated vegetable shortenings are used for frying. These are composed chiefly of cottonseed oil, sometimes with minor portions of soybean oil. Other vegetable oils are not used to any great extent because of their higher cost. Hydrogenation, a process of adding hydrogen to the unsaturated fatty acid component of fat, makes the fries more stable against rancidification during prolonged storage. Normally, hydrogenated shortenings also have a high smoke point and are resistant to foaming and to gum formation during frying. Liquid cottonseed oil is also being used for frying purposes.

Fat is supplied in either drums or tank cars. It is melted and held temporarily in storage tanks from which it is pumped to the fryers as needed.

The supply in the fryer is maintained at constant level by addition of fresh fat to replace that absorbed by the potatoes. Addition of fresh fat serves to retard the deterioration that normally occurs in fat held at frying temperatures. The number of hours required for addition of fresh fat to become equivalent to the total quantity in the fryer is known as the "fat turnover" period. Obviously, rate of fat turnover will be most rapid in a system containing the least total fat for a given rate of production. The ratio of fat to product being fried should therefore be kept at a minimum consistent with satisfactory operation of the equipment in order to achieve a high rate of turnover. Some operators consider a satisfactory rate to be around 10 to 16 hours but shorter periods may be realized. Under such conditions, it is usually considered permissible to continue frying without discarding any fat unless, for example, continuity of feed to the hot fat is interrupted, thereby prolonging the turnover period and allowing extensive deterioration of the fat. During a shutdown, the fat should be cooled as rapidly as possible and held under tight cover to minimize oxidation.

Fat deterioration.--Fat may deteriorate in several ways. One is by hydrolysis, a breaking down of the fat into free fatty acids and glycerol, through reaction with water or steam. Since water is carried into the system by the slices, it is desirable to remove as much surface water as possible.

The higher the free fatty acid content of the fat, the lower will be the smoke point -- that is, the temperature at which the fat begins to smoke. Normally, commercial shortenings contain less than 0.1 percent of free fatty acids but this content is unavoidably increased with use. These acids have an acrid flavor, a sharp odor, and a deleterious effect upon quality of product. Some operators consider a free fatty acid content of 1 percent for French fries to be the upper limit of acceptability and that the fat should be discarded at this point. Analysis for free fatty acid is frequently used for quality control purposes. Free fatty acids tend to volatilize during frying but their volatility is not sufficient to prevent a gradual build-up. As previously pointed out, rate of turnover must be sufficiently high to maintain the fat in good condition, or else it must be discarded periodically. Satisfactory conditions may result in a steady-state free fatty acid content of 0.4 to 0.7 percent.

Another type of fat deterioration is oxidation, a combining of fat with atmospheric oxygen, which contributes to darkening of the fat, development of off-odors and off-flavors, development of foaming, and reduction in stability or shelf-life of the product. Contact with air at the surface is unavoidable but excessive oxidation can be avoided by eliminating opportunities for aeratic of the hot fat within the circulating and centrifuging or filtering system usec in conjunction with the fryer. Although the end result of oxidation is rancidi ty, fats do not normally become rancid during frying, but deteriorated fats in products may become so during prolonged storage.

Polymerization of fat may also take place. This reaction is essentiall a combination of unsaturated fat molecules to form products of higher molecula weight. Oxidation may or may not be involved. Polymerization becomes evident by increased viscosity of the fat and by formation of gum or gummy deposits.

Defatting and Cooling

Excess fat must be removed from French fries after frying. One method is to pass the product over a vibrating screen and allow free fat to drain off Another defatter shakes the French fries in a stream of hot air in a specially designed chamber (25). Defatting is also accomplished by use of a section of conveyor belt from which the fries cascade to a second conveyor belt. Free fa collected on the surface of the belts is removed continuously by a specially designed wiping or scraping mechanism. Recovered fat is returned to the fryin system.

The product is then air-cooled while being conveyed to the freezing tunnel. In addition to reducing the refrigeration load on the freezer, coolin also firms the pieces and tends to reduce breakage, which is important if the product is to be packaged before freezing (53). The fries may be given an add tional inspection after defatting and cooling to remove overfried or otherwise defective pieces and to insure uniformity in quality.

Freezing

Most processors freeze French fries on a continuous belt in a freezing tunnel. Temperatures of -30° to -40°F. are maintained and the product is froz

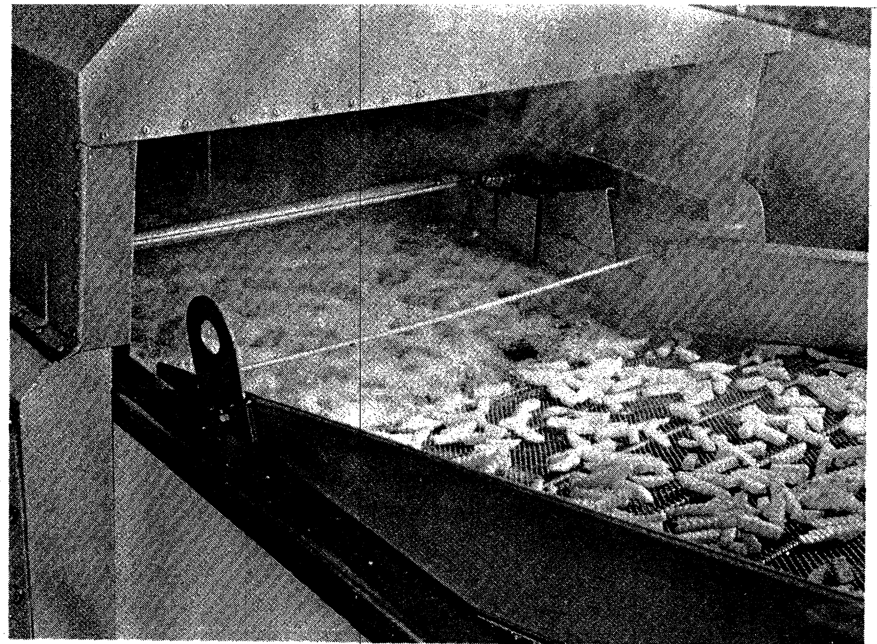


Figure 12.--French fries emerging from a fryer.

Figure 13.--Defatting screen (right center) discharging on an inclined cooling belt (center).

rapidly under these conditions. According to Schaal (40), only 12 minutes are required at -40°F. Rapid freezing causes the least change in texture of products (31).

Some fries are packaged in retail cartons before freezing. Possibility of piece breakage is increased when unfrozen fries are packaged, as compared with frozen. The overwrapped cartons are frozen in a blast or multiple-plate contact freezer. Plate freezing may take 2-1/2 hours for the product to reach 0°F. (3).

Packaging

Frozen French fries are usually packaged in 9-ounce and 16-ounce paper cartons for the retail trade. Polyethylene bags of 1- and 2-pound sizes are also used for retail purposes. Institutional packs usually consist of 5-pound paper or polyethylene bags but other sizes are packed according to customer demand.

The packaging operation, particularly as applied to retail cartons, is a relatively costly one because of the labor involved in filling and weighing each package and adjusting final weight to insure a proper fill. Much effort has been devoted to the development of automatic carton filling and check-weighing equipment for frozen fries and use of one such unit has been described (9). A combination of machine filling and hand packing to adjust final weight is frequently used. Filling institutional packages is simplified, not only because of their larger size but also because it is not necessary for each bag to weigh exactly 5 pounds as long as the total weight of 6 bags in each shipping carton is 30 pounds. Overwrapping retail cartons and casing and sealing both retail and institutional shipping cartons are accomplished with the aid of automatic equipment. The cased packages are stored at 0°F.

PRODUCT YIELDS

The yield of frozen French fries, which can be expected to fall within the range of 30 to 45 pounds per 100 pounds of raw potatoes, is subject to wide variation with quality, size, varietal differences, and other factors. Freshly harvested potatoes, for example, usually have much lower peeling and trimming losses than do stored potatoes and consequently give higher product yields.

The flow sheet on page 30 shows an average material balance with yields expected during processing. No distinction is made between yields of retail pack as compared with institutional pack. Unless large potatoes are used, yields of institutional pack will likely be lower, since the shorter cuts must be removed from the desired longer strips. However, if both retail and institutional packs are being produced from the same lot of potatoes, increased yields can be obtained by use of the shorter cuts for retail packs. Further yields can be realized if the short pieces normally removed from those intended for retail are marketed for special purposes.

Field-run potatoes with a considerable number of small tubers (under 1-1/2 inches in diameter) will give lower yields of fries than will potatoes graded for sizes best suited for French fries. Varieties with an elongated shape, such as the Russet Burbank, give a higher yield of usable French-fry cuts than do round varieties.

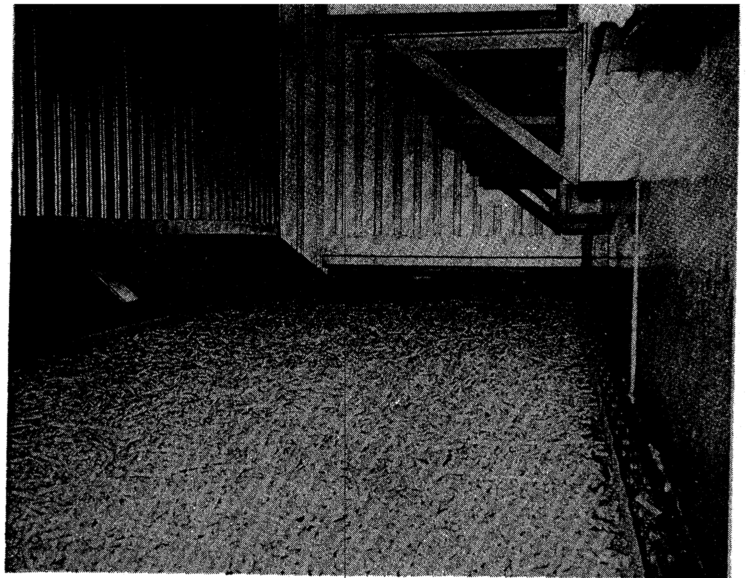


Figure 14.--Interior view of freezing tunnel for French fries.

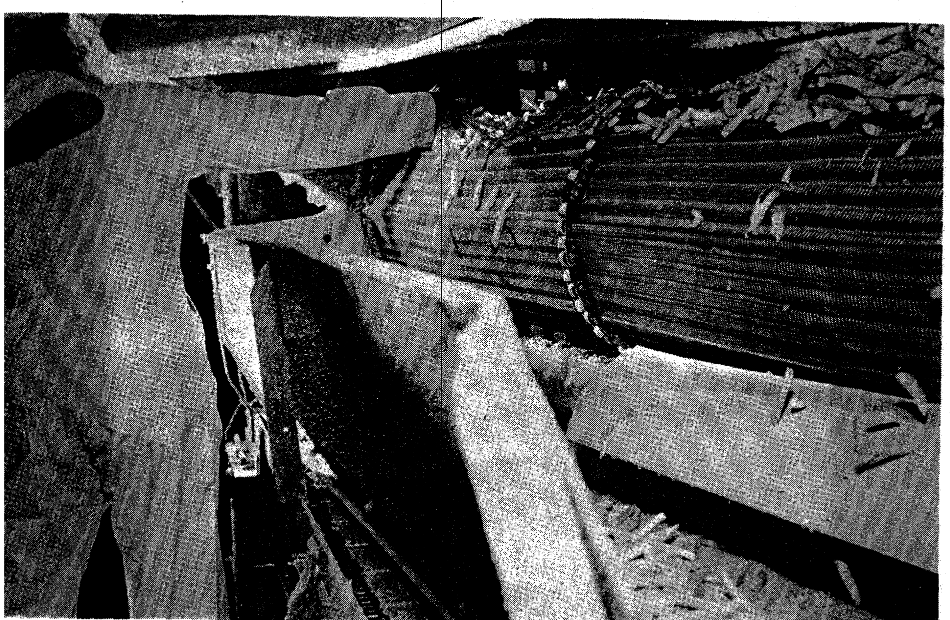


Figure 15.--Frozen French fries leaving continuous belt in freezing tunnel.

A well-integrated plant will make the most efficient use of sizes of potatoes by diverting the smaller ones, as well as slivers and short or broken slices, to co-product processing lines.

QUALITY CONTROL

Quality control of frozen par-fries and French fries usually begins with determinations of specific gravity, analyses for sugar content, or laboratory-scale frying tests. This information enables the processor to select raw material and

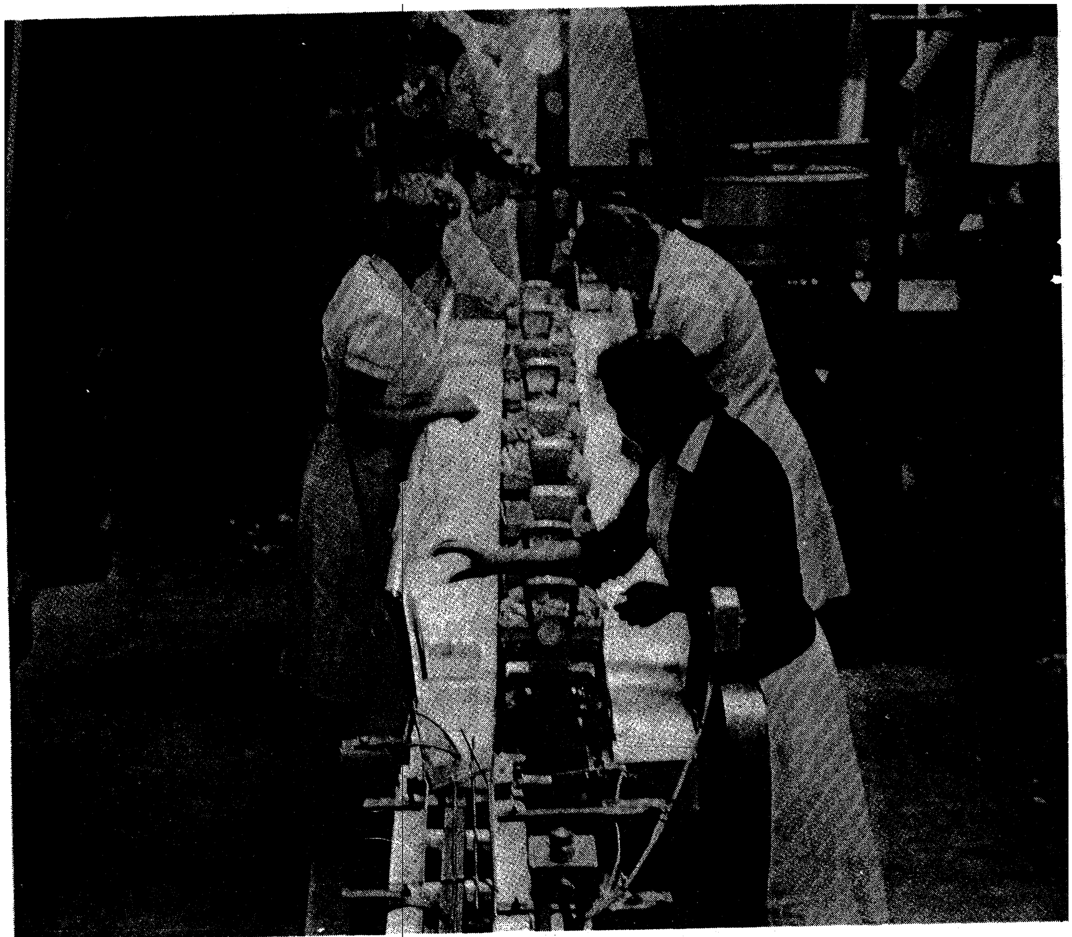


Figure 16.--Check weighing French fries packaged for the retail trade.

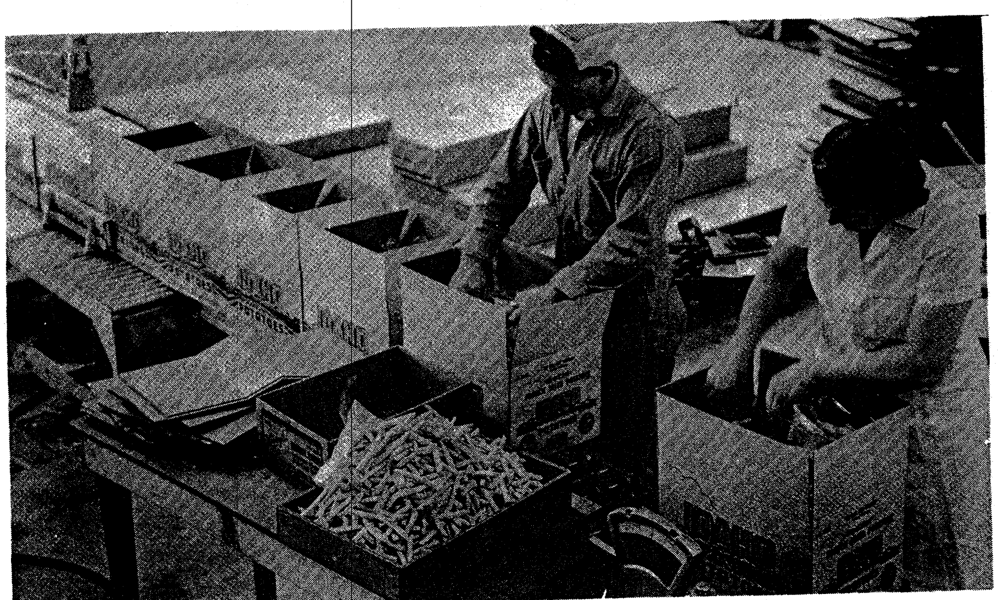


Figure 17.--Casing frozen par-fries for institutional trade.

to specify the conditioning treatment that may be required. Similar tests are made after the conditioning period as a check on effectiveness of the treatment and to determine the best blanching and frying conditions. From such records, the processor is able to control quality throughout various stages of processing.

Flavor, surface color, fat absorption, form and symmetry, external texture (crispness), and internal texture (mealiness) were listed by Benes et al. (15) as the most important quality factors for French fries. Color preference was for a light golden brown free from mottling with darker brown or black streaks or spots. The strips should be reasonably uniform in length and regular in cross section. The surface texture should be crisp without being hard, leathery, or gummy while the interior or core should have a mealy texture similar to that of a good quality baked potato. There should be no separation between core and crust. No bitterness, rancidity or other off-flavors should be detectable.

Buyers frequently set their own standards of quality for the finished product. Such standards may concern piece size, color, fat content, and number of pieces per package, as well as package label, weight, and instructions for use. Buyer's specifications may vary, depending upon consumer preference in the area in which the product is to be sold (49). Some processors run quality control checks every half hour to determine compliance with their customer requirements. A quality appraisal of the reheated product, prepared for serving according to customer use instructions, is made periodically as a further check. This consists of a visual examination for color and trimming defects or defective pieces and a judgment of texture by hand manipulation or by tasting. Fat content is sometimes used as a quality standard and methods of analysis have been described (36). The fat content may vary appreciably among processors according to raw material, frying practices, and other processing conditions. A buyer may specify a maximum fat content or a satisfactory range of variation.

The fat content of frozen fries in retail packs is usually about 4 to 6 percent and that of the par-fried product around 4 to 5 percent. These figures are considerably lower than those for French-fried potatoes prepared in the home from raw potatoes because of differences in preparational procedures. Fat absorption varies to some extent with specific gravity of potatoes, size of strips, retention time in the hot oil, and effectiveness of defatting after frying.

To a large degree, however, quality of frozen French fries and other potato products is difficult to specify in analytical terms. Much must be left to personal judgment, opinion, and experience, particularly with respect to texture and flavor. The person in charge of quality control must therefore use a combination of objective and subjective tests which will insure consumer satisfaction.

Standards for grades of frozen French fried potatoes have been established by the Agricultural Marketing Service, U.S. Department of Agriculture (5). Factors rated include a maximum 30 score points for color, 40 for freedom from defects, and 30 for texture. Factors not scored numerically, including varietal characteristics and flavor, also enter into grading.

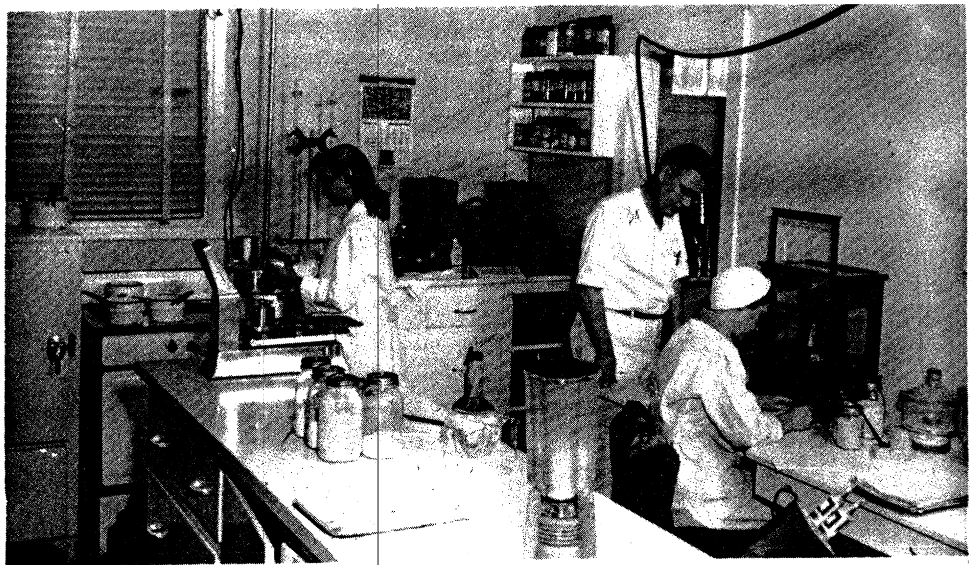


Figure 18.--A typical testing and control laboratory.

FROZEN POTATO CO-PRODUCTS

Co-products of frozen French fries have proved advantageous in two ways. First, manufacture of one or more products such as patties, hash browns, diced, mashed, puffs, etc. (see table 2) diversifies the operation and enables a processor to take advantage of variations in quality, grade, and sizes of his raw material (8,10). Co-products provide profitable outlets for potatoes too small for French-fry cutting and for the slivers and short pieces that would otherwise constitute a waste. Second, the number of new frozen potato products has greatly extended the availability of convenient, ready-to-serve items for both institutional user and home consumer. A flow sheet that outlines the principal processing steps for a number of co-products is shown in figure 19. The following information describes some of the processing operations in greater detail.

Potato Patties

In the manufacture of potato patties, slivers and short pieces separated from the French-fry line are steam blanched and then cooled and shredded or chopped. Whole small potatoes may be sliced or shredded and processed in the same manner as slivers and nubbins. Another method is partial cooking of small potatoes in steam or hot water before shredding or chopping. Shredding after cooking is thought to give a product with better frying characteristics than does shredding before cooking. The shredded material is mixed with salt or other seasoning and flour. In some cases, onion powder is added for flavor. A patty-forming machine shapes either round or rectangular patties weighing about 3 ounces each. The product can be frozen before or after packaging. Waxed paper between patties keeps them separate in cartons.

The potato patty is a versatile product that can be prepared for serving by frying in deep fat or in a skillet, by broiling, baking, or by boiling and mashing. It can also be prepared as an au gratin dish. Portion control for institutional feeding is also simplified by the use of patties.

Hash Brown Potatoes

Several methods are used to produce this product. In one process, small whole potatoes are completely cooked, cooled, shredded, and packed loose in cartons before freezing. Sliver and nubbin by-products from the French-fry line are also used. This material is shredded, chopped, or diced and is then blanched or cooked. If the material is blanched or cooked first, provision must be made for adequate cooling in order to avoid sticking or gumming in the cutting equipment.

Diced Potatoes

This product is prepared from small potatoes or pieces by dicing into cubes approximately 3/8-inch in size and blanching in water or steam. Onion flavoring is added in some instances. The product can be loose frozen or packaged and then frozen in a contact or blast freezer. Frozen diced potatoes serve as an all-purpose dish, since they can be prepared as a hash-brown product by browning in a skillet or can be used for preparing mashed potato or potato salad and a variety of other potato dishes.

Mashed or Whipped Potatoes

Slivers and small pieces of potato are steamed and mashed with mashing rolls or by extruding through a ricer. A finisher can be used to remove lumps and fiber. Salt and milk solids can be added. For whipped potatoes, the mashed material is vigorously beaten. A volumetric piston filler can be used to meter the product into film-lined cartons that are frozen in an air blast. Mashed potatoes for the institutional trade are produced from slices, cuts, or shreds which are blanched or cooked and frozen. Preparation for serving consists of heating in a steam-jacketed kettle or double-boiler. The product is mashed after the addition of milk or water.

A frozen mashed product known as "potato whirls" is produced in England. According to Talburt and Smith (45), "whole potatoes are peeled by abrasion, trimmed to remove eyes and other defects, then sliced mechanically and cooked in steam-jacketed boilers. Eggs, milk, margarine, seasoning and other ingredients are added during mashing. The final product has a very creamy texture. Individual portions are given a whirl or spiral configuration by means of a chocolate forming machine specially adapted to this purpose. Four completed whirls are packed in polyethylene within a 7-1/2-ounce carton and frozen."

Potato Puffs

Slivers and small pieces are also used for the production of frozen potato puffs. The raw material is cooked with steam and mashed and then mixed with flour, eggs, and seasoning in a batter mixer. A basic formula (4) consists of cooked peeled potatoes, 79.5 percent; butter or margarine, 4.5 percent; cream (light), 9.0 percent; egg yolks, 3.5 percent; and egg whites, 3.5 percent. Onion flavoring may be added. The mixture is extruded hot in the form of croquettes approximately 3/4 inch in diameter by 1-1/2-inches long. These are allowed to cool, then fried in deep fat and frozen.

Patties	Mashed or whipped	Diced	Puffs	Hash brown	Dehydrofrozen pieces
Blanching	Cooking	Dicing	Cooking	Cooking	Slicing
↓	↓	↓	↓	↓	↓
Dewatering	Mashing	Blanching	Mashing	Cooling	Blanching
↓	↓	↓	↓	↓	↓
Cooling	Mixing (2)	Dewatering	Mixing (3)	Shredding	Dewatering
↓	↓	↓	↓	↓	↓
Shredding	Finishing	Cooling	Extruding	Inspecting	Dehydrating (4) (Partial)
↓	↓	↓	↓	↓	↓
Mixing (1)	Whipping	Inspecting	Deep fat frying	Packaging	Cooling
↓	↓	↓	↓	↓	↓
Shaping	Cooling	Freezing	Cooling	Freezing	Inspecting
↓	↓	↓	↓		↓
Inspecting	Inspecting	Packaging	Inspecting		Freezing
↓	↓		↓		↓
Packaging	Packaging		Freezing		Packaging
↓	↓		↓		
Freezing	Freezing		Packaging		

Figure 19.--Partial flow sheets for processing frozen potato co-products. (1) Mixed with flour and seasoning, (2) mixed with milk solids and salt, (3) mixed with flour, egg solids, shortening and seasoning, (4) dehydrated to 50% or more weight reduction.

Shredded and Extruded Products

Shredded potato products that are formulated by blanching and mixing with flour, salt, monosodium glutamate and spice or other ingredients, then extruded in the form of small "bite-size" logs and deep-fat fried appear to be increasing in popularity. Such products are reported to have been introduced in 1958 (11). Since then, a number of others have appeared. Each is produced in a somewhat different manner and reflect the individuality and processing experiences of processors.

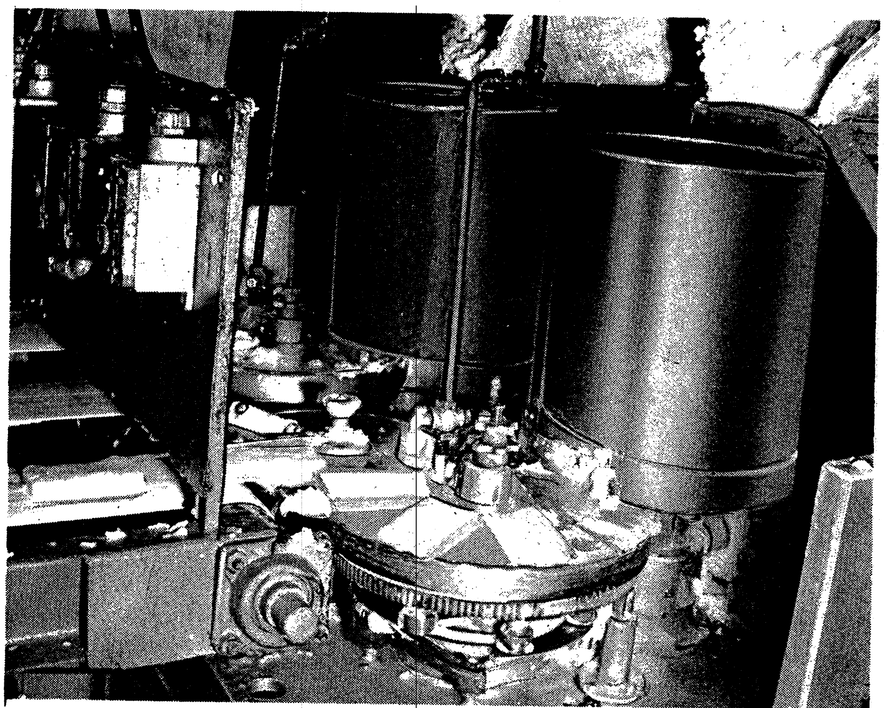


Figure 20.--Forming potato patties.

Au Gratin Potatoes

Cooked diced potatoes are mixed with a sauce consisting of milk, cheddar cheese, salt, monosodium glutamate and pepper. The mixture is approximately two-thirds potato and one-third sauce. Other ingredients such as flour, shortening, and sugar may be added. A topping consisting of cheddar cheese, toasted bread crumbs, and margarine or other formulations are sprinkled on the product before freezing.

Potato Cakes

Tressler and Evers (51) give the following description for processing: "Potato cakes are prepared by incorporating beaten eggs and salt with cold mashed potatoes or grated raw potatoes. The chopped parsly, chopped celery or celery seed, grated onion, small and irregular blanched strips of potatoes rejected from the French-fry line may be used after they have been cooked further on a wire-mesh conveyor in a continuous steam-blancher and then inspected and riced in a pulper. If grated raw potatoes are used, more eggs will be required

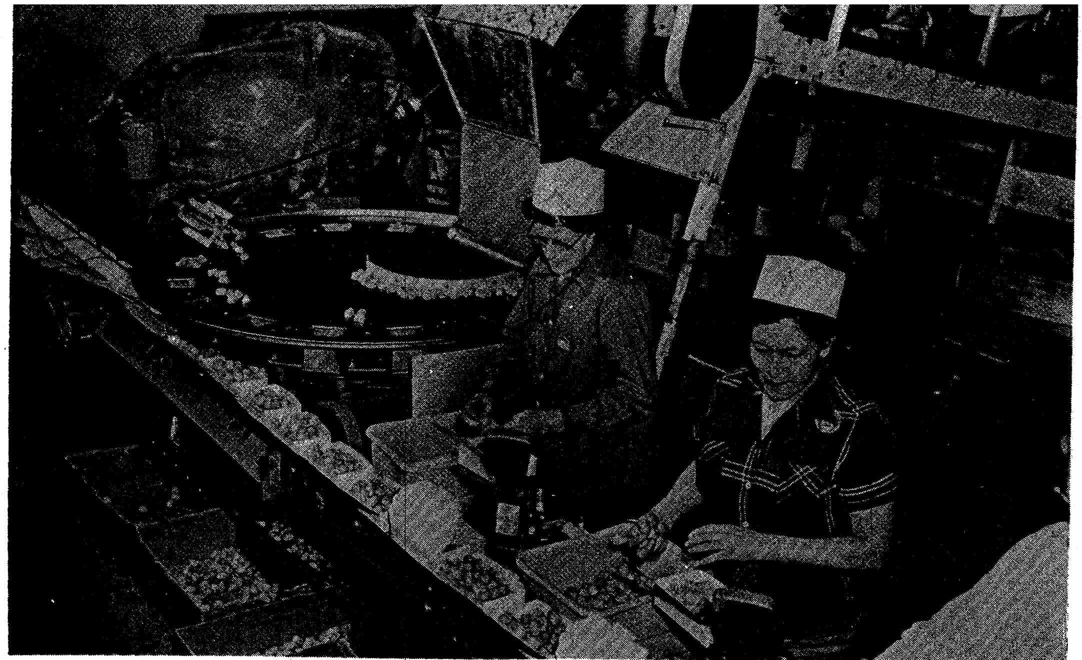


Figure 21.--Packaging and check weighing a type of shredded potato product.

to hold the cakes together than if either cold mashed potatoes or the steam-blanched, irregular strips from the French-fry line are used. After thorough mixing, the mash is formed into cakes which are dipped in either fine bread or cracker crumbs, or flour, and then fried by the shallow fry method. Midway through the frying, the cakes are flipped over and browned on the other side. After cooling, they are packed in consumer cartons which are closed and over-wrapped before freezing, or are placed on a tray as a component of a frozen precooked dinner."

Rissole Potatoes

This product is prepared by blanching small whole peeled potatoes followed by frying in deep fat to a golden brown color.

Precooked Frozen Dinners

The first frozen dinners were produced in 1945 (51). These were intended primarily for airplane passengers. Frozen French fries, puffs and patties were included in some of the initial 18 menus. Since then, frozen dinners have become widely popularized and production has expanded at a phenomenal rate. French-fried and mashed or whipped potatoes are used most frequently but the variety available includes boiled, scalloped, au gratin, stuff-baked, rissole, hash brown, potato cakes, and others. Military specifications (7) list au gratin, mashed and oven-browned potatoes for inclusion in precooked frozen meals for in-flight food service.

Dehydrofrozen Products

A new method of food preservation, known as dehydrofreezing, was developed by the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture (44). As the name suggests, dehydrofreezing consists of a combination of dehydration and freezing. Fruits and vegetables which are suited to this process are first dehydrated to approximately half their original weight. No loss in quality results from the partial dehydration. The product is then frozen. Dehydrofreezing effects substantial savings in container, shipping, storage, and handling costs since both weight and volume are usually reduced by at least half.

Dehydrofreezing has been applied commercially to several potato products. Dehydrofrozen or "concentrated" mashed potato is prepared by first cooking, mashing, and mixing milk solids and salt with the potato. The mashed product is extruded and dehydrated in a continuous drier to a moisture content of about 12 to 15 percent. In this case, the original weight is reduced as much as 75 percent. The product is frozen, packaged, and distributed to both the institutional and retail trade. It is readily reconstituted by addition of hot water or hot milk and mixing or whipping to the desired consistency. Dehydrofrozen mashed potato flakes with a moisture content of around 12 percent have recently been introduced. This product contains no added sulfite or antioxidants (29).

Potatoes are also dehydrofrozen in piece form to around 50 percent or more weight reduction. The pieces may be dice, e.g. 3/8-inch cubes or so-called stew cuts of approximately 1 x 1 x 1/2 inch. Intermediate sizes, utilizing broken pieces from French-fry cuts or other byproduct material, are also dehydrofrozen.

Complete dehydration of large dice and pieces of potato is impractical because of heat damage incurred in removal of all moisture from the centers of the pieces and also because of the difficulty of rehydration. These problems are largely avoided when the pieces are only partially dehydrated as in the dehydrofreezing process. The large pieces are especially desirable for stews, salads, casseroles, etc.

ESTABLISHING A PROCESSING PLANT

Detailed information on setting up a plant to produce frozen potato products is beyond the scope of this publication. However, some of the more important considerations are pointed out. A "Management Handbook to Aid Emergency Expansion of Dehydration Facilities for Vegetables and Fruits" published by the U.S. Department of Agriculture (12) covers details pertaining to choice of plant site, raw material requirements and procurement, transportation facilities, costs, organization and management services, training of operating personnel, and related topics. Much of this information applies to establishment and operation of a frozen-products plant. A suggested flow diagram is shown in figure 23.

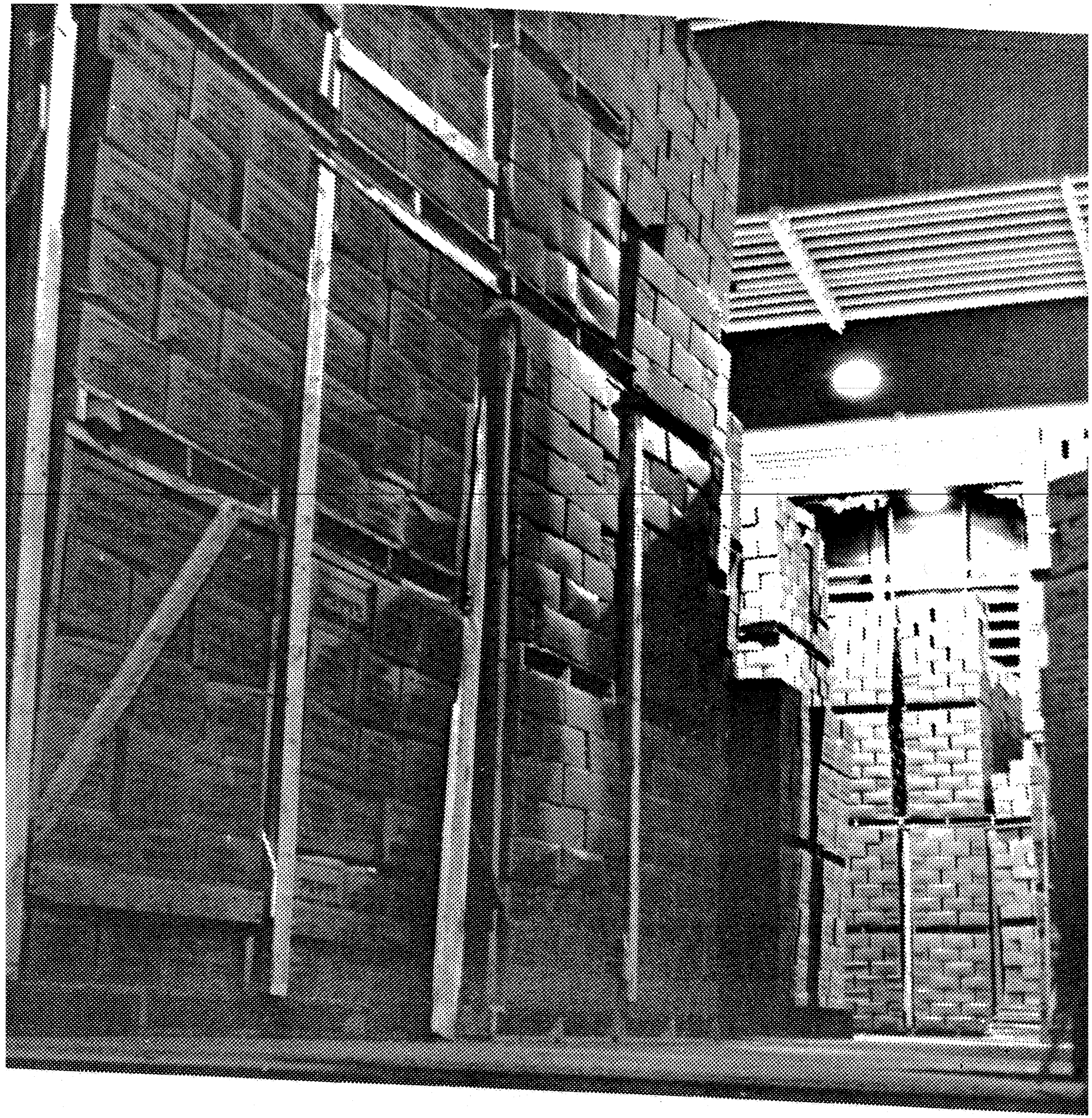


Figure 22.--Storage room for frozen products.

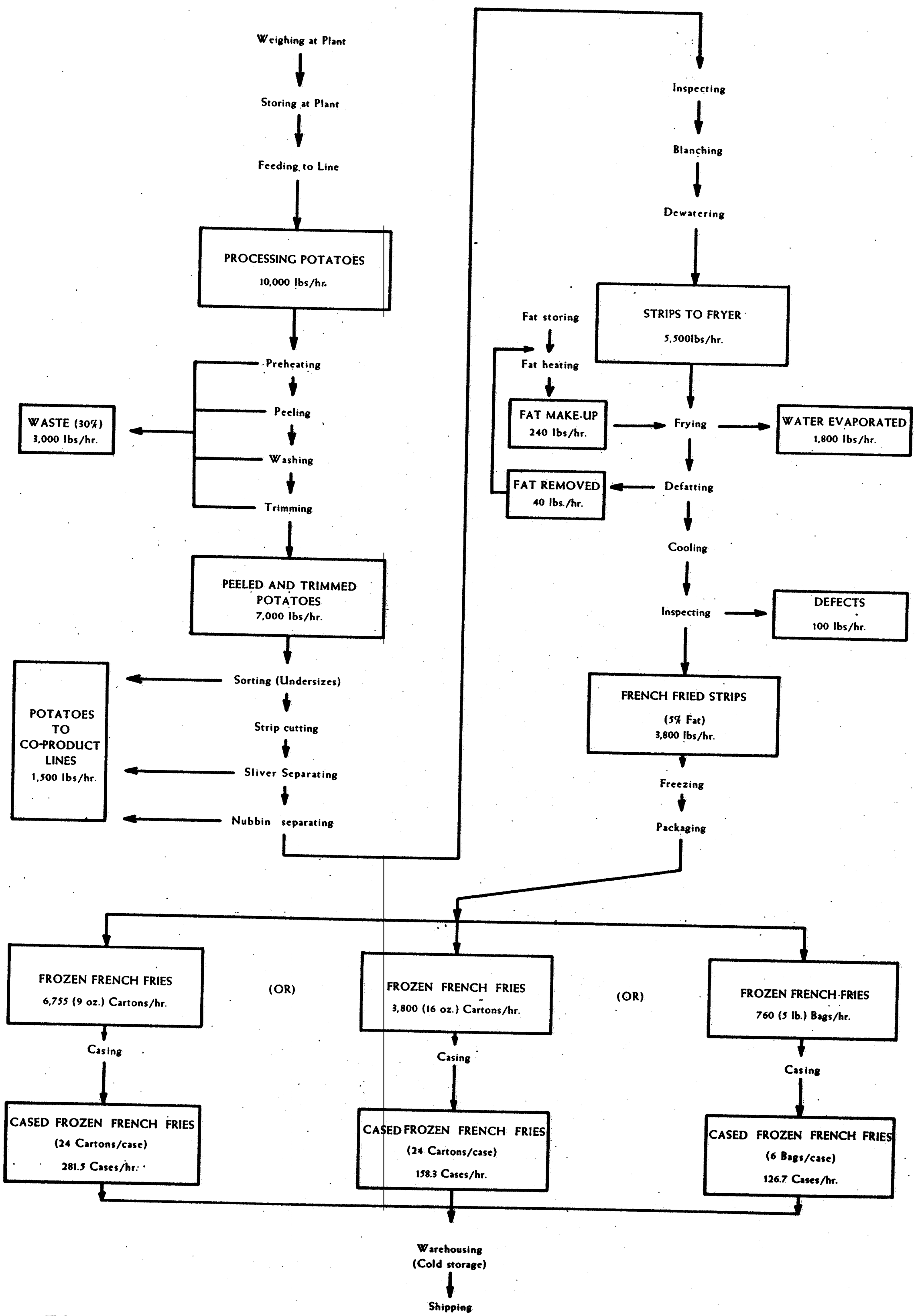


Figure 23.--Proposed flow sheet and material balance for frozen French-fried potatoes.

Sawyer (38) summarized some of the key questions that need to be answered by the prospective processor. These include:

(1) Can the growers in the selected area consistently grow the variety and quality of potato required for processing? What is the range of solids content? Will the potatoes condition satisfactorily?

(2) Are the growers taking full advantage of research and extension efforts to improve their cultural and handling practices?

(3) What proportion of the total production in the area will go to the new plant and to what extent will the processor be able to select his raw material?

(4) To what extent has processing already been established and integrated with the potato industry in the area?

(5) Are growers organized? What is their attitude toward processing and in contracting potatoes for this purpose?

(6) What are the comparative costs of growing potatoes in competing areas?

(7) Can processing and fresh marketing be integrated effectively to maximize returns from the crop?

(8) Are storage facilities adequate and sufficiently modern to meet the processor's requirements? Can sprout inhibitors be applied in existing storage facilities?

(9) How much will it cost to build the plant and how much additional capital will be required for operation?

(10) Can distribution outlets be readily established for marketing the particular brand of product to be processed?

(11) Will disposal of liquid and solid wastes from the plant create a problem?

The feasibility of processing potatoes into frozen and dehydrated products in California was investigated by Tinley and Deloach (48). Processors must be very discriminating in their choice of location. Availability of a constant supply of suitable raw material must be assured. Total solids content has major importance because it influences both yield and quality. Climatic and cultural factors, as well as variety markedly influence solids content. Areas such as the Pacific Northwest, Colorado, Red River Valley, Maine and other northern states that have clear sunny days with cool nights have advantages in being able to produce potatoes of higher solids than those with relatively high day and night temperatures. Much can be done, however, in selecting varieties and adopting cultural practices which favor high-solids potatoes in any given area.

Cost of producing potatoes in a given area in comparison with that in competing areas must be carefully considered in conjunction with quality and uniformity of raw material. In locating the plant, accessibility and convenience of facilities for shipment and distribution of the processed product must be considered.

A processor is usually reluctant to establish his plant in an area where his requirements take a major part of the crop produced. The volume produced should be sufficiently large to enable the processor to select raw material in quantities sufficient for the entire season. As an alternative, he may contract for supplies or produce his own if land is available. He must carefully appraise the long-term production capabilities of the area.

It may be necessary at times to ship potatoes from producing areas other than the one in which the processing plant is located. However, if the processor must depend to any large extent upon potatoes grown more than a hundred miles distant, costs may prove prohibitive. Freight advantages in shipping products must of course be considered.

It is essential that a plant be capable of operation at least nine months of the year and preferably longer. This means that potatoes must be available from storage for a number of months. Storages must have adequate capacity with provision for control of temperature and humidity. Increasing use of sprout inhibitors makes it advisable that storages permit application of sprout inhibitors through the ventilating or air circulating system.

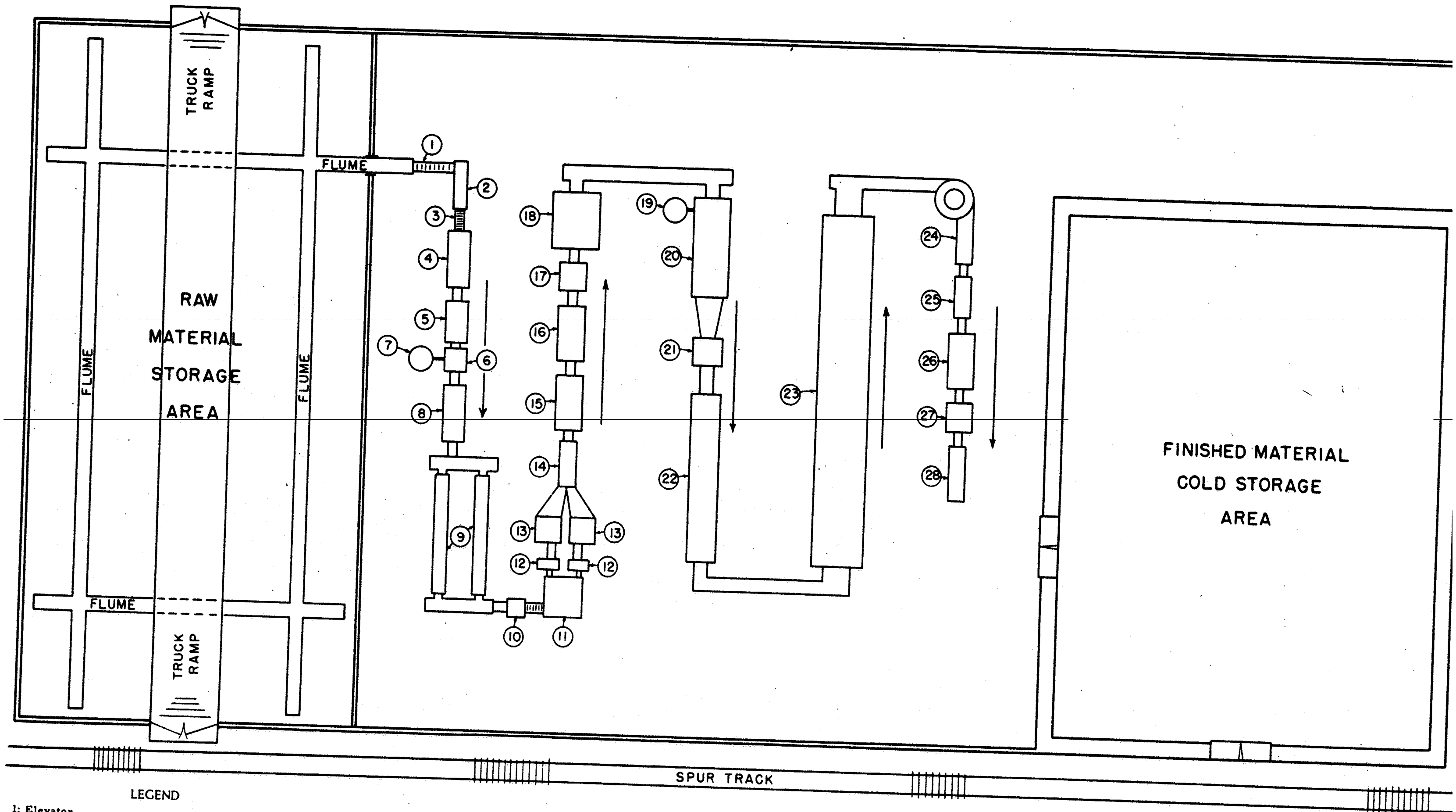
Careful planning and management are needed to assure availability of suitable raw material each day of plant operation. To provide a constant flow of raw material into the plant it may be necessary to construct an adjacent building for storage and conditioning. It should be sufficiently large to hold at least a two-week supply and preferably more.

The prospective manufacturer should have in mind a well-integrated process. Slivers, short pieces and small tubers will constitute a loss unless provision is made for other products in which raw material unsuited for French fries can be utilized. In some localities, it may be possible to divert small potatoes and waste to a nearby dehydration or starch plant. In addition to manufacture of frozen co-products, consideration can also be given to the ultimate expansion to include other types of potato processing such as manufacture of dehydrated products.

Complete building and equipment costs for a plant processing 100 to 200 tons of potatoes per day can be expected to range from over a half million to a million dollars or even more, depending on design, equipment, and number of products contemplated. Investment economies may, of course, be effected in various ways such as leasing or acquisition of existing buildings and purchase of used equipment. The prospective processor must have, in addition to funds sufficient for the fixed investment, adequate capital or credit for operating expenses, labor, purchase of raw material, financing of warehoused stock, and other contingencies. Total capital and credit requirements may therefore range from well over a million to two million dollars.

Outlets must be established for distribution and marketing the products. This usually requires large expenditures for advertising and promoting a new brand. A tie-in with a well-established brand or marketing organization to achieve an economically satisfactory level of sales may be advisable.

Waste disposal problems are becoming increasingly serious, particularly in areas where processing has undergone considerable expansion. Common practice has been to dump processing wastes into a nearby stream, but processors are subject to regulations designed to prevent pollution of streams. Coarse waste particles can usually be screened out and disposed of as cattle feed. However, dissolved solids and finer particles which do not readily settle out pose much greater difficulties either for recovery of byproducts or for reduction of biological oxygen demand to a point sufficiently low to permit disposal in a stream



SUGGESTED FLOOR PLAN FOR
FROZEN FRENCH FRIED POTATO PLANT

LEGEND

1: Elevator
2: Sorting belt
3: Elevator
4: Washer
5: Preheater
6: Lye peeler
7: Lye make-up tank
8: Washer
9: Trimming tables
10: Size grader
11: Surge tank
12: Slicers
13: Eliminators
14: Inspection belt
15: First blancher
16: Second blancher
17: Dewatering screen
18: Pre-dryer
19: Fat make-up tank
20: Fryer
21: Defatter
22: Cooling belt
23: Freezing tunnel
24: Carton filling machine
25: Check weighing machine
26: Carton closing machine
27: Overwrapping machine
28: Case closing & sealing machine

Figure 24.--Suggested floor plan for frozen French-fried potato plant.

or in a city sewage disposal system. Liquid wastes may be run into lagoons in some instances where sufficient land is available and odor nuisances are not objectionable.

PLANT OPERATION

The minimum-size plant advisable for the production of frozen French fried potatoes is one designed to process not less than 10,000 pounds of raw, field-run potatoes per hour. This capacity is based on the use of standard commercially available equipment necessary to carry out the major unit operations. Larger plants may use either larger equipment, within limits, or multiples of standard-sized units as may be deemed advisable. Initial capital investment, labor and other costs, however, are expected to be higher for a small plant.

Flow Plan

The flow-sheet and material balance shown in figure 23 is predicated on the use of potatoes containing 20 percent solids. The quantities shown in the boxes are averages from values published in the literature and other sources. Equipment manufacturers were consulted regarding the capacities of various production units. This information is summarized as follows:

Peeling and Trimming Losses

The yield of French-fry cuts is governed by peeling, trimming and cutting losses. These losses will vary with the size, condition, and grade of potatoes used, the peeling method employed, and other factors. Peeling losses usually range from 10 to 30 percent. Additional trimming losses, ranging from 5 to 15 percent, can be expected. An overall peeling and trimming loss of 30 percent by weight of raw potatoes is assumed to be a fair average.

Potatoes to Co-Product Lines

The weight of material diverted to the co-product lines is largely dependent upon the size of the tubers. Field-run potatoes containing a high percentage of small sizes will incur heavy peeling and trimming losses. Small potatoes will also produce a higher proportion of slivers and nubbins for a given yield of suitable French-fry cuts than will large tubers. Removal of slivers and nubbins may involve a loss of 10 to 20 percent, in addition to the peeling and trimming losses. The yield of raw French-fry cuts can thus be expected to fall within the range of 40 to 70 percent of the weight of potatoes processed. A yield of 55 percent is selected as the average.

Fat Make-up

The fat make-up, amounting to 5 percent, was derived in the following manner. Eight retail-size packages of frozen French fried potatoes produced by major processors in the United States were purchased on the open market. These packages contained 3/8 or 1/2-inch, straight or crinkle cut, par-fried or fully fried potato strips. The institutional-size bags contained approximately 5 pounds. The average results of the chemical analyses of samples, performed by this Laboratory, are:

	Water Percent	Fat-free solids Percent	Fat Percent
Average (rounded)	67.0	28.0	5.0
Range "	63-70	25-32	4-6

On the basis of 5 percent fat content, the calculated composition of French fried strips produced from potatoes containing 20 percent solids is: water - 67 percent, fat-free solids - 28 percent, and fat - 5 percent.

Defects

Defects consisting of discolored, scorched, or otherwise unsuitable strips, removed at the inspection line, are assumed to be 1 percent of the raw potato input.

Packaging and Casing

No distinction is made in the flow sheet between the yield of fully fried potatoes packaged for the retail trade and the par-fried potatoes packaged for the institutional trade. About 30 to 45 pounds of finished French fries may be obtained from 100 pounds of raw potatoes. On the basis of 10,000 pounds of raw potato input, this should yield an average of about 3,800 pounds of finished commodity per hour.

Sanitation

Plant sanitation must be seriously considered, and the need for utmost cleanliness, at all times, cannot be overemphasized. This applies particularly to potato co-products which normally do not go through a sterilization stage similar to the frying operation to which French fries are subjected. The products should be prepared, processed, and packaged with a minimum of delay between the various steps of production. Possible contamination from bacteria, molds, dusts, pests, rodents, condensates, and other unsanitary sources should be kept at a minimum. Rigid control should be exercised over sanitation of the plant proper, equipment, grounds, and personnel.

Building and Grounds

A minimum of three acres of land should be provided for the operation of a plant designed to process 10,000 pounds of raw potatoes per hour. The suggested plan (page 38) has a total floor area of about 48,000 square feet. This area includes sufficient space for storing a 30-day supply of raw potatoes. Space for finished product is sufficient to hold the frozen French fries produced in 30 days. No allowance is made for storage or processing of material going to co-product lines.

The arrangement of the equipment is suggestive only and the lay-out is intended primarily to show the various stages in the production of frozen French fried potatoes. Other arrangements are possible without seriously affecting plant operations.

Sufficient floor area is allowed for offices, laboratory, cafeteria, men's showers and ladies' restrooms, boiler, shop, and refrigeration equipment, with some room to spare for the storage of miscellaneous supplies.

It is assumed that the building will be provided with the necessary utilities, such as industrial lighting and power, sewer lines and floor drains.

ACKNOWLEDGMENTS

Frontispiece: Courtesy of Lamb-Weston, Inc., American Falls, Idaho

Figures 1, 19, 23, 24: Prepared by Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Albany, California.

Figures 2, 4, 12, 15, 18, 22: Courtesy of J. R. Simplot Co., Caldwell, Idaho.

Figure 3: Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture, Washington, D. C.

Figure 5: Courtesy of Butterfield Foods, Inc., Muncie, Indiana, and FMC Corporation.

Figure 6: Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, New Orleans, Louisiana. Courtesy of Food Industries.

Figures 7, 13: Courtesy of Western Idaho Potato Growers, Inc., Nampa, Idaho, and Christian Manufacturing Engineers.

Figures 8, 20: Courtesy of Birds Eye Division, General Foods Corp., Maribou, Maine and Food Engineering.

Figure 9: Courtesy of J. R. Simplot Co., Caldwell, Idaho, and Magnuson Engineers, Inc.

Figure 10: Courtesy of Idaho Frozen Foods, Inc., Twin Falls, Idaho, and Christian Manufacturing Engineers.

Figure 11: Courtesy of Lamb-Weston, Inc., American Falls, Idaho, and Heat and Control, Inc.

Figure 14: Courtesy of Western Idaho Potato Growers, Inc., Nampa, Idaho, and Lewis Refrigeration Co.

Figures 16, 17: Courtesy of Idaho Potato Processors, Inc., Burley, Idaho, and American Box Corp.

Figure 21: Courtesy of Ore-Ida Potato Products, Inc., Ontario, Oregon, and American Box Corp.

LITERATURE CITED

1. Adams, H. W., Hickey, F. D., and Willard, M. J., Jr.
   1960. Lye-Pressure Steam Peeling of Potatoes and Other Products. Food Technol. 14(1): 1-3.
2. Alexander, L. M., Schopmeyer, G. E., and Anderson, R. B.
   1949. Potato Storage and Quality of French Fries. I. Katahdin. Amer. Potato J. 26(12): 439-445.
3. Anon.
   1954. From Specialty to Staple in Record Time. Quick Frozen Foods 16(12): 42-43, 114-116.
4. Anon.
   1955. Potato Puff Formula. Food Engin. 27(10): 194.
5. Anon.
   1954. United States Standards for Grades of Frozen French Fried Potatoes. Federal Register (19 F.R. 6723).
6. Anon.
   1956. How to Improve French Fried Potato Quality. Institutional Feed. and Housing 7(3): 42-43.
7. Anon.
   1956. Meals, Pre-Cooked Frozen. Military Specification MIL-M-13966A, Quartermaster Corps, U. S. Army.
8. Anon.
   1957. Creates Frozen Coproducts. Food Engin. 29(2): 94-95.
9. Anon.
   1957. Automated French Fries. Mod. Packaging 30(10): 134-135.