Manufacture, Storage and Transport of Frozen French Fries

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Importance of Frozen Potato Products

Frozen potato products claim a growing percentage of the world's potato production. Demand is steadily increasing in all regions but especially in Asian Pacific countries. U.S. export of frozen fries approached $350 million in 2001 (USDA/FAS) and has increased substantially since. The Pacific Northwest accounts for approximately 70 percent of U.S. potato exports.

The United States currently processes 60% of all potatoes used for human consumption. In 2000, frozen fries consumed 28.6% of U.S. potatoes and other frozen products accounted for an additional 5.2%.

Types of Frozen Products

Almost 85% of U.S. frozen processed potatoes are marketed as frozen french fries. The remaining 15%, mostly byproducts of french fry processing, are processed into hash browns, so-called "tater tots" and similar "preformed" products. These are made mainly of french fry trimmings and are formed into various products on what is known as the "patty line".

Desirable Characteristics of Processing Potato Varieties

Because long fries are preferred by the industry, virtually all frozen processing varieties produce long to oblong tubers. Most are also russet-skinned (the corky brown skin found on "bakers" in the grocery retail trade). Russet skins are typically thick and resistant to injury during harvest and handling, traits which discourage tuber decay and dehydration in storage. Shepody, a long white, is a notable exception. Shepody is more prone to harvester injury and storage complications and is therefore often processed directly from the field. However, with suitable care in harvest and careful storage, it can be successfully stored and processed up to 6 months.

Potato varieties vary in appearance, season of maturity, internal composition, yield and tuber quality, pest and disease resistance and adaptability. Early-maturing varieties typically have short storage dormancy and are usually processed at harvest or shortly afterward. Leading frozen processing varieties are relatively late maturing, have long storage dormancies and can be processed for several months. Russet Burbank is

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[2]Information from the "It's French Fries!" website *(http://www.tx7.com//fries*) and the U.S. Potato Board ("All About Fries", on CD) was very useful in the preparation of this summary.

widely considered to be the most storable of all processing varieties. It is relatively resistant to decay, dehydration and other post-harvest problems and tends to maintain acceptable fry color later than most varieties.

The newer processing varieties Ranger Russet and Umatilla Russet have lower reducing sugars and higher solids (starch) than Russet Burbank, especially at harvest. Both produce lighter-colored fries with somewhat better texture than Russet Burbank from short-term storage but Russet Burbank maintains acceptable fry longer into the storage season than either. While Ranger will process satisfactorily through March and Umatilla through April, Russet Burbank will often produce satisfactory fries in June or even later.

Russet Burbank is more susceptible to physiological disorders such as Hollow Heart, Internal Brown Spot, Sugar-ends and Stem-end Discoloration caused from heat, moisture and other environmental stresses during the growing season than other leading varieties. These disorders severely reduce processing quality, especially for frozen fries which must be uniform in appearance. Sugar-ends, for example, cause "dark-end" fries which are unacceptable to the industry and must be discarded. Some fields of Russet Burbank grown in the northcentral U.S. in 2001 produced 80 to 100% dark-end fries and were not usable for french fry processing.

Most varieties including Shepody, Ranger Russet and Umatilla Russet are less susceptible to physiological disorders than Russet Burbank and typically process more dependably during short-term storage. However, Russet Burbank is often preferred for long-term storage despite heightened susceptibility to physiological problems.

Frozen processing varieties are preferably high in starch (high dry matter, high specific gravity) and low in reducing sugars. Approximately 80% of tuber dry matter is starch. High dry matter potatoes are frequently thought of as "dry" for most culinary purposes whereas low dry matter varieties are considered "moist". As shown in Table 1, tubers with less than about 18% dry matter are seldom used for frozen processing or chips because of poor texture.

Approximately two-thirds of the water in french fries is replaced by oil during frying. Therefore, varieties with high water/low dry matter produce oily, soggy french fries. Because more water must be removed during processing, product recovery is lower and the cost of fry production is higher making such varieties unprofitable in most situations. New varieties such as Umatilla Russet and Wallowa Russet tend to have higher starch and lower sugar concentrations than Russet Burbank and therefore produce fries with better texture and lighter color through the first few months of storage.

Effects of Crop Production Inputs on Processing Quality

Potatoes can be processed either directly from the field (25% of U.S. production for frozen processing) or from storage (75%). The two crops are handled somewhat differently. Crops processed from the field are often harvested early when vines are still green and tubers are still actively growing. Skins are thin and significant mechanical injury can occur during harvest. Such potatoes would not store well because of excess decay and potentially severe moisture loss.

Late harvest favors maximum yields and high starch content. Consequently, potatoes intended for out-of-storage processing are typically harvested as late as possible but before severe soil freezing. Potato tubers can experience freezing injury at approximately 28^{o}F/-2.2^{o}C. Frozen tissues invariably die and can lead to serious losses in storage if decay pockets are allowed to expand. Tuber sugar concentrations tend to increase with decreasing soil/tuber temperature below about 45^{o}F (7.2^{o}C). As noted, increasing reducing sugar levels translate into increasingly dark fry color. Care should be taken to avoid either chilled or frozen potatoes.

Stored potatoes are usually harvested at least two and preferably three weeks after vine kill to allow for skin thickening and "maturation." Vines are typically killed with contact herbicides but mechanical beating and propane flaming are practiced in some regions. Crops in some producing areas may be killed by early frosts.

Vine killing not only "matures" tubers but also aids harvest by reducing vine biomass. Dead vines become dry and brittle and are easily removed from the tubers. Stolons (long, root-like, modified underground stems which connect tubers to the plant) also die in response to vine death and separate easily from the tubers during harvest.

Soil fertility affects not only yield and tuber grade but also maturity and processing quality. Nitrogen rates are especially important. High tissue nitrogen content late in the season delays tuber set and maturation and, therefore, reduces tuber starch or dry matter content. Fertilizer recommendations vary by region and should always be based on local recommendations and intended harvest date. In most instances fertilizers should not be applied within 6 weeks of harvest for stored potatoes. Early-harvest crops obviously require less nitrogen than late crops but may benefit from fertilizer applications as late as 30 days preharvest.

Harvest

Storage potatoes should be harvested moist but not wet and cool but not cold. The ideal soil moisture is about 60% of available and the best temperature range is between 45^{o}F (7.2^{o}C) and about 60^{o}F (15.5^{o}C). Storage potatoes should always be harvested no earlier than two weeks after vine death to assure good skin set and resistance to harvester injury.

Wet, muddy potatoes are difficult to dry in storage. Furthermore, decay bacteria are mostly anaerobic and thrive in free moisture on tuber skins. They easily invade lenticels (natural pores in tuber skins) under such conditions and begin actively digesting tuber tissues. The danger is further increased by the fact that tubers coated with moisture or mud are especially vulnerable because tuber respiration ("breathing") is greatly inhibited due to lack of oxygen and tissues begin to die. Placing wet, muddy potatoes in storage should be avoided if at all possible.

Temperature extremes should also be avoided during harvest. Tubers with pulp (internal) temperatures below 45^{o}F

(7.2^oC) are prone to mechanical injury and a condition known as “shatter bruise” in which portions of tubers exposed to direct harvester impact actually shatter. Shatter bruise is aggravated by cold temperature, high tuber turgidity (high moisture content) and skin immaturity. Interestingly, “blackspot bruise” which causes black or bluish discoloration in tissues is favored by warm temperatures and relatively low tuber moisture content. Varieties differ markedly in susceptibility to both types of bruising.

Hot tubers are difficult to cool in storage and are susceptible to a number of problems including early decay and severe moisture loss. For these and all the above reasons, tubers should always be harvested under moderate moisture and temperature regimes.

Storage

Potato storage is designed to control tuber respiration and its byproducts and prevent greening, sprouting, dehydration and decay. Storage is also intended to minimize reducing sugar concentrations in order to favor light colored fries (Figure 1).

Respiration is roughly defined as:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{Energy (Heat)}$$

Respiration requires oxygen to break down reducing sugars ($C_6H_{12}O_6$, or glucose and fructose) to liberate energy (and heat), carbon dioxide and water. Skillful storage involves supplying sufficient oxygen to maintain respiration while removing respiratory products, carbon dioxide, water and heat, either of which can reduce tuber quality and/or cause serious decay.

Potatoes form chlorophyll and turn green only when exposed to light. Therefore, greening is controlled by keeping storages dark insofar as possible. Greening is usually accompanied by increasing levels of glycoalkaloids, mostly solanine, which can be poisonous at high concentrations or when consumed in large amounts. Practically speaking, glycoalkaloids are not a serious consideration to humans at normal levels of consumption. Many other crops such as tomato and lima bean also contain toxic alkaloids which could be harmful if consumed to great excess.

Most processing potatoes are stored in bulk piles in “common” or “ambient” storages that lack refrigeration and depend solely on skillful movement of ambient air for controlling temperature and humidity. A small percentage of the crop is held in refrigerated facilities for late processing into the following summer.

Common storage relies on “common sense” and attention to detail. Success is also highly affected by the condition of the crop going into storage. The utmost care should be taken to place only clean, healthy, mature tubers of the correct moisture content and temperature into well-prepared storage facilities. Varieties differ in storability. Russet Burbank stores better than all other leading processing varieties.

During the first two weeks of storage, potatoes are typically held at about 55^oF (12.8^oC) and high (90-95% relative) humidity to favor suberizing or wound-healing. Following the healing period, temperatures are slowly dropped (0.5°F/0.3°C per day) until the final holding temperature is reached. Because both sugar concentrations and chip color increase with declining storage temperatures, most potatoes for frozen french fry processing are stored relatively warm at approximately 45-50°F or 7.2-10.0°C (Table 3) depending on the variety. Some varieties can be stored slightly cooler without sugar buildup and subsequent darkening of fries while others should be stored slightly warmer.

Common or ambient storages depend on air movement for cooling and maintaining tuber health. Most modern structures are designed to uniformly and consistently deliver up to 20 cfm (cubic feet per minute) per ton of potatoes from the bottom upward through the top of the pile (8-20 ft/2.4–6.1m); many older structures have much less ventilating capacity. Good air movement is especially important early in the season for removing field heat and/or excess moisture. The presence of disease or field frost also calls for high rates of air movement to cool and dry the potatoes.

Air can be moved either in ventilation (air in/air out) or recirculation (movement only within the storage) mode. Storages are cooled by ventilating; that is, moving in cool outside air (mostly at night) and simultaneously exhausting warm storage air. Care must be taken to avoid chilling or freezing potatoes near ventilation inlets. For that reason, external and internal air are typically mixed in a proportioning chamber or "plenum" to provide the proper temperature prior to contact with tubers. Because air movement can remove tuber moisture, especially early before wounds have healed and skins have fully thickened, humidity is held at 90-95% relative throughout the storage season (Table 3) unless the crop is threatened by excess moisture or disease. Severe disease, such as late blight followed by bacterial decay, can completely destroy the entire crop unless extreme measures are taken. Therefore, every attempt should be made to cool and dry crops at risk from decay. High relative humidity is also not recommended for poorly insulated storages prone to condensation on roof and walls.

After tubers have reached the final storage temperature, fans may be operated only intermittently (as needed) in either circulation or ventilation mode. After the final storage temperature is reached, ventilation may be needed only to provide adequate oxygen, prevent excess carbon dioxide and to equalize temperatures throughout the storage.

Most modern potato storages are fully instrumented and automated. However, facilities should be inspected daily to assure that all is well and the crop is sound. Odors suggesting decay and/or ammonia should be immediately investigated. Infrared heat-detecting devices are useful in locating "hotspots" caused by disease organisms. Diseased areas can sometimes be corrected by operating fans continuously, reducing relative humidity insofar as possible and forcing more air through the affected area(s) by diverting flow from other sections. Obviously, severely blighted or otherwise compromised potatoes should never be placed in long-term storage.

Because all potato varieties have a finite dormancy, some method of sprout control is needed for crops stored more than two or three months. Two chemical sprout inhibitors are in common use. Maleic hydrazide (various formulations and trade names) is applied to actively growing plants in the field when tubers are at least as large as golf balls. The active component is translocated to all portions of the plant, but preferentially to tubers. Potatoes treated with maleic hydrazide will not sprout during a normal cool storage season (<45^{o}F or 7.2^{o}C) but maleic hydrazide does not perform well under warm storage conditions. It is much less effective than the more common CIPC or "sprout nip" at temperatures approaching 50^{o}F (10^{o}C).

The use of maleic hydrazide requires that growers decide well ahead of harvest which fields will be stored and which will be marketed directly from the field. Since marketing plans frequently change, maleic hydrazide applications are sometimes wasted on non-stored potatoes. Maleic hydrazide is the material of choice for small acreage growers without modern storage facilities or access to commercial application of CIPC.

Sprout Nip (CIPC or Chloropropham in various formulations) is labeled for custom application through the storage ventilation system. CIPC is quite effective and can be commercially applied any time after the "curing period" but before sprouting begins. Since CIPC stops cell division, too early application can interfere with wound healing. Seed potatoes should never be stored in buildings treated with CIPC the preceding year.

Processing

Raw product plays an important role in processing, fry yield and finished quality. Every effort should be made to obtain potatoes with few external and internal defects and of the proper starch and sugar content. Tuber malformations and mechanical injury can lead to excessive peel and trim loss (Table 2). Internal defects such as hollow heart (HH), brown center (BC), sugar ends (SE), internal brown spot (IBS), stem end discoloration SED) and net necrosis (NN) caused by the potato leafroll virus (PLRV) can also drastically reduce usable product yield which seldom exceeds 50% at best (Table 2). Low starch can lead to poor texture and excess oiliness while high reducing sugars cause undesirably dark fry color. Established processing varieties such as Russet Burbank, Umatilla Russet and Ranger Russet typically provide both good texture and good fry color (Figure 1).

USDA grade standards for processing potatoes are available online at http://www.ams.usda.gov/standards/vppot.pdf. Most major processing companies impose grade standards more strict than the USDA version(s). In addition to enforcing grade standards, most also offer financial incentives for factors such as low mechanical injury and bruising, high starch content, low sugar-ends and other quality characteristics they deem especially important to their operation.

Trimming and Peeling – Trimming and peeling potatoes reduces overall weight by approximately 22% (Table 2). Potatoes are peeled in a number of ways but steam peeling is the preferred method. Steam peeling involves placing the potatoes in a hot, pressurized tank for a specified time after which the pressure is rapidly released. Skins are cooked and effectively loosened. Skin remnants are removed by pressurized water. Peels may be disposed of as cattle feed, decomposed to form methane or eventually returned to fields by various methods including irrigation.

Tuber Inspection – Peeled potatoes are inspected on a conveyor line and questionable tubers (decay, excessive bruising, off-shapes, net necrosis) are discarded. Much of the sorting is done by hand but machines are becoming increasingly more common in an effort to reduce labor costs.

Cutting – Cutting methods vary widely among processors and depend on the type of cut ("straight", "waffle", "crinkle") desired. Potatoes for straight-cuts typically are forced through pyramid-shaped cutters by water pressure to form individual "strips" with practically parallel sides. Such cutters are frequently referred to as "water knives". Waffle, crinkle, spiral and other specialty cuts use somewhat slower methods.

Strips may be further identified by the approximate dimensions of the cross-section. Typical sizes include the following (converted to centimeters from inches):
0.64 x 0.64
0.95 x 0.95
1.27 x 0.64
1.9 x 0.95
Strips either straight cut or crinkle cut with a cross-sectional area predominantly less than that of a square measuring 0.95 x 0.95 cm (3/8 x 3/8 in) are often referred to as "Shoestrings".

The industry prefers long fries of approximately 5–8 cm in length and will pay a premium for such. The USDA has established the following guidelines for describing fry length:

1. Extra long – eighty (80) percent or more of the fries are 2 inches (~5.0 cm) in length or longer and 30 percent are more than 3 inches (~7.6 cm) or longer.
2. Long – Seventy (70) percent or more are 2 inches long or longer and 15% or more are 3 inches or longer.
3. Medium – Fifty (50) percent or more are 2 inches in length or longer
4. Short – Less than 50 percent are 2 inches long or longer.

The USDA has also developed strict standards for both cooked color and physical grade of frozen fries. Summary details and an official USDA french fry "Color Chart" are available online at http://www.tx7.com/fries. As with physical tuber grades, Most companies impose higher frozen fry standards than required by the USDA.

"Fry" Inspection – After cutting, strips are placed on an inspection belt for further sorting. Fragments and "shorts" are typically removed by hand, but companies are rapidly replacing people with machines at every opportunity. Fries with dark or blackened areas can be automatically removed by machines at up to 1,000 strips per second. Secondary machines (sophisticated optical lasers) remove black or discolored portions of strips to salvage usable bits for pre-formed products such as hash browns and "tater tots".

Blanching – Hotwater blanching reduces total raw product weight an additional 5-10% (Table 2). Defect-free strips are blanched in order to kill enzymes and partially cook the tissues. Blanching is generally accomplished by running strips through a hot water bath on a conveyor. The duration and temperature of blanching are adjusted as needed to remove excess sugars and otherwise standardize the strips to produce a light, uniform golden brown color when fried (Figure 1). If necessary, sugar concentrations can be adjusted upward as needed after blanching by either running the strips through a tank containing a sugar solution (often based on corn syrup) or spraying the sugar onto the strips on a conveyor. Sugar can be added to darken fry color to whatever level preferred. According to U.S. government standards for frozen french fries, blanching and/or parfrying may include the addition of any ingredient permissible under the Federal Food, Drug and Cosmetic Act.

Drying – After blanching, and any related treatments, strips are partially dried with hot air. Drying time and temperature are varied as needed to maximize quality of the frozen pack and optimize quality for the intended cooking method. Strips intended for deep-frying are dried to approximately 70-75% moisture; strips intended for oven cooking are dried to about 65-70%; microwaving strips are dried to 55-60% moisture. These percentages are based on the fact that frying removes more water than baking which, in turn, removes more than microwaving. Adjusting moisture levels prior to cooking helps assure that each cooking method produces fries of approximately equal texture and dryness.

Par-frying – Par-frying reduces raw product weight an additional 16% despite7-8% oil absorption (Table 2). Dried strips are partially fried or par-fried for about 90 seconds in oil somewhat hotter than normal frying oil. Par frying assures that all enzyme activity is terminated and tissues are stablilized for long-term frozen storage as needed. All frozen fries are par-fried at the processing plant and final-fried just before serving.

Freezing – Par-fried strips are individually quick frozen at about –10^{o} to –20^{o}F (-23.3 to -28^{o}C) on conveyor lines to stabilize the tissues in preparation for packaging and long-term storage. At that temperature ice crystals remain small so that cells are not ruptured. Individually quick frozen fries do not stick together. So-called preformed products such as tater tots are also frozen as individual units.

The entire trimming, peeling, processing and freezing process reduces total product weight by approximately 50% (Table 2). Exact percentages will vary according to tuber starch content and the size of strips. Low gravity (low solids, low starch) potatoes absorb more oil but still lose more moisture and total weight than hi-starch potatoes. Smaller strips tend to lose more weight because of increased surface area which leads to increased evaporation.

Packaging – Frozen parfries are packaged in vapor-proof bags of variable size and shape depending on the intended customer(s) and shipped in cardboard boxes (cases) holding up to 50 lbs (18.6 kg) each.

Frozen Product Storage

Parfries can be held long-term in a frozen state (Table 3). Enzyme systems are destroyed during parfrying and the tissues therefore remain basically stable until thawed. Smaller cuts can be stored up to 12 months and larger cuts up to 18 or 24 months at about 0^oF (-18^oC) without serious loss of quality due to dehydration. However, processors prefer to store only 6-9 months. Parfries should remain frozen, preferably at about 0^oF (-18^oC), until shortly before final cooking and consumption.

Due to the extremely low temperatures involved and vapor-proof packaging, humidity is not a critical factor in storage of parfries. However, parfries eventually lose moisture and quality even when frozen and cannot be stored indefinitely.

Frozen fries are almost as fragile as eggs and should be handled accordingly. Damaged boxes almost certainly indicate a high percentage of broken fries. According to the U.S. Potato Board, dropping boxes twice from a height of 1 meter (3 ft.) reduces the proportion of fries over 5 cm (3 in.) long from about 40% to 20%.

Standard boxes (cases) of frozen fries should not be stacked more than 6 high either in storage or shipping containers. Higher stacks tend to crush boxes near the bottom and cause breakage of fries.

Boxes should never be piled directly on the floor or flush against walls or ceilings for extended periods. They should be carefully stacked on pallets to promote air circulation beneath. Further, a gap of at least 5 cm. (2 in.) should be maintained between boxes and walls or ceilings not only to avoid drawing heat from the outside but also to promote good air movement.

Transportation

Parfries should be held at about 0^oF (-18^oC) and kept frozen until shortly before final cooking and consumption. Therefore, every attempt should be made to use reliable refrigeration facilities at all stages of storage and transport. Parfries which have been thawed and refrozen develop musty, stale flavor and odors and show poor texture and darker color when fried.

As noted above, parfries are typically packaged in plastic bags of various sizes and placed in cardboard boxes holding up to 50 lbs (about 18.6 kg) each. Cardboard boxes are stacked on pallets and wrapped for stability before being placed in trucks or shipping containers. As suggested above, processors prefer that total transportation and storage time combined not exceed 6-9 months for maximum quality.

Preparation for Final Cooking and Consumption

Frozen “parfries” can be prepared for table use in numerous ways such as microwaving, oven cooking and deep-frying. For optimum flavor, texture and temperature, fries should be prepared within 5 minutes of consumption.

As mentioned earlier, high solids (high starch, high dry matter) potatoes are desirable for frozen fry processing for a number of factors. Dry matter content also affects final cooking. Compared to high solids fries, low solids (high moisture) fries:

- Take longer to prepare,
- Use more oil,
- Break down fry oil faster; and
- Yield up to 15% fewer servings

Long fries not only look better than short fries but also absorb less oil, have better texture and break down fry oil more slowly.

Oven Cooking – Frozen parfries in a suitable container are placed in an oven preheated to approximately 218^{o}C (425^{o}F) and allowed to remain for about 15 minutes or until the interior portions of the larger pieces are totally cooked.

Deep Fat Cooking – Parfries are placed in a suitable rack or basket and immersed in clean suitable oil or fat at a temperature of about 185^{o}C for about 90 seconds or until bubbling (due primarily to water loss) subsides and the larger pieces are properly cooked.

Quality Evaluation and Problems in Freezing and Storage

The United States Department of Agriculture, Agricultural Marketing Service provides 16 pages of precise grade and quality standards for frozen french fries online at http://www.ams.usda.gov/standards/fzpotfrf.pdf. A handy fry color rating chart can be downloaded from http://www.tx7.com/fries/images/standrd2.jpg. USDA Grade standards for hash browns are available at http://www.ams.usda.gov/standards/fzpothab.pdf. Most processing companies and fast food chains maintain higher standards than required by the USDA.

Table 1. Relationship Between Tuber Dry Matter Content and Optimum Use[1]

Specific Gravity	% Dry Matter	Texture	Typical Uses
Below 1.060 (Very Low)	Below 16.2	Very soggy	Pan frying, salads, canning
1.060 - 1.069 (Low)	16.2 – 18.1	Soggy	Pan frying, salads, boiling, canning
1.070 – 1.079 (Medium)	18.2 – 20.2	Waxy	Boiling, mashing; fair to good for chip processing and canning
1.080 – 1.089 (High)	20.3 – 22.3	Mealy, dry	Baking, chips, frozen processing; some cultivars slough when boiled
Above 1.089 (Very High)	Above 22.3	Very mealy or dry	Baking, frozen fries, chips; tendency to make brittle chips, slough when boiled

[1]Adapted from: Mosley, A.R. and R.W. Chase. 1993. Selecting Cultivars and Obtaining Health Seed Lots. In: Potato Health Management, APS Press, 1993. Pp. 19-27.

Table 2. Approximate Weight Losses in Various Frozen Processing Operations[1]

Processing Operation	% Wt. Loss or Gain(+)	% Total Wt. Loss
Peeling, Trimming Raw Potatoes	22	22
Hot Water Blanch	5-10	32
Par-Frying & Cooling		
Oil Absorption	+7 or 8	24
Moisture Loss	24	48
IQF Freezing	1-2	50

[1]Numbers based on potatoes with 20-21% solids (1.095 or higher specific gravity); values will be higher for low gravity potatoes.

Table 3. Recommended Storage Conditions

	Temperature, °F/°C	Storage Period, Months	Relative Humidity, %
Tuber Crop	45-50/7-10	1-10[1]	90-95
Frozen Fries			
Small Cuts	0/-18	12[2]	Vapor-Proof Pkg.
Large Cuts	0/-18	18-24[2]	Vapor-Proof Pkg.

[1]Sprout suppression required for storage beyond 2-3 months.
[2]Processors prefer to store no longer than 6-9 months.

Figure 1. Typical frozen fries after final cooking