Apples

Revised 2018

Thermal Properties

	Fresh		Dried	
	English	**Metric**	**English**	**Metric**
Moisture, %	83.93	--	31.76	--
Protein, %	0.19	--	0.93	--
Fat, %	0.36	--	0.32	--
Carbohydrate, %	15.25	--	65.89	--
Fiber, %	2.70	--	8.70	--
Ash, %	0.26	--	1.10	--
Specific Heat Above Freezing	.91 Btu/lb*°F	3.81 kJ/(kg*K)	0.61 Btu/lb*°F	2.57 kJ/(kg*K)
Specific Heat Below Freezing	.47 Btu/lb*°F	1.98 kJ/(kg*K)	0.68 Btu/lb*°F	2.84 kJ/(kg*K)
Latent Heat of Fusion	120 Btu/lb	280 kJ/kg	46 Btu/lb	106 kJ/kg

Storage Conditions

Temperature	30-32°F (-1 to 0°C), with exceptions
Relative Humidity	90% - 95%
Freezing Point	Approximately 29°F (-1.7°C)

U.S. federal grades for apples, based primarily on color requirements, but also on freedom from decay, disorders and blemishes, as well as firmness of fruit, are “U.S. Extra Fancy”, “U.S. Fancy”, and “U.S. No. 1”.

Most apples are packed into bushel cartons, usually 40 lb (18.2 kg), depending on variety, and sold by fruit count. Fruit are commonly packed on 4 to 5 soft fiberboard trays made of soft polystyrene or from recycled newspaper, and cartons are often un-vented. Venting to improve cooling velocity is important. A two-layer carton that is wider, known as the 60 x 40 pack, is becoming more common. It has the advantage of minimizing fruit handling as the cartons are placed directly onto display racks at retail.

Most apples are sold loose, although fruit are increasingly packed in polyethylene bags of 3, 5, or 10 lb (1.4, 2.3, or 4.5 kg). Consumer packages of different combinations and sizes are also becoming popular in some retail outlets. These packages reduce the time consumers spend in the produce section, and also reduce losses caused by consumer sorting and handling of individual fruit.

Most apples maintain their quality best when held between 30 and 32°F (-1.8 and 0°C), although some varieties are cold-sensitive at this lower temperature and have to be held at 38 to 40°F (3.3 to 4.4°C). Internal browning of the flesh is the most common indication of cold/chilling sensitivity. The local State Agricultural Experiment Station or other extension authorities will usually have data on what varieties in the area are cold-sensitive and ideal conditions for holding each variety.

Maintaining the proper relative humidity around stored apples is very important. Apples have approximately 84% moisture at the time of harvest, and to maintain this water content and prevent shriveling of the skin, the storage relative humidity should be 90% or higher. With good air circulation, a higher relative humidity (95 to 98%) may be maintained without mold formation.

The freezing point of apples varies considerably, but most types will not freeze until the flesh is below 29°F (-1.7°C). Freezing discolors the surface and browning can occur internally. To prevent unnecessary injury, apples should not be handled while frozen.

Storage with Other Commodities

Other temperate climate tree fruits can be stored with apples if they have the same temperature and relative humidity requirements, and if they are not sensitive to the ethylene produced by the apples. Odor from celery, cabbage, carrots, potatoes, onions, and garlic will be absorbed by apples and should therefore not be stored in the same room with apples. Also, odors from apples are readily absorbed by meat, eggs and dairy products, which should be stored in other rooms.

Apples produce ethylene gas as a natural product. Commodities sensitive to ethylene at 32°F (0°C) should not be stored with apples. Commodities that are adversely affected by ethylene at 32°F (0°C) include: asparagus, cabbage, carrots, lettuce and other salad greens, watermelons, kiwifruit, nursery stock, and some kinds of cut flowers, potted plants and florist greens. When an apple storage room and other storage rooms holding ethylene sensitive commodities open onto a common corridor, it may be necessary to continuously flush the corridor with outside air to prevent transfer of the ethylene from the apple storage room to the other rooms.

Ammonia Damage

Ammonia fumes that have escaped from refrigeration systems can cause damage to apples exposed to a low concentration for a long time or a high concentration for a short time. The first visible symptoms occur at the lenticles (dots) on the skin. Red changes to blue-black and yellow or green changes to brown. Normal skin color will be restored when the ammonia has been removed from the room, if the exposure has not been long and the concentration of ammonia has not been high. Prolonged exposure to low concentrations or short exposure to high concentrations will cause death of the tissue adjacent to the lenticles (dots). The dead tissue turns brown, becomes sunken and is likely to be infected with fungus diseases.

The human nose is very sensitive to ammonia. It detects less than 20 ppm (ul/l) ammonia in the air. 100 ppm (ul/l) ammonia is hazardous to humans exposed for 8 hours or longer. More than 8 hours is required for permanent damage to apples to occur when exposed to 500 ppm (ul/l) ammonia.

Electronic ammonia detectors should be installed in warehouses, which use ammonia as the refrigerant, if 24-hour human surveillance is not practiced.

An ammonia leak should be isolated by shutting valves and then the escaped ammonia fumes can be removed from the building by aeration and water washing of the ammonia from the air. Refrigeration coils should be deiced, because ammonia dissolved in ice will be slowly released into the room over a long period of time.

Storage Period

The good quality storage life of apples is influenced by fruit maturity when picked, delays before cold storage, storage temperature, and the presence of other foods in the room. Varieties differ widely in their inherent length of keeping. Some, such as McIntosh, ripen quite rapidly at 32°F (0°C) and therefore have a relatively short storage life. Others, such as Rome, ripen more slowly at 32°F (0°C) and therefore keep longer. Some varieties are susceptible to storage diseases and disorders and therefore have a short storage life.

Orchard culture and climate influence storage life. Less than ideal soil conditions influence the composition of apples and thus their storage life. Cool, cloudy growing seasons result in a shorter life.

Fruit size and pre-handling procedures also influence storage life. Large, over-sized fruit have a shorter life than normal ones. Rough handling shortens the expected storage period.

Variety	Potential months of storage at 32°F (0°C)	Potential months of storage in Controlled Atmosphere (CA*)
Cortland	2 to 3	4-6
Delicious	3	8-12
Empire	2 to 3	5-10
Fuji	4	8-10
Gala	2 to 3	5-6
Golden Delicious	3 to 4	8-10
Idared	3-4	7-9
Jonagold	2	5-7
Jonamac	2	3
Law Rome	3-4	7-9
Macoun	3	5-7
McIntosh	2-3	5-7

Mutsu	3-4	6-8
Spartan	3-4	6-8
Stayman	2-3	5-7

*The potential months for storage are for rapid CA and range from those obtained with standard CA to those obtained with low oxygen storage.

Pre-storage Treatment

Apples may be stored "orchard run" or packed in boxes or cartons. Some storages supply a service of treating the orchard run apples with diphenylamine for prevention of storage scald. This is done by drenching bulk bins with the storage scald inhibitor. Packed boxes or cartons should have already had some such treatment if the variety is scald susceptible.

Some varieties, such as Golden Delicious, are very subject to water loss. The fruit boxes or bulk bins may be covered with polyethylene film. These covers should not be sealed or the fruit may develop an off flavor. The tops of bins should be covered with film after field heat has been removed.

Many apples are waxed after storage and before packing for market. The wax is applied to improve the cosmetic appeal of the apples and to reduce water loss and shriveling.

Diseases, Disorders and Injuries

Diseases in stored apples are caused by fungi, which penetrate the fruit in the orchard and/or after harvest. Diseases may frequently be distinguished from disorders and injuries by the presence of fungal spores which usually develop on the surface of the fruit at the center of the lesion. Disorders develop over a period of time when the normal biological processes are changed by conditions which may be present in the orchard or in storage. Injuries are caused by a single traumatic event in the orchard or after harvest. Colored pictures of many apple diseases, disorders, and injuries have been printed in two publications. *Market Diseases of Apples, Pears, and Quinces*, Agricultural Handbook No. 376, may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. *Postharvest Disorders of Apples and Pears*, Publication 1737/E, may be obtained from Communications Branch, Agriculture Canada, Ottawa, K1A OC7, Canada.

Diseases	
Alternaria Rot	Universal, small, firm, slightly sunken spots, brown around the edges but mostly with rough black rust. At higher temperatures, spots may enlarge to brown or grayish rotted areas. Often develops by mid-season in cold storage on apples showing sun-scald, bruising or chemical injury and frequently follows storage scald, soft scald and Jonathan Spot. Rot does not spread from one fruit to another. **Control:** Careful handling and prevention of mechanical injury or storage disorders; prompt cooling and storage.
Bitter Rot	Occurs in areas east of Great Plains, especially in hot, humid districts. Appears in orchard but may also affect apples in storage and after removal. Firm and uniform brown color,

	somewhat sunken and often shows wet pink or cream-colored spores; does not spread from one fruit to another, dormant below 50°F (10°C). **Control:** No warehouse control. Orchard control involves removing old bitter rot mummified apples and spray program; cold storage at 32°F (0°C) will check, but rot resumes growth on removal.
Black Rot	East of Rocky Mountains. Brown, irregular spots, later dark brown or black, firm with scattered black pimples containing spore masses; on removal from storage rotted areas become soft and mushy. **Control:** No warehouse control. Spray program in orchard. Prevention of insect and mechanical injuries to fruit and proper storage and transit refrigeration will hold it in check.
Blotch	Middle West. Mostly on McIntosh, Maiden, Blush, North-Western Greening, Rome Beauty, Yellow Newtown and Yellow Transparent; light-brown fan-shaped areas with fringed margins, later nearly black and markedly sunken, subsequently cracking. **Control:** No warehouse control. Spray program in orchard.
Blue Mold Rot	Universal and very common: soft watery spots sharply defined from sound tissue, rotted portion can readily be scooped from sound tissue; in a moist environment white fungus and later blue spore masses appear, accompanied by musty odor and flesh tastes musty. **Control:** Maintain proper storage temperatures, careful handling, packinghouse sanitation, avoiding chemical injury during washing, use of approved fungicides such as benomyl or thiabendazole (TBZ) in wash water, and prompt refrigeration.
Bull's Eye Rot	Primarily in the Pacific Northwest. Rot develops slowly in cold storage from spores on apples when harvested, does not spread from one fruit to another; most frequent on Winesap, Yellow Newtown, and Delicious. Spots of various sizes, singly or in groups, may be pale yellowish or brown, but often spot is brown with a pale center. Rotted tissue is firm and somewhat mealy and does not separate readily from healthy tissue, shallow or deep. **Control:** Usually worse after rainy harvest period and if fruit cooling is delayed. Best control is orchard spray.
Core Rot	Sometimes apples that seem sound externally are found to be internally decayed, following infection through an open calyx tube. This infection may occur in the orchard and has been known to occur when apples were submerged during washing. **Control:** No warehouse control.
Fisheye Rot	In Pacific Northwest, resembles Bull's Eye Rot, spongy and stringy; infected tissue does not separate easily from healthy tissue. This disease is associated with wet harvest seasons. It can develop at 30 to 32°F (-1 to 0°C) but is usually found late in season in stored apples; does not spread. **Control:** No warehouse control.
Brooks Fruit Spot	Usually in Northeast United States. Deep red or black on red areas and dark green on green or yellow areas; spot later becomes black in center; later slightly sunken and in over-ripe

	fruit, surrounded by brown band. Fruit looks speckled. Affected areas are shallow, change little in cold storage. **Control:** No warehouse control. Controlled by spray program.
Gray Mold Rot	Quite universal. Initially pale, translucent, watery appearing but firm with light brown to brown areas; later softening and with freckled appearance. Spreads from decayed to healthy apples, causing "nests" in stored fruit. Gray mold develops faster in cold storage than any other decay. **Control:** Source of infection is in the orchard. Orchard sanitation and fungicides like benomyl or thiabendazole (TBZ) in fruit wash or drencher help control.
Scab	Occurs widely in areas where there is considerable rainfall during growing season. Development in storage is due to large infections in orchard. Irregular circular dark spots with definite borders, sometimes smooth, but also roughened or russeted surface; can enlarge slightly in cold storage. **Control:** No warehouse control. Controlled by spray program in orchard.
Flyspeck	Appears as clusters of small, slightly raised, black specks on the fruit surface. This superficial fungus disease is present on the fruit at harvest. **Control:** No warehouse control. Controlled by orchard sprays, only.
Sooty Blotch	Common in Central and Eastern United States. Irregular sooty patches or spots, easily removed by scraping or moistening and wiping fruit; does not develop or spread in transit or storage. **Control:** No warehouse control. By orchard spray program.

Orchard Related Storage Disorders	
Bitter Pit	Sunken spots often distributed over calyx end of apple, resembling small bruises or hail injury, initially appearing water-soaked, with intensified green or red color, finally becoming brown, gray or sometimes black. When fruit is peeled or cut, numerous brown areas appear, mostly just beneath skin but also may be deep in flesh. Affected tissue sometimes has a bitter taste. Appearance varies somewhat on different varieties. Spots may increase in numbers and intensity upon removal from cold storage. Worse on large fruit from light crops and young trees. **Control:** Related to orchard practices, especially irregular heavy irrigation or rainfall or heavy nitrogen fertilization. Calcium deficiency, light cropping and early harvest aggravate it. A pre-storage drench with 2 to 4% calcium chloride will reduce its development during storage.
Cork Spot	Widely distributed and often confused with other disorders producing corky spots. Due to boron deficiency in soil; usually fruit lacks characteristic shape, ripens earlier with dull color. Irregular corky spots frequently in core tissue. Present on fruit at harvest. Any corky-type disorder on apples should be diagnosed by a fruit specialist if there is any claim against the

	warehouse. **Control:** No warehouse control.
Water Core	Water-soaked areas in flesh, more often near core and around core "dots." When only core area is involved, disorder cannot be detected without cutting fruit. Visible water often accompanies sunburn, caused by high heat and intense sunshine. Does not develop or spread in transit or storage and if slight in degree, may actually disappear in apples while in storage. When large portions of apple are involved, especially in Delicious, Jonathan, Rome Beauty and Stayman, internal breakdown may follow. Fuji appears relatively resistant to damage from water core. **Control:** Harvest before extensive water core develops. Most susceptible varieties are Delicious, Fuji, Winesap, and Stayman.
Water Core Breakdown	If water core in apples is serious it may eventually cause breakdown of the flesh. With this type of breakdown remnants of the severe water core or water soaked flesh can often be seen. However, some studies indicated that water core breakdown may appear even though the water cored areas have disappeared. Slight water core usually, if not always, disappears in storage. In the late stages of this breakdown, affected fruit may have a dull skin and the fruit is spongy. Severely affected fruits may smell and taste fermented. When the breakdown is near the surface of the fruit, the soft area can be detected by touch of the points at the calyx end of Delicious. **Control:** It is worse in large, late picked fruit and is aggravated by delayed storage. The problem is delayed by CA storage. Among the susceptible cultivars are: Delicious, Stayman, Jonathan, Winesap, Cox's Orange Pippin, Miller's Seedling, James Grieve, Bramley Seedling, Worcester, Braeburn and Holstein Cox.

Storage Chilling Disorders	
Brown Core	Occurs principally on apples from New York and New England. Most serious on McIntosh, but also found on Empire, Idared, and others. No external symptoms. When fruit is cut, core is first brown between seed cavities, then in whole core area and brown streaks may extend into flesh. Associated with too low storage temperature, appearing late in season and increases after fruit is removed from storage. Tendency to brown is in fruit before it is stored. Cloudy, rainy weather, when apples are maturing, aggravates disorder. **Control:** Hold apples with brown core tendency at 36°F (2°C) and market in 2-3 months, or put them in controlled atmosphere storage at 36°F (2°C).
Internal Browning	Affects only certain apples in certain regions, notably Yellow Newtown and Bellflower grown where weather is cool and foggy, as in the Watsonville area of California. Detected only by cutting fruit. Mostly browning in the core; worse on larger fruit; tendency is inherent in fruit but is aggravated by storage at 30 to 32°F (-1 to 0°C) and increases with longer storage period.

	Control: Store at 38 to 40°F (3 to 4.4°C) in CA storage.
Low Temperature Breakdown	Tissue affected by this disorder is likely to be firmer and more moist than tissue affected by senescent breakdown. In the earlier stages fruit must be cut for the discolored areas to be seen. There are a variety of symptoms, even in one sample of fruit. The normal syndrome is markedly brown vascular bundles ("core dots"), browning of the flesh and a clear halo of unaffected tissue beneath the skin. Low temperature breakdown develops before the apples are senescent. Jonathan may show the trouble within 12 weeks at 30°F (-1°C) and Cox's Orange Pippin sooner at 32°F (0°C). The disorder is found in Twenty Ounce, Northern Spy, Jonathan, Cox's Orange Pippin and Bramley Seedling and several others. **Control:** Store at 38 to 40°F (3 to 4.4°C) in CA. With Jonathan it has been reduced by postharvest calcium treatments.
Soft Scald	Distinguished by round or ribbon-like browned areas of skin and possibly underlying flesh with sharp line of separation of healthy and diseased tissue. Becomes progressively worse when apples removed from storage. Most common on Jonathan, but also on other varieties, such as Honeycrisp; favored by storage below 36°F (2°C) during early part of storage season. Possibly an expression of Soggy Breakdown. **Control:** Avoid storage at low temperatures (30-32°F/-1 to 0°C) during first 2 months of storage.
Soggy Breakdown	Different from internal breakdown. Light brown areas in outer fleshy part of apple, sharply defined from healthy tissues, initially moist and soggy. Adjacent sound areas have fermented taste, fruit may seem to be spongy, more prevalent in apples stored at 30 to 32°F (-1 to 0°C), generally increased greatly by delaying storage of fruit. **Control:** Store at 36 to 40°F (2 to 4.4°C) or store at 32°F (0°C) in CA storage. Varieties most susceptible are Golden Delicious, Grimes Golden, Jonathan, Northwest Greening and Wealthy. Soggy breakdown doesn't appear in CA storage with Jonathan even when the temperature is this low.

Senescent Breakdown Disorders	
Senescent Breakdown	With slight variations among varieties, symptom development is usually: flesh becomes very soft, first on one side then on entire fruit; apple is easily punctured with thumb and is easily bruised; flesh becomes dry, mealy and lacks aroma and flavor; browning of the fruit flesh and vascular strands in the flesh; skin becomes dull, dark, or water-soaked in appearance; fruit splits open. Although it is most common on McIntosh, almost all apple varieties are susceptible to some type of senescent breakdown. Senescent breakdown has been aggravated by low calcium levels in the fruit, very hot and dry weather before harvest, delayed harvest, slow cooling in storage, delayed establishment of low O_2 in CA, high storage temperature, prolonged storage, and for McIntosh, CA storage with low CO_2 (1% or lower). **Control:** Senescent breakdown can be controlled or alleviated by drenching the apples with 2 to 4% food grade calcium chloride, rapid cooling, rapid establishment of the proper CA atmosphere, and sale of the apples soon after CA rooms have been opened.

Other Storage Disorders

Other Storage Disorders	
Superficial Scald or Storage Scald	Very common, widespread and serious disease, affects the skin of the apple, mostly on the green side. Superficial browning of skin, but in severe cases, decay follows. Usually not severe while apples are in storage. When moved out of storage, scald develops rapidly. Worse on fruit that was immature at harvest and after a warm harvest period. **Control:** Pre-storage drenching of bins of apples with diphenylamine. Varieties most seriously affected are Cortland, Delicious, Law Rome, Granny Smith, Stayman, Winesap, and York Imperial. McIntosh develops scald in some seasons.
Jonathan Spot	Initially appear as bluish-black circular spots in the skin, then becomes brown and sharply sunken, later becoming lobed and more sunken. Spots may be irregular in outline on Idared. Tends to develop in transit or storage on fruit that seemed to be sound when shipped. It is aggravated by late harvest, delayed storage, high storage temperature, and CO_2 levels below 1% in CA. **Control:** Prompt refrigeration after harvest, avoiding delays at ordinary temperatures. Store in CA with adequate CO_2.

Injuries	
Bruising	Bruises on fruit at harvest time, in the packing operation and in transit, may influence adversely the storage life of apples. While the warehouseman has no control over such bruising, he should be aware of the significance of mechanical injury on the ripening and deterioration of apples in storage, especially if some claim is made regarding the condition of the apples while in storage. One of the types of bruises that may be confused with freezing injury is that found in apples at the lower side of the bottom layer of boxes in a reefer car or trailer. If such bruises are not detected when the fruit is accepted for storage, claims may be made later that the apples were frozen in the warehouse. This type of bruise

	is flat, water-soaked and darkened in appearance, generally firm. In cross section, the bruise is usually water-soaked and glassy and may be shallow or deep and wedge-shaped. Hence, a glassy, water-soaked bruise is not necessarily a sign that freezing has occurred. The transit bruises are caused by pressure and the jolting of the transport vehicle in motion. Bruise breakdown, which is seen as brown tissue radiating into the flesh from a bruise may develop on any apple variety but is most common on soft fleshed varieties as McIntosh and Golden Delicious.
Chemical Injury	Reference will be made merely to the fact that chemical injury may occur from orchard sprays, postharvest drenches with storage scald inhibitors and calcium chloride, during the washing of apples before packing, and when fruit comes in contact with salt or fertilizer. If fruit delivered to the warehouse is suspected to be chemically injured, the diagnosis is best made by a fruit inspector or qualified pathologist.
Freezing Injury	Slight freezing injury may not be noticeable externally, or even internally, although such apples will be softer and not keep as well after defrosting. But, if severe, the surface is discolored and darkened in irregular-shaped areas, and is water-soaked. In frozen condition, apple skins show network of wrinkles and, of course, apple has "hard feel." Best indication of freezing found is when defrosted apples are cut. Core "dots" will be brown as well as strands in flesh if freezing has been severe. In extreme cases, flesh has solid discoloration, shades of brown or even black with water-soaked appearance. Frozen apples usually decay if left in storage. Slightly frozen apples will defrost with no apparent after-effect except slight softening, if thawed slowly. It is best not to move or handle apples when frozen because bruising injures frozen apples severely. Sometimes internal breakdown is mistaken for freezing injury. If there is any question about cause where claims are made, a fruit inspector or qualified pathologist should diagnose the problem. **Control:** Prevent cold "pockets" in storage by air movement and do not allow temperature to drop below 30°F (-1°C).
Hail Injury	Usually on one side of fruit, sunken spots with brown, corky, dry tissue beneath which do not tend to decay. Fruit may grow distorted. Injury near harvest may result in increased decay incidence. **Control:** None.
Heat Injury	On slightly injured apples, isolated spots of brown spongy tissue; if severe, whole apple may seem to be baked due to excessively high temperatures in orchard. Skin may look sunburned, even if not brown, with collapsed tissue beneath, which may lead to fruit becoming distorted. Sun scald cannot be controlled by diphenylamine. **Control:** Surround™ is being used in the northwest to reduce sun scald.

Freezing

Not all varieties of apples give the most desired finished frozen product, whether for the bakery trade or other purposes. Most State Agricultural Experiment Stations have information on what varieties in the area freeze well and are useful to bakery or other processing industries.

The apples are washed, peeled, cored, and sliced with specialized pieces of equipment. Inhibiting the browning reaction of the slices when exposed to air is the most important step in preparation for freezing. Also, removing the air from within the apple slices themselves inhibits internal browning.

There are several complicated patented processes for inhibiting the browning reaction, but most commercial processors rely on salt brining, sulfuring sulfur replacements, blanching, sugar solutions, or a combination of these procedures.

Soaking the slices in a 1% salt solution sufficiently long for the salt to penetrate and force out some of the intercellular air is probably the most common procedure. Soaking in a solution of 0.2 to 0.25% sulfur dioxide for 1 minute is a more efficient procedure but requires constant control of the strength of the solution. Sodium sulfite, sodium bisulfate, or sodium metabisulfite, are alternates for sulfur dioxide, requiring a longer soaking period, but are less corrosive.

Replacements for sulfite use in browning inhibition are constantly being developed and studied. One of the most common replacements for this purpose now is a blend of ascorbic acid, citric acid and calcium chloride.

Blanching the slices in steam or boiling water to inactivate the enzymes, that are part of the browning reaction, is practical. However, it leaves a softer slice than is desired for some uses. Sugar solutions are used in place of the salt brine, but this sometimes limits the use to which the apples can be put. Ascorbic acid (vitamin C) is sometimes sprinkled on the surface to inhibit browning, but it is an expensive procedure.

Soft slices can be firmed somewhat by soaking in a 0.05 to 0.50% calcium chloride brine for 5 to 30 minutes, depending on the strength of the brine.

Dry sugar and fruit in the ratio of 5 parts fruit to one of sugar, is usually added to the 30 to 50 lb. fiberboard, plastic or metal containers used for apples. If sulfur has been used to inhibit browning, a can with a lacquered lining is needed to prevent a black discoloration from occurring, in a reaction between the container and the residual sulfur.

Freezing should be as rapid as possible and is usually accomplished, with cans in a staggered position to permit good air circulation, in a blast freezer at from -10 to -30°F (-23 to -34°C).

Dehydrofreezing

Dehydrofrozen apple slices are ones that have had water removed by controlled dehydration procedures to about 50% of their original weight. The slices are dehydrated by standard belt or rotary

drying equipment after the apples have been washed, peeled, cored, sliced and treated to prevent browning. They are then packaged and frozen in the same manner as regular slices.

The advantages of dehydrofrozen slices are: more pieces to the space, less weight per unit, and they reconstitute readily to any degree of moisture level desired in the finished product.

WFLO is indebted to Dr. Chris Watkins, Cornell University, Ithaca, New York, and Dr. Elhadi Yahia, Universidad Autonoma de Queretaro, for the review and revision of this topic.