Part II

Major Processed Products

18 Apples and Apple Processing

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18.1 INTRODUCTION

Apple has been grown by mankind since the dawn of history. This is mentioned in early legends, poems, and religious books. The "fruit" that the Bible says Adam and Eve ate in the Garden of Eden is believed by many to have been an apple. The ancient Greeks had a legend that a golden apple caused quarreling among the gods and brought about the destruction of Troy. The Greek writer Theophrastus mentions several cultivars grown in Greece in the fourth century B.C. Apple trees were grown and prized for their fruit by the people of ancient Rome.

The apple species *Malus pumila*, from which the modern apple developed, had its origin in southwestern Asia in the area from the Caspian to the Black seas. The Stone Age lake dwellers of central Europe used apples extensively. Remains found in their habitations show that they stored apples fresh and also preserved them by cutting and drying in the sun. The apple was brought to America by early colonists from Europe.

Some cultivars originating in Europe were grown by the colonists, but the main method of planting apples in the new land was by seed. As the pioneers migrated westward, they carried apple seeds with them and established plantings where they settled. Almost everyone is familiar with John Chapman, "Johnny Appleseed," born in June 1774 in Leominster, MA, and the story of how he carried apples west like many of the early settlers.

In these early times, most of the apple crop was home processed into cider. The common seedling trees were satisfactory for this cider production. Not many of the cultivars brought across

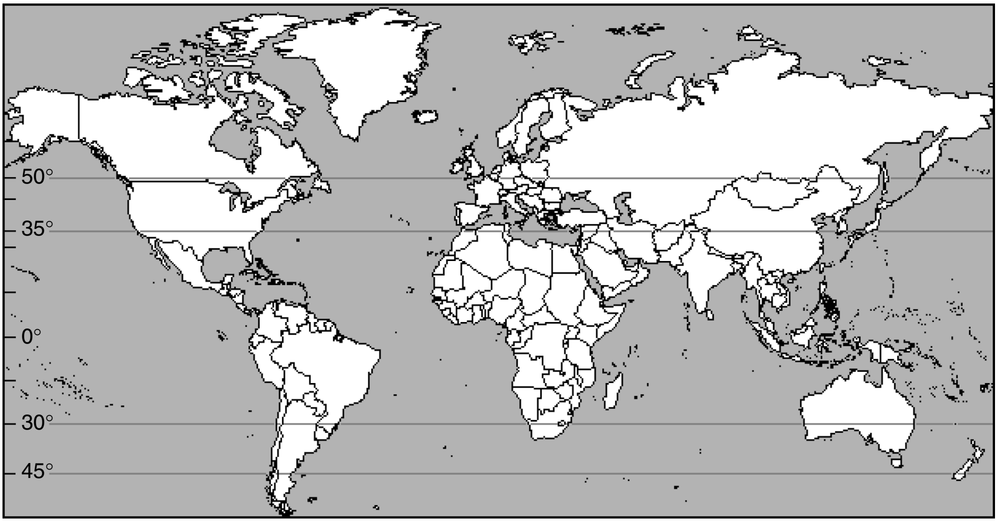

FIGURE 18.1 Primary apple-growing latitudes of the world. Data from U.S. Apple Situation — Apple Commodities page, U.S. report, http://www.fas.usda.gov/htp/circular/2003/9-12-03%20Web%20Art%20 Updates/2003%20USApple%208-23-03.pdf.

the Atlantic by our ancestors adapted well to the North American climate. There was a need to develop American cultivars from the seedlings to improve the apple production and storage characteristics. Those selected cultivars were given local names (Upshall, 1970).

18.2 U.S. AND WORLD APPLE PRODUCTION

The apple is more widely grown than any other fruit. Apple trees of one cultivar or another grow all around the world but are mainly concentrated in the Northern hemisphere. About 95% of all apples grown, with some exceptions due to isolated microclimates, are found between the 35°N and 50°N latitudes and between the 30°S and 45°S latitudes. These bands of primary apple growing areas around the globe are pictured in Figure 18.1.

Annual world production of apples was about 45 million metric tons during 2002 to 2003. World apple production trends are given in Table 18.1. World production declined during the period mentioned for the second consecutive season due to lower production in both China and the U.S. These reduced production rates offset increased apple production by other major producers, including Turkey (USDA, 2003). Apple production in some selected countries for this season is illustrated in Table 18.2. Northern hemisphere countries, particularly China, the U.S., Turkey, Italy, and Poland dominate the world market. During the 10-year period from 1992 to 2002, apple production in China increased dramatically (Figure 18.2), from approximately 20% to over 45% of the world production (USDA, 2003). Production and storage facilities in China are expected to improve, and lower Chinese fruit prices will also boost fruit sales. However, if urban Chinese consumers have increasingly greater purchasing power, China may actually import more apples.

Commercial apple production for the U.S. during the 2002/03 period was approximately 3.9 million U.S. tons. This was down by approximately 4% from the 5.2 millon tons produced in 2001/02 due to reduced supplies, higher domestic prices, and a strong U.S. dollar which reduced U.S. apple exports. Apple production in the U.S. is primarily in the states of Washington, New York, Michigan, California, Virginia, and Pennsylvania (Figure 18.3). These states produce over three quarters of the total U.S. production. The other regions — New England, eastern, central, and other western states — produce the remainder.

TABLE 18.1
World Apple Production Trends, 1999 through 2003

Areas	1999–2000	2000–2001	2001–2002	2001–2003
North America	5.40	5.13	4.78	4.41
Europe	8.90	9.45	8.03	7.65
China	20.80	20.43	21.00	20.50
Southern Hemisphere	4.03	4.40	4.14	4.36
WORLD TOTAL	**38.13**	**39.41**	**37.95**	**36.92**

Note: Expressed in million metric tons.

Source: United States Department of Agriculture, Foreign Agricultural Service. World Apple Situation: Acreage Continues to Decrease in Major Producing and Trading Countries, March 2003. http://www.fas.usda.gov/htp/circular/2003/3-7-03%20Web%20Art.%20Updates/World%20Apple%20Situation%202002-03.pdf; *FAO Production Yearbook,* Vol. 45, Food and Agriculture Organization of the United Nations. 1991.

TABLE 18.2
Production of Apples in Specified Countries, 2002–2003

Northern Hemisphere			
Belgium–Luxembourg	351	Netherlands	365
Canada	510	Poland	2,107
China	20,500	Russia	1,400
France	2,140	Spain	742
Germany	1,429	Sweden	54
Greece	220	Taiwan	10
Hungary	470	Turkey	2,500
Italy	2,210	U.K.	134
Japan	912	U.S.	3,900
Northern Hemisphere total			**32,858**
Southern Hemisphere			
Argentina	1,000	Chile	1,060
Brazil	825	New Zealand	462
Australia	328	South Africa	680
Southern Hemisphere total			**4,355**

Note: Expressed in 100 t.

Source: USDA, world statistics from USDA/FAS World Horticultural Trade and U.S. Export Opportunities, March 2003.

Apple production in the U.S. has declined due to continued reduction in apple acreage as a result of financial problems that have forced many growers out of business. Apple-bearing land in 2002–2003 in the U.S. is estimated at 430,000 acres as compared to 470,000 acres in 1989/99. According to the U.S. Department of Agriculture (USDA) (USDA, 2003), the apple industry faces low domestic prices, caused primarily by overproduction, stagnant domestic demand, and remarkably increased imports of lower price apple juice from China.

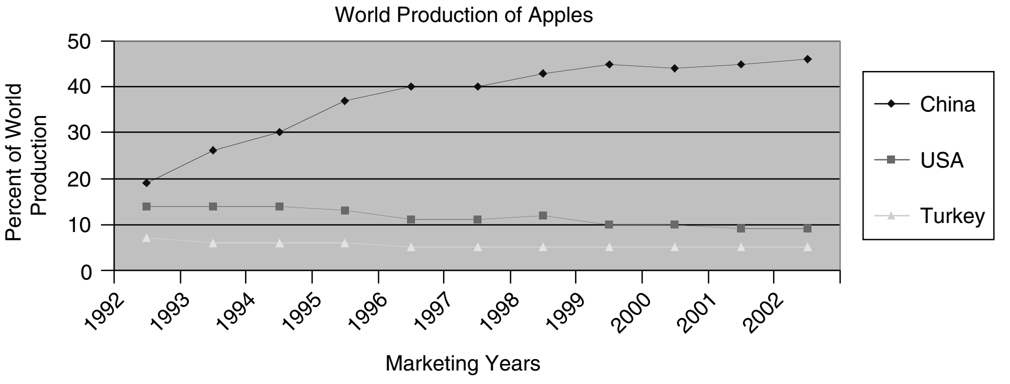

FIGURE 18.2 World production of apples (1992–2002). Data from World Apple Situation — Apple Commodities page, http://www.fas.usda.gov/htp/circular/2003/3-7-03%20Web%20Art.%20Updates/World%20Apple%20Situation%202002-03.pdf.

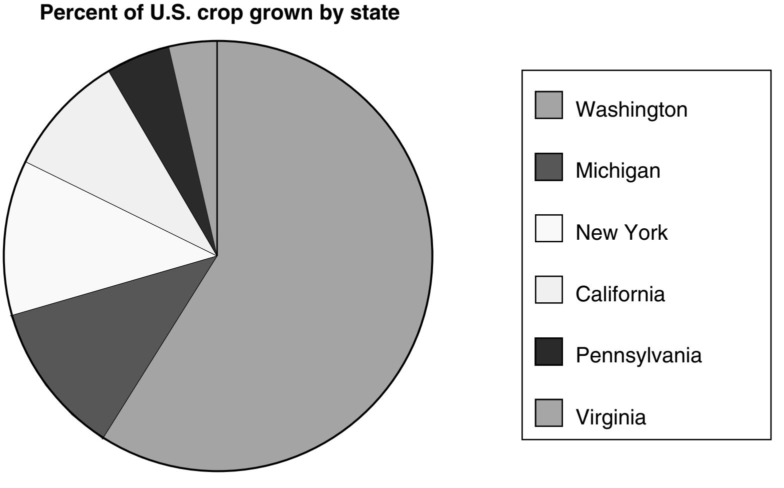

FIGURE 18.3 Percentage of U.S. apple crop grown by major producing states. Data from World Apple Juice Situation — Apple Juice Commodities page, http://www.fas.usda.gov/htp/circular/2003/4-4-03%20Web%20Art.%20Updates/Apple%20Juice%20Feature%2004-03.pdf.

In 2002, the percentage of apples marketed fresh was 63% of the total, and 37% was processed. Of the processed apples, 18% was utilized in juice and cider, 13% was canned, 3% was dried, 2% was frozen, and 1% was used in other miscellaneous products such as vinegar, wine, and jelly. Over the past 10 years (1992 to 2002), the utilization of the apple crop has changed to a higher percentage of fresh apples (from 55 to 63%) and a lower percentage of juice, canned, dried, and frozen apple products (USDA-NASS, 2003).

World apple juice production is expected to remain strong, with record production in China, which in 2002–2003 accounted for 33% of the world production. This is more than double the market share of 15% that China held in 1998–1999. The U.S., on the other hand, now accounts for only 12% of world apple juice production, which is half its 1998–1999 level (Figure 18.4). In the U.S., some processors have had to import apple juice products, particularly in the forms of concentrate. This was to ensure an adequate supply of raw material for their manufacturing facilities to maintain consistent distribution from year to year. U.S. imports of apple juice increased from approximately 210,000 t in 1998–1999 to 260,000 t in 2002–2003.

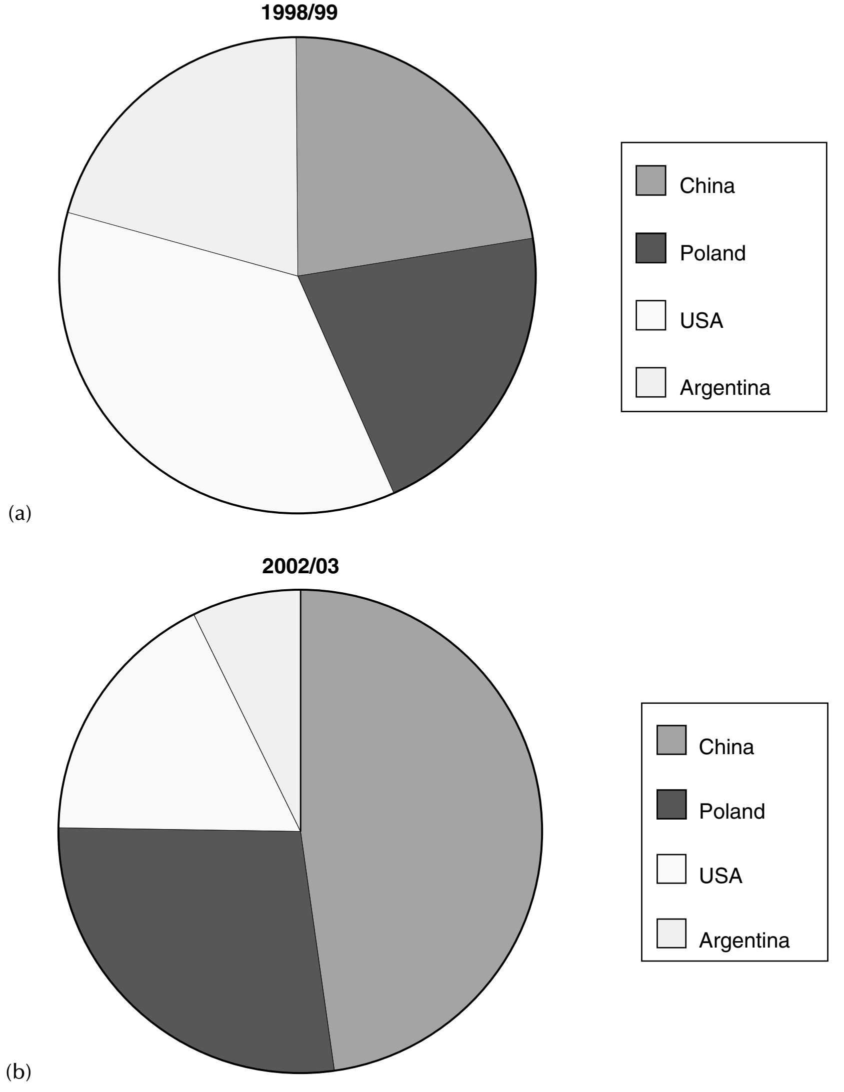

FIGURE 18.4 Share of world apple-juice production (1998/89 vs. 2002/03).

18.3 APPLE CULTIVARS

There are hundreds of apple cultivars, many of them are shown with color plates in *The Apples of New York* by Beach et al. Only about 20 cultivars are now grown commercially in the U.S. More than 90% of the production is represented by 14 cultivars (Table 18.3). Of these, five — Red Delicious, Golden Delicious, Gala, Fuji, and Granny Smith — account for most of the world apple production.

The recent trend in the U.S. is to plant newer apple cultivars. These newer cultivars, are now appearing in fruit markets. Gala, Fuji, Jonagold, Braeburn, and Lady Williams are relatively new varieties that the consumer has accepted as an alternative to traditional varieties. Gala and Fuji, in particular, have displace older varieties in terms of their market share. Most of the new commercial plantings are selected red strains of the primary cultivars. Some cultivars, like Gala, mature in 100 days or less while others, like Lady Williams, grown in Western Australia, require over 200 frost-free days to reach maturity. Some cultivars are very winter and frost hardy while others are very

TABLE 18.3
Apple Production by Cultivar in the U.S., 2002

Cultivar	Primary Region	Production (000 42 lb units)
Delicious (all)	West	63,625
Golden Delicious	West	27,891
Gala	West	18,960
Fuji	West	20,656
McIntosh	East	7,840
Rome Beauty	East	7,922
Granny Smith	West	19,394
Jonathan	Central	3,561
York	East	3,724
Stayman	East	1,268
Cortland	East	1,750
Newtown	West	1,319
Winesap	West	431
Northern Spy	East	1,085
Rhode Island Greening	East	1,264
Gravenstein	West	134

Source: USDA 2003.

tender. Some cultivars like Delicious require long cold winters to break dormancy, others like Anna, a cultivar grown in Israel, can be grown in mild Mediterranean type climates.

Washington State grows 54% of the apples produced annually in the U.S., over 116 million 42-lb units as compared to about 24 million 42-lb units in New York, the second largest producer. The pie chart in Figure 18.3 shows the apple production percentages by growing region. Consumers are requesting high quality apples with distinctive flavors. The trend in a Washington State tree survey shows continuation of the dominance of Delicious, Golden Delicious, and Granny Smith. California does not produce many Delicious apples, but acreage of Gala and Fuji are increasing. Future U.S. planting densities will increase when new plantings are made, therefore annual apple volume will continue to increase.

18.3.1 Origin of the Current Popular Cultivars

The original **Red Delicious** apple was discovered as a chance seedling in 1881 by Jesse Hiatt near Peru, Iowa. Stark Bros. Nurseries, Louisiana, Missouri, bought the rights to Red Delicious in 1894 and promoted it heavily. Presently over 100 strains of Red Delicious have been propagated by growers and nurserymen. Red Delicious is a sweet, mild apple for eating, not cooking. The trees are productive and adaptable to different growing conditions.

Golden Delicious originated around 1900 in West Virginia but is not related to the Red Delicious apple except that it was also purchased, promoted, and named by Stark Bros. Nurseries. It is of interest that these two most popular apples are not the result of organized fruit breeding programs. "Goldens" have a sweet, delicate flavor and store well. The Golden Delicious is the parent of several modern varieties such as Jonagold, Spigold, Gala, and Mutsu.

McIntosh is the dominant commercial apple in New England and eastern Canada. The first tree was a chance seedling, introduced around 1811, on John McIntosh's farm in Matilda, Ontario. It is a thick-skinned, tender-fleshed, aromatic apple. McIntosh apples ripen early and were a commercial favorite of growers trying to deliver early to the fresh-apple-hungry metropolitan areas of New York and Chicago. McIntosh is a parent of Spartan, Empire, and other hardy modern cultivars.

Granny Smith, the third most popular apple in the world, originated in the 1860s. It was a chance seedling in Marie Smith's back yard near Sydney, Australia, thus, the name Granny Smith. The Granny Smith needs a long growing season and is grown commercially in the U.S. mainly on the West coast. It is a very firm, green, juicy, tart apple ideal for apple pie and contributes acidity when used in juice production.

Jonathan was a seedling from Esopus Spitzenburg. Esopus Spitzenburg, although not a major cultivar today, originated in 18th century in Esopus, New York, and was claimed to be Thomas Jefferson's favorite apple grown at Monticello. Jonathan was named after Jonathan Hasbrouck near Woodstock, New York. Jonathan is the primary variety grown in several areas outside the U.S., including Hungary. It is a very good flavored apple that is superior for eating and makes excellent applesauce and apple juice. Jonathan is a parent of many modern cultivars such as Jonagold.

Cortland is a McIntosh/Ben Davis cross developed in 1915. Although larger than McIntosh, it is not as flavorful and ripens a week later. Cortland is another early ripening favorite to sell in the fresh market early.

Newtown originated in Newtown, Long Island, in the early 1700s. It once was considered the most flavorful and best all-around quality dessert apples. Newtown became known for its superb flavor and keeping quality. It is a hard, crisp, juicy, and tart apple that grows best in temperate climates such as Virginia and Oregon. Newtown picked late in the harvest season ripens gradually in storage. Benjamin Franklin introduced the English to Newtown apples in 1759, thus beginning the U.S. apple export trade.

Winesap is a small English cider apple that was brought to Virginia in colonial times. It is tart, crisp, flavorful, and an excellent storage apple. Winesap popularity spread across the U.S. and was one of the major cultivars grown in the early Yakima region of Washington. However, modern storage technology has reduced its popularity. Winesap grows best in temperate climates. It is the parent of the Stayman Winesap variety grown from a seed by Dr. J. Stayman in Kansas in 1866.

Northern Spy was first grown near Rochester, New York, about 1800 and became well known after the Civil War. This hearty apple is a favorite for eating and cooking in the north. It is a late-blooming, biennial apple that has kept it from commercial popularity in modern times. These late apples still may be ripening on the trees into December.

Rhode Island Greening first grew in 1748 in Newport, Rhode Island, at a tavern owned by Mr. Green. The smooth, waxy skinned fruit was juicy, tart, and distinctively flavored. Guests of the tavern took cuttings of the tree to adjoining states, making it one of the first cultivars propagated throughout the colonial Northeast.

Gravenstein is an early season European or Russian cultivar that arrived in the U.S. by the 1820s. Plantings of this apple were developed in the Northern California coastal region. The fruit is large, juicy, and tart but only a fair keeper. The apple ripens slowly on the tree over several weeks. Gravenstein apples make excellent applesauce and pies.

Detailed descriptions of these and many other of the world's apple cultivars are available in books by Upshall (1970) and Bultitude (1983).

The newer cultivars — Gala, Jonagold, and Fuji — came from breeding programs. Gala originated in New Zealand and is a cross between Golden Delicious and Kidds Orange. Jonagold, discussed previously, originated in New York State as a cross between Golden Delicious and Jonathan. Fuji came from Japan and is a cross between Delicious and Ralls Janet. Several red mutations of these cultivars have been selected and are now grown and available to the consumer.

18.4 HANDLING OF APPLES FOR PROCESSING

All of the apple varieties grown commercially are used to some extent in processed products. Some varieties, such as York Imperial, are grown almost exclusively for processing. Only sound, ripe fruit should be used for processed products. Processing quality can be affected by decay, damage, maturity, firmness, color, soluble solids, acids, and other chemical compounds, such as tannins, contained in the fruit (Downing, 1989). In one study (Harper and Greene, 1993) of price discounts and premiums for three processing apple cultivars, it was determined that discounts were statistically significant for fruit size, bruising, bitter pit, decay, misshapen apples, and internal breakdown. Insect damage and apple scab did not result in significant price discounts.

The cultivar used in processing will be dictated to some degree by the quality of the product to be produced. Many of the apples that have some imperfections, such as skin blemishes or off shapes rendering them undesirable for the fresh market, are utilized by processors. These are perfectly good quality apples and are in high demand. An average of about 20% of the Delicious and other fresh market apples are processed. Varieties such as Golden Delicious, Rome Beauty, Granny Smith, McIntosh, and others may have more than 20% of the volume diverted to processing. Delicious apples that are firm, sweet, and juicy yield a good volume of high quality juice. Although sauce can be produced using Delicious apples the product would not be of good quality, particularly in relation to texture and color. The applesauce yield is less with the Delicious apple due to the thicker skin that results in greater loss during peeling. Golden Delicious on the other hand not only makes a good quality juice but produces a high quality sauce and sliced processed product. Cultivars utilized in processed products are determined by availability of the raw product, quality of the product produced, and market demand from the region grown.

Apples may be grown specifically for processing, a practice common among orchards in the Eastern U.S., but most apples sold to the processor are salvaged from fruit grown for the fresh market. Production costs for processing apples have been reported to be lower than costs for fresh market apples (Childers, 1983). This is not necessarily true. Because a premium price is paid for large, bruise-free apples delivered to the processor, growers must give full attention to the cultural management details similar to those given apples grown for the fresh market. Production practices for apples vary with the climate and soils in which they are grown. Space does not permit a detailed description of these practices. Interested readers are referred to several of the many books by Childers (1983), Tukey (1978), and Westwood (1978). Plus extension publications available: Heinicke (1975) Lord and Costante (1977), Forshey (1980 and 1981), Swales (1971), and U.S. Department of Agriculture Farmers Bulletin No. 1897 (1972).

Apples for processing should be harvested at optimum maturity for good fresh market storage and handling. Only in a few instances are apples harvested with the processed product in mind. To date the majority of the apple crop is still harvested by hand. Large bins, about 4 ft by 4 ft by 2½ ft high, holding 750 to 1000 lb of fruit have replaced the old traditional 42-lb wooden field box. Fruit is picked in canvas bags or lined buckets, placed in the large bins, and loaded with fork lifts on trucks, or stacked for transport by special straddle bin carriers to the packing house or processing plant. If there has been extensive fruit damage from hail or sunburn, apples that will not pack out to an acceptable grade will be harvested "field run" or "orchard run" and delivered directly to a processor. Mechanical harvesters designed to shake the tree and catch the falling fruit without bruising have not been perfected for apples. It is estimated that less than 10% of the apples in the world are harvested by mechanical methods (Downing, 1989).

Processing of apples is mainly regarded as a salvage operation. The majority of the processing apples are sort-outs from the fresh market packing line. The volume available depends on fresh market demand and the quality of the current apple crop. As a result those apples to be processed are picked and stored in the same manner as fruit destined for the fresh market. Few if any processors can utilize all of the fruit as it is delivered to the plant during the harvest season. Early in the season some fruit to be processed will be stored directly in the bins in regular atmosphere storage without the benefit of refrigeration. This type of storage is short term and limited to the plant's immediate processing capacity. Early in the season, continuing through January and early February, there are large quantities of fruit available from refrigerated storage. Refrigerated storage temperatures range from 1 to 4°C, depending on the cultivar in question.

After January or February, processing apples are available from controlled atmosphere storage. Controlled atmosphere (CA) storage normally consists of a modified atmosphere, 2 to 3% oxygen and 1 to 4% carbon dioxide in conjunction with reduced temperatures. Both the atmosphere and storage temperature must be adjusted for the cultivar in question. Controlled atmosphere apples are generally stored four to six months before removal from storage and distribution to market. Apples from controlled atmosphere storage are generally in very good condition. However, the apples should be allowed to "normalize" several days prior to being processed. There is some loss of apple flavor and acid during CA storage but not significant enough to make the apples undesirable for processing. These apples are capable of producing good quality processed apple products. Due to higher cost of controlled atmosphere storage, the maximum volumes of apples are marketed fresh and the desired quantities of apples for processing are not always available.

Apples from both refrigerated and controlled atmosphere storage are capable of producing quality products (Drake et al., 1979). The product produced and the grade desired must be taken into consideration by the manufacturer when considering apples from not only the different types of storage but directly from the field as well. The processor may choose to hold the fruit at elevated temperature to allow for further maturation development (softening, color change, etc.). Some cultivars such as Delicious require additional press aid and filtration as they advance in maturity and become softer. Different grades of applesauce can be manufactured from the same cultivar depending on the type of storage, time of storage, and maturity when processed.

18.4.1 Processed Apple Products

Americans consume an average of 47 lb per capita of apples and apple products per year; 17 lb of this was as fresh apples in 2002. Over 27 lb of apples per capita are processed apple products. Apples are processed into a variety of products, although apple juice, averaging 19 lb of apples per capita, is the most popular processed apple product. Apples for processing should be sound, mature, reasonable size, and of uniform shape to be peeled. These peeled apples are processed into canned, frozen, and dehydrated apple slices and dices, plus several styles of applesauce. Applejuice is processed from apples that are unsuitable for use in other peeling operations. "Eliminator" apples, smaller than 2 1/4 in., are too small to peel, even for applesauce, and are diverted to juice.

18.4.2 Apple Juice Processing

By far the largest volume of processed apple products is in the form of juice, with approximately110,000 t (70/71° Brix equivalent) of apple juice produced in the U.S. in 2002/03. On the other hand, imports of apple juice into the U.S. from China, Argentina, Chile, and other countries continue to increase.

Apple juice is processed and sold in many forms. Fresh apple juice or sweet cider is considered to be the product of sound, ripe fruit that has been pressed and bottled or packaged with no form of preservation being used, other than refrigeration. This type of fresh juice is normally sold at roadside stands or in the fresh section of stores not far from the producer.

Worldwide, naturally fermented applejuice is called apple cider and is usually fermented to a specific gravity of 1 or less (National Association of Cider Makers, 1980). In the U.S. apple cider refers to "sweet cider" that is made from the unfermented applejuice pressed from early-season, tart apples.

Shelf-stable apple juice is sweet cider that has been treated by some method for preservation. This processed apple juice can be in several styles: clarified juice, crushed apple juice, "natural" unfiltered juice, or apple juice concentrate, either frozen or high brix. Apple juice that has been clarified with some form of depectinization and filtration before pasteurization and bottling is the most popular apple juice product produced in the U.S. "Natural" juice is juice as it comes from the press with often about 2% ascorbic or erythorbic acid added to preserve color. It is then pasteurized and bottled. Some forms of natural apple juice are produced with the use of heat treatment only. This process results in a darker apple juice. Crushed apple juice is a product with a high pulp content. The crushed apple juice is produced, without the aid of a cider press, by passing coarsely ground apples through a pulper and desecrator before pasteurization. Frozen apple juice concentrate can be either natural or clarified juice concentrated to 42° Brix, packaged and quick frozen. Commercial apple juice concentrate is normally the clarified apple juice that has been concentrated to 70° Brix or higher, evaporating much of the water.

Most commercial cultivars of apples will produce an acceptable juice, particularly when blended. The character of the apple juice is directly related to the cultivar and maturity of the apple used to make the product. Juices produced in the eastern U.S. are more acid than those juices produced in the west (Downing, 1989). This flavor difference is directly related to the cultivars predominantly grown in these areas. In both eastern and western juice manufacturing facilities, the juice product is usually a blend of the juice from two or more cultivars. This blending procedure allows for a more uniform product throughout the season and from season to season. Regardless of the cultivar, only sound, ripe fruit showing no decay should be used. "Wind falls" or apples picked up from the ground should not be used for juice due to the pronounced "musty" or "earthy" flavor the apples pick up. Immature apples produce a juice lacking in flavor and very "starchy" and astringent. Over-mature apples are very difficult to press, clarify, and filter.

Figure 18.5 illustrates the process typically used for making apple juice and concentrate. Apples for juice are dumped, either by the bulk truck load or pallet bins, into a water filled receiving tank. In this tank the apples are soaked to remove soil and other foreign material. The raw fruit is then conveyed from the water to be inspected, and any damaged or decayed fruit removed or trimmed. In recent years there has been concern for the presence of over 50 ppb of *patulin* in the finished juice. Patulin is a micotoxin produced by the mold *Penicillium expansium,* found in "bulls eye" rot of apples. Although this micotoxin is easily destroyed by oxidation, the concern of patulin is an indicator to determine if the juice was produced from mistreated or spoiled apples. Some manufacturers rely on brush scrubbers to remove any decayed areas on the fruit to eliminate patulin producing mold spots from the apples.

Sorting and trimming of apples to remove damage or decayed fruit is mandatory. If not removed, damaged or decayed fruit may also impart off-flavors to the finished product and increase the risk of microbiological contamination.

Before pressing, whole apples are ground into a mash or pulp for extraction. This mashing process is accomplished with either a disintegrator, hammer, or grating mill. These mills crush or cut the apple to proper consistency, depending on the maturity of fruit. When milling firm fruit for juice, small particles are desired. As the season progresses and the apples become softer, pressing becomes more difficult, thus bigger particles of pulp are preferred for pressing.

Equipment used to extract juice from apples is of several types and many variations (Nelson and Tresler, 1980). The pressing process can be batch or continuous, depending upon the type of press used. More common types of presses apply pressure via hydraulic, pneumatic, screw, basket, or traveling belt methods. The vertical hydraulic press is a batch type operation and very labor intensive but requires no press aid, and the juice has a low level of solids. Although the hydraulic press is one of the older types of juice extraction, it is still in widespread commercial use around the world.

There are several other types of juice presses that are modern versions of the basic hydraulic press. These newer presses are automated, allowing a greater percentage of juice extraction from a given volume of apple pulp. However, these presses require press aids, as added 1 to 2% paper pulp and/or rice hulls, to reduce slippage and increase juice channels in the mash. Predrainers of different types, including rotating basket and traveling belt, have been used to extract free-run juice from the mash. This reduces the volume being mixed with the press aid for final pressing.

The apple mash has many natural enzymes but at rather low concentrations. Enzymes are substrate specific, which means a given enzyme can catalyze only one particular reaction. Pectolytic enzyme products contain the primary types of pectinases: pectinmethylesterase (PME), polygalacturonase (PG), pectinlyase and pectin transeliminase (PTE). PME deesterifies the galacturonic acid, liberating methanol from the side chain, which then allows PG to hydrolyze the long pectin chains.

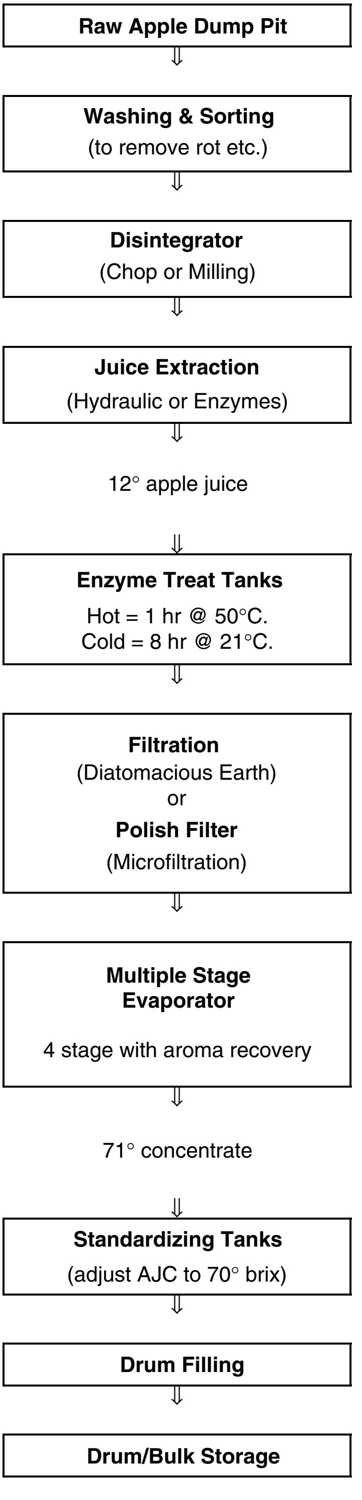

FIGURE 18.5 Apple juice concentrate flowchart.

Enzymatic mash treatment has been developed to improve the pressability of the mash and therefore the throughput and yield. The enzymes added at about 80 to 120 ml/t of apple mash break down the cell structure. High molecular weight constituents of cell walls, like protopectin, are insoluble, inhibit the extraction of the juice from the fruit, and keep solid particles suspended in the juice. Pectinase used in the apple process is extracted from the mold *Aspergillus niger,* a commonly occurring natural product. Pectinase developed for apple mash pretreatment acts mainly on the cell wall, breaking the structure and freeing the juice. Also, the viscosity of the juice is lowered, and it can emerge more easily from the mash. The high content of pectin esterase (PE) causes the formation of deesterified pectin fragments that have a low water-binding capacity and which reduce the slipperiness. These pectins consist of chains of galacturonic acid joined by alpha-glycoside linkage. Xylose is covalently bound as a monomer, and galactose and arabinose as polymers. These polymers form a link with the cellulose. The entire system forms a gel that retains the juice in the mash. Even if the pectins are partially broken down by the pectinase enzyme, more juice is released from the mash and pressing or extraction becomes easier. When used with mash predraining, the pomace acts like a pressing aid. By inexpensive pretreatment of mash with enzymes and heating to 50°C, the press throughput can be increased about 30 to 40% and juice recovery increased over 20%. Mash pretreatment will also increase the flux rate of ultrafiltered apple juice up to 50%.

When using enzymes for mash treatment, particularly in Europe, care must be taken to avoid over treatment, thus rendering the pressed apple pomace undesirable for commercial pectin extraction processing. Residual pectic enzymes in apple concentrate can cause set-up problems when the concentrate is used in making apple jelly.

In recent years there has been development of juice extraction by "liquefaction" of the raw fruit by using enzymes. Apple mash contains pectins, starch, arabinose, hemicelluloses, and cellulose. The liquefaction procedure is facilitated by heating the mash and treating with an enzyme "system" to completely break down and free the juice from the mash. The commercial enzyme systems available contain up to 120 substrate specific enzyme components. The liquefied juice is extracted from the residual solids by the use of decanter centrifuges and rotary vacuum filters. Some processors have added additional cellulase enzyme to the mash to further break down the cellulose to soluable solids, increasing the juice brix nearly 5%.

Mention should be made of the *counter-current extraction method* or diffusion extraction first developed in the 1970s in South Africa and refined in Europe (Brunische-Olsen, 1969). Europeans report a recovery of 75 to 80%, but this depends on water temperature, enzymes, and apple variety. The counter-current system recovery is best with hard apples and does not work well with soft dessert apples. In this system the mash is heated, predrained, and counter-washed with water and recycled hot juice. Capacity of the system is about 5 tons/h. A 90 to 95% recovery is obtained when the throughput is reduced to 3 tons/h. Due to dilution, the final juice brix drops from 11° Brix to between 6° and 8° Brix. Some industry regulators consider the extracted juice not true apple juice.

Juice yields from the different types of extraction processes vary greatly from about 70 to 95%. Juice yield depends on many factors, including the variety and maturity of the fruit; type of extraction, equipment, and press aids; time; temperature; and the addition and concentration of commercial enzymes to the apple mash.

After juice extraction, raw apple juice for clarified juice is enzyme-treated to remove suspended solid material (Smock, 1950). The soluable pectin in the juice has colloidal properties and inhibits the separation of the undissolved cloud particles from the clear juice. Pectinase enzyme hydrolyzes the pectin molecule so it can no longer hold juice. Treatment dosage of pectinase depends on the enzyme strength and varies from one manufacturer to another. A typical "3×" enzyme dosage would be about 100 ml/1000 gal of raw juice. Depectinization is important for a viscosity reduction and the formation of galacturonic acid groups that help flocculating the suspended matter. This material, if not removed, blinds filters, reduces production, and can result in a haze in the final juice product.

Two methods of enzyme treatment are commonly used: (1) hot treatment where the enzymes are added to 54°C juice, mixed, and held for 1 to 2 h or (2) cold treatment where the enzymes are added to room temperature (20°C) juice and held for 6 to 8 h. The complete breakdown of the pectin is monitored by means of an acidified alcohol test; 5 ml of juice is added to 15 ml of HCl-acidified ethyl alcohol. Pectin is present if a gel develops in 3 to 5 min after mixing the juice with the ethanol solution. When no gel formation is observed, the juice depectinization is complete.

Other polymers such as starch and arabans may cause post-process clouding in a clear juice and can be treated with amylase and arabinase enzymes. The purpose of using enzymes is to bring about a partial or complete breakdown of these substances in the process.

The fractured pectin chains and tannins are scavenged from apple juice by addition of about 1 to 1.5 lb of 200 bloom, type A or B gelatin per 1000 gal of juice. Best results are obtained when hydrating 1% gelatin in 60°C water. Gelatin can be added in combination with the enzyme treatment or bentonite, or by adding midway through the enzyme treatment period. The positively charged gelatin will facilitate removal of the negatively charged suspended colloidal material from the juice. Bentonite, a clay fining agent commonly mined in Wyoming, has been successfully used in the wine industry. The legal limits for use are 8 lb/1000 gal of product. Common usage is about 3 to 5 lb of rehydrated bentonite per 1000 gal of juice to be fined. Bentonite can be added to increase efficiency of settling, for protein removal, and to prevent cloudiness caused by metal ions. An excellent reference on enzyme treatment of apple juice is presented by Kilara and Van Buren and can be found in *Processed Apple Products* (Downing, 1989). Enzymes are usually not used when producing cloudy or natural apple juice.

After the enzyme treatment and the fining and settling process, the apple juice is pumped from the settled material (lees) and further clarified by filtration. Many types of juice filters are available and their capacity can accommodate any scale of production. These include pressure leaf, rotary vacuum, frame, belt, and millipore filters. To obtain the desired product color and clarity, most juice manufacturers use a filter medium or filter aid in the filtration process. The filter mediums include diatomaceous earth, paper pulp pads, cloth pads or socks, and ceramic membranes, to name a few. The filter aid helps prevent blinding of the filters and increases throughput. As the fruit matures, more filter aid will be required. Several types of filter aids are available, the most commonly used is diatomaceous earth or cellulose type materials. Additional juice can be recovered from the tank bottoms ("lees") by centrifugation or filtration. This recovered juice can then be added back to the raw juice prior to filtration.

Diatomacious earth (kieselguhr) is a form of hydrated silica. It has also been called *fossil silica* or *infusorial earth*. Diatomacious earth is made up of the skeletal remains of prehistoric diatoms that were single-cell plant life related to the algae that grow in lakes and oceans. Diatomacious earth filtration is a three-step operation. First a firm, thin, protective precoat layer of filter aid, usually a cellulose, is built up on the filter septum (which is usually a fine-wire screen, synthetic cloth, or felt) by recalculation. Second, the use of the correct amount of a diatomite body feed or admix (about 10 lb/100 ft^2 of filter screen). Third is the separation of the spent filter cake from the septum prior to the next filter cycle.

Before filtration, centrifugation may be used to remove a high molecular weight suspended solids. In some juice plants, high speed centrifugation is used instead of filtration. This centrifugation process produces a product not as clear as filtered juice; however, it allows more or less continuous production. Centrifugation used with filtration reduces the solids about 50%, thus reducing the amount of filter aid required.

Pressure, vacuum, and membrane filter equipment are available, and all can produce an acceptable product. The type of filter used must match the capacity to maintain plant production. The filtration process is critical not only from production consideration, but quality of the end product. Both pressure and vacuum filters have been used with success in juice production (Nelson and Tresler, 1980). Membrane (ultrafiltration) filtration is a recent development. Ultrafiltration based on membrane separation has been used with good results to separate, clarify, and concentrate various food products. Ultrafiltration of apple juice cannot only clarify the product but, depending on the size of the membrane, can remove the yeast and mold microorganisms common in apple juice.

Preservation of apple juice can be by refrigeration, pasteurization, concentration, chemical treatment, membrane filtration, or irradiation. By far the most common method is heat pasteurization based on temperature and time of exposure. The juice is heated to over 83°C, held for 3 min, filled hot into the container (cans or bottles), and hermetically sealed. The apple juice is held 1 min, then cooled to less than 37°C. When containers are closed when they are hot and then cooled, a vacuum develops, reducing the available oxygen that also aids in the prevention of microbial growth. After the heat treatment the juice product may also be stored in bulk containers, but aseptic conditions must be maintained to prevent microbial spoilage. Aseptic packaging is another common process where, after pasteurization, the juice is cooled and packaged in a closed, commercially sterile system under aseptic conditions. This process provides the shelf-stable juice in laminated, soft-sided consumer cartons, bag-in-box cartons, or aseptic bags in 55-gal drums.

Apple juice concentration is another common method of preservation. The single-strength apple juice is concentrated by evaporation or freeze concentration, preferably 70 to 71° Brix. By an alternate method, the single-strength juice is preconcentrated by reverse osmosis to about 40° Brix, then further conventionally concentrated. This method of final concentration is energy-saving. The reduced water activity and natural acid make the final concentrated apple juice relatively shelf stable at room temperature. There are several evaporation systems used for apple juice, including rising film evaporators, falling film evaporators, multiple effect tubular and plate evaporators. Due to the heat sensitivity of the apple juice, the multiple effect evaporator with aroma recovery is most commonly used. The general method in a multiple effect evaporator is heating the juice in the second stage to about 90°C and evaporate-capturing the volatile (aroma) by distillation. This is followed by reheating the 20 to 25° Brix juice concentrate in the first stage to about 100°C and evaporating it to about 40 to 45° Brix; heating it again to about 45°C and evaporating it in the third stage to about 50 to 60° Brix; then, final heating in the fourth stage to 45°C and evaporating it to 71° Brix. The warm concentrate is chilled to 4 to 5°C prior to standardizing to 70° Brix prior to barreling or bulk storage.

Preservation by use of chemicals such as benzoic or sorbic acid and sulfur dioxide is not commonly practiced. If chemicals are used, it is only to reduce spoilage of unpasteurized juice either in bulk storage or as an aid in helping to preserve refrigerated products.

There are several other methods of apple juice preservation that have not been adopted commercially but may be used in the future. These include, but are not limited to, irradiation and ultrasonics.

Apple essence is recovered during the concentration of apple juice. The identification of volatile apple constituents, commonly known as essence or aroma, has been the subject of considerable research. Early progress was very slow due to two problems: first, the difficulty of recovering representative quantities of the volatiles, and, second, the analytical techniques that were labored and unsusceptible to trace components. The essence recovery problems were resolved in 1944 by H. P. Milleville and R. K. Eskew at the USDA, with the development of the essence recovery system during apple juice concentration. This system was the forerunner of the commercial concentration systems used throughout the world today (Milleville, 1944).

The analytical problems were solved by the application of a combination of mass spectrometry and gas chromatographic instrumentation. In 1967 researchers at the USDA identified 56 separate compounds from apple essence. These compounds were further refined by organoleptic identification, using a trained panel of sensory specialists. These laboratory evaluations revealed 18 threshold compounds, identified as Delicious apple components consisting of alcohols, aldehydes, and esters. Three of the 18 compounds had "apple like aromas," according to the taste panel. These were 1-hexanal, trans-2-hexenal, and ethyl 2-methyl butyrate (Flath et al., 1967).

It is generally agreed there are six components contributing the most to the quality of apple essence or aroma. These can be divided into three desirable and three undesirable components as tabulated in Table 18.4.

TABLE 18.4
Six Important Apple Essence Components

Desirable Apple Essence Components:	
Ethyl 2-methyl butyrate (E2MB)	Ripe apple aroma
1-Hexanal	Green apple aroma
Trans-2-hexenal	Green apple aroma
Undesirable Apple Essence Components:	
Ethyl acetate	Airplane glue aroma
1-Butanol	Solvent or petroleum aroma
c-3-Hexanol	Green grass aroma

Until recently, the apple concentrate producers around the world have had little economic incentive to refine their essence recovery methods nor have they cared about the quality of the raw fruit used in essence production. The distillation process naturally recovers any lighter volatiles including ethyl alcohol. Care must be exercised so as not to recover and keep essence from fermented juice, spoiled, or over age fruit. Early evaporation systems with essence recovery were required to register with the Bureau of Alcohol, Tobacco, and Firearms (ATF). This requirement was discontinued in July 1982 (27 CFR Parts 18 to 240) as apple juice processors had demonstrated that their goal was to produce good quality concentrate, not alcohol.

Through the previously mentioned component research it was also confirmed the desirable volatiles in apples decrease significantly in storage. Apple juice produced from late season cold storage or CA stored apples will not produce the typical "fresh" apple aroma.

18.5 PROCESSED APPLE PRODUCTS

In 1992 approximately 45% of the total U.S. raw apple crop was utilized for processing. Canned applesauce and apple slices rank second to apple juice in importance among processed apple products. This represented 738,100 tons or 13.7% of the total U.S. apple crop (International Apple Institute Clinic, 1993). Of the processing apples, an average of 75% are used for applesauce, 12% for slices, and 12% for other canned products such as apple pie filling, whole baked apples, and spiced apple products. Of the processed apples, 7.2% are dried (USDA/AMS, 1992). The major geographical areas processing canned apple products in the U.S. are the Appalachian area (North Carolina, Virginia, and West Virginia) and Pennsylvania, followed by Michigan, New York, and the West. The Appalachian region produces about 40% of the processed canned product; New York, 20%; Michigan, 17%; and Washington, 11% (Marketing Northwest Apples, 1992).

18.5.1 Apples for Processing

Most all apple cultivars can be used for processing applesauce but only a few are considered ideal. Quality attributes in raw apples that produce a high quality finished product are described by LaBelle (1981). Desirable characteristics in apples for applesauce include high sugar solids, high acid, aromatic, bright golden or white flesh, variable grain or texture, and sufficient water-holding capacity. In the Appalachian region the most important sauce-type apples are York Imperial, Golden Delicious, Jonathan, Stayman, Rome, and Winesap. New York uses primarily Rhode Island Greening, Northern Spy, Twenty Ounce, Cortland, and to a lesser extent, Mutsu and Monroe. In the western states, particularly California, Gravenstein and Yellow Newtown are used, along with Granny Smith and Golden Delicious. McIntosh, though not considered an ideal sauce apple, is used in the Northeast because it is so plentiful. McIntosh is generally blended with three or four other cultivars, a common technique used by processors to maintain a uniform product in taste and texture.

Processing operations for applesauce and frozen and canned apple slices are summarized in Figure 18.6. A typical apple blend for applesauce might be primarily York (more than 50%) with Golden Delicious and Rome, each contributing a lesser percentage. Nearly 100% of McIntosh sauce is made for the New England market. For many years Northern Spy was a favorite of processors in Michigan and the Northeast but production of this cultivar has decreased significantly in recent years because of poor productivity. Jonathan is more commonly used for processing applesauce in Michigan. Rome is a popular cultivar in a number of regions because the tree yields a heavy crop and because the apple's shape is well suited to mechanical peeling. However, for applesauce, Rome is less desirable than most cultivars because of poor flesh color (Way and McLellan, 1989). Sauce made with a high percentage of Rome apples will have an off-color and weak, runny texture. Processors in the Appalachian region consider York the ideal processing apple. York has a very firm creamy yellow flesh producing a high quality sauce with grainy texture and good color. The fruit resists bruising and stores exceptionally well, characters favored by processors. York apples have a small core and thus yield a high percentage of processed product when peeled, cored, and trimmed (Rollins, 1989).

Golden Delicious, a popular fresh-market apple, is also processed in large quantities. Its high soluble solids and resistance to oxidative browning of the flesh make it attractive for sauce and slicing. Applesauce produced from Goldens in the Pacific Northwest exhibits a runny consistency due to the higher moisture content of the apples grown with extensive irrigation programs. It is often necessary to sweeten this applesauce with dry sugar rather than syrup to improve the consistency.

Apples for canned slices must be firm, maintain integrity of the flesh when sliced, and have good color. York, Stayman, Golden Delicious, Northern Spy, Rhode Island Greening, Yellow Newtown, and Jonathan are preferred for making slices. Sweetness is less important in making slices than in sauce. Regardless of whether apples are for sauce or slices the most important factors are fruit quality and maturity. Eastern sound and mature Delicious apples can produce a high-quality processed apple slice (Childers, 1983).

Huehn (1987) characterized the "ideal" processing apple as: a perfect sphere; 3 in. in diameter with a small core; thin, light-colored skin; firm flesh; pressure test of 89 N October 1st; 67 N about June 1st; from common storage; high, minimum 13° Brix; soluble solids; mildly acidic, 0.2 to 0.25%; and of pleasing taste, such as Northern Spy, with a long supple stem strongly attached to the fruiting spur until the day of harvest at which time it could be easily detached. If such an apple existed, processors would probably emphasize freedom from defects, size, and shape in their grade and pricing structure.

Apples for applesauce, slices, and other canned products are received and handled by the processor similarly. When a load of fruit is received, a representative sample is taken for grading and testing. The standard tests include flesh firmness, soluble solids (brix), acid, defects, and decay. Processing apples are graded after peeling into categories based on the percentage trim waste and presence of major defects: U.S. No. 1 — less than 5% trim waste; No. 2 — 5 to 12% waste; cider — more than 12% trim waste; and Culls — less than 2 1/4 in. size and without major defects. Prices paid to the grower are based on grade and size; large fruit commands a premium price. Some processors also downgrade for bruises. Fresh bruises are generally not considered serious because they do not interfere with the finished product; however, if the fruit is stored, bruised tissue becomes corky and may appear as a defect in the finished product. Tests to predict the quality of finished product from raw-product indices have not been too successful (Wiley and Thompson, 1960; Wiley and Toldby, 1960).

Apples for processing are dumped in water, blended at dumping, washed, size graded, peeled, cored, inspected for defects, and trimmed before delivery to the designated processing line. See the apple processing flowchart. Automatic peeling and coring machines have replaced the once

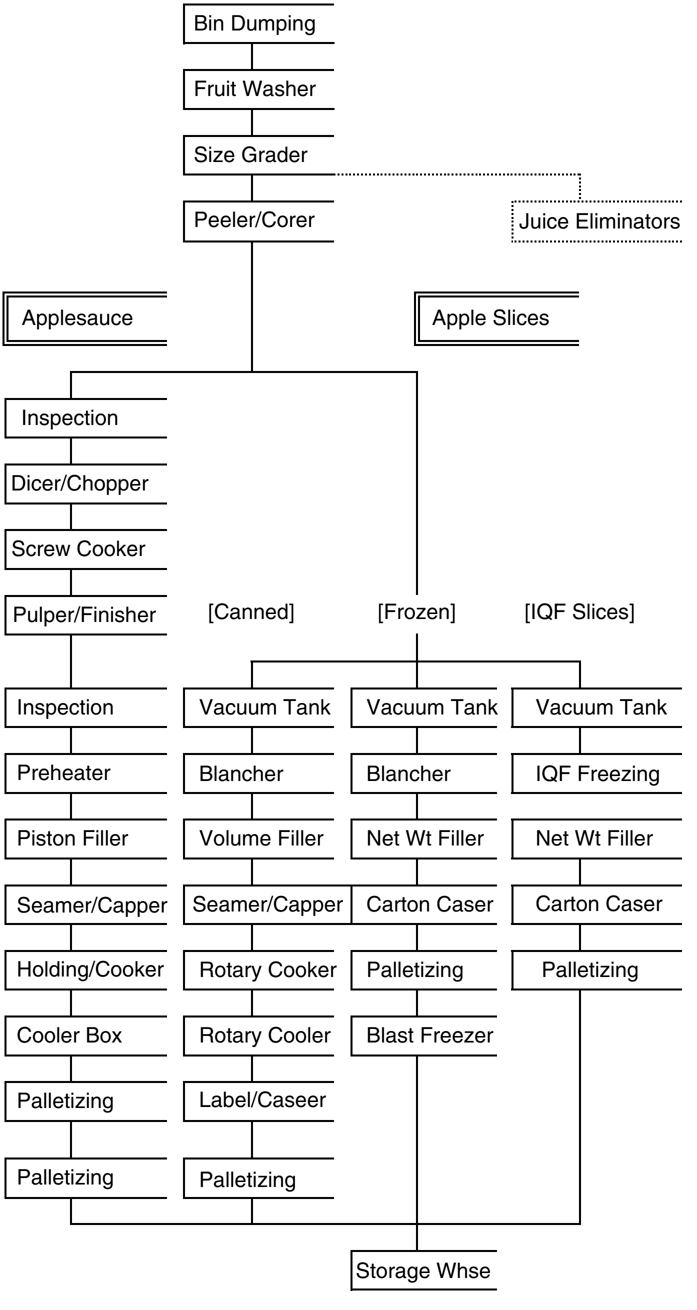

FIGURE 18.6 Apple processing flowchart.

common labor intensive hand-fed peelers. Automatic peelers require more uniform sized, firm fruit because soft fruit tends to spin off these peelers. Some processors use sodium hydroxide (NaOH) or potassium hydroxide (KOH), chemical peelers that produce a reduced trim waste. Another method used by some processors relies on high-pressure steam for peeling.

Labor shortages and higher production costs have encouraged apple processing plants to become highly automated. Electronics has enabled a number of hand labor tasks to be automated (Cogley, 1976) including defect elimination. The potential for using robotics in several facets of apple processing has been described (Yang and O'Connor, 1984).

18.5.2 Applesauce

Apples previously selected and prepared for sauce are diced or chopped and fed to a stainless steel screw type cooker, either live steam injected or steam jacketed. Sugar, either liquid blend or dry, and other desired ingredients are added into the sauce just before cooking. Liquid sugar is preferred because it imparts a desirable "sheen" to the finished applesauce appearance. Cooking to a temperature of between 93 and 98°C for about 4 to 5 min softens the fruit tissue and inactivates the polyphenoloxidase that is responsible for enzymatic browning. Time, temperature, and raw product input must be controlled to produce sauce of good texture, color, and consistency.

After cooking, applesauce is passed through a pulper with a 0.065- to 0.125-in. "finishing" screen that removes defects and defines texture as smooth or grainy. Large screens produce a more grainy sauce. Baby food sauce is "finished" with fine, 0.033 in. screens to a very smooth texture. The hot applesauce is poured over a flat plastic sheet with back lighting and inspected for defects. Any defects such as specks, peel, blossoms, or stems are removed by hand, using a flexible vacuum tube (Cogley, 1976).

The inspected applesauce is preheated to 90°C and piston-filled into glass jars or metal cans immediately. Applesauce must be closed at a temperature of 88°C in the seamer or capper. To insure a vacuum in the container, a jet of steam may be passed over the top of the container just prior to sealing. As the steam condenses, a vacuum is created in the container. This step is important in cans to prevent headspace detinning. The containers are held for 1 to 2 min prior to cooling to insure sterilization of the lids or caps. Water is cooled in draper belt, walking beam, or reel coolers to an average of 35 to 40°C to prevent "stack cooking" in the warehouse.

The finished product may be conveyed to the labeler and/or caser prior to palletizing. Alternately, the containers may be conveyed to a palletizing machine where they are "bright stacked," unlabeled for completing future private label orders. Some processors pack aseptic individual molded plastic single-serving size containers.

In addition to regular applesauce, many processors produce specialty products such as natural, no sugar added, "chunky," cinnamon, or a mixture of applesauce and other fruit such as apricot, peach, or cherry.

18.5.3 Sliced Apples

The dumping, washing, grading, peeling, and coring steps for processing apple slices are similar to those used for sauce production with a few notable exceptions. Slice packs generally consist of a single cultivar, thus eliminating the need for blending. Apple slice texture is very important. Therefore, apples with firm flesh and high quality are desired. Consistency of slice size can be controlled by using fruit from within a preselected size range. The slicing operation is usually an integral part of the peeling and coring process where the apples are sliced into 12 to 16 pieces in the coring section. After slicing, the apples are inspected for defects such as blossom or calyx, carpel tissue, skin, and bruises and are conveyed over a shaker screen to remove small chips. The slices must be handled quickly at this point to avoid enzymatic browning.

Apple slices contain about 25% occluded oxygen that is removed by vacuum treatment. The apple slices are placed in a vessel that is sealed and a 27- to 29-in. Hg vacuum drawn. The vacuum is broken by the injection of water, salt, ascorbic acid, and/or sugar. The apple slices are then steam blanched to soften and to allow specified container fill. Several automated systems to vacuum treat and blanch apple slices have been described (Ellett, 1968 and Keifer, 1963). From the blancher, the slices are filled hot, 77 to 82°C, into cans (sizes 303, $2^1/_2$, or No. 10). The slices are normally over-filled into cans from premeasuring pockets. An automatic plunger gently pushes the over-fill volume into the can.

The cans are closed with a steam-vacuum process after adding hot water or syrup to insure there is no entrapped air. Some processors use the steam flow closing method. A jet of live steam is passed over the top of the can immediately prior to applying the lid to insure a vacuum will be developed.

The canned apples must be processed immediately after closing to a can center temperature of 82.2°C; there are several types of sterilizers available, Batch retort vessels, and continuous rotary cookers that operate either at atmospheric or pressurized conditions. Immediately after sterilizing, the cans should be cooled at 37 to 40°C to prevent "stack burn" or loss of product color in storage.

Refrigerated, frozen, or dehydrofrozen apple slices, representing only about 15% of the apples processed, are prepared much like canned apple slices except they are not heat processed. To prevent enzymatic browning, sliced raw product is subjected to one of several available antibrowning treatments.

Apple slices to be bulk frozen are vacuum treated and blanched in the same manner as canned apple slices. From the blancher, the apples are filled into 30-lb tins or poly-lined boxes by an automatic particulate net weight filler. The tins or boxes are then sealed, frozen and stored frozen at –17°C or lower.

Individually quick frozen (IQF) apple slices are usually treated with a sodium bisulfate bath after inspection. The slices are then filled into vacuum tanks where the vacuum is pulled and broken with a brine or ascorbic acid solution. From the vacuum tank, the apples pass through an IQF unit where the slices are individually frozen. Various freezing mediums can be used: the apple slices are subjected to nitrogen (N_2) or carbon dioxide (CO_2) on a metal draper type belt. The freezing air is forced upward through a perforated tray that fluidizes the product, plus acts as a freezing medium. From the freezing unit, the slices are filled into tins or poly-lined boxes and stored frozen at –17°C or below.

Dehydrofrozen apple slices are dehydrated and frozen to less than 50% of their original weight and volume. The dehydrofrozen slices are packed in cardboard containers or large metal cans with polyethylene liners and rapidly frozen in forced-air freezers before storing. Frozen slices are thawed then soaked in a combined solution of sugar, $CaCl_2$, and ascorbic acid or SO_2. The advantage in processed dehydrofrozen slices over regular frozen slices have been noted by Hall (Hall, 1989b).

Fresh and refrigerated sliced apples are desired by many bakeries in the manufacture of their products. From the slicing and inspection operations, the apple slices are normally treated with 0.2 to 0.4% SO_2 alone or in combination with 0.1 to 0.2% $CaCl_2$. Ascorbic acid has been substituted for SO_2 with good results (Ponting et al., 1972). Calcium-treated apples appear to resist enzymatic browning and microbial spoilage better than non-Ca treated slices (Hall, 1989b). Fresh slices, if blanched, will resist browning up to 48 h; however, blanching does result in loss of sugar, acid, and flavor that can produce a blander product. The treated slices are passed over a shaker screen and packed into 30-lb poly-lined boxes for shipment. This type of product is usually shipped and used in a very short period of time.

Apple-pie filling is another preparation of apple slices. Varieties preferred in Michigan for good quality pie filling are Ida Red, Jonathon, Empire, Spy, and York of medium-firmness, with 12 to 16 pressure test. As given previously in this section, the apples are selected, peeled, cored, and sliced into 12 or 16 segments. The slices are vacuum treated in a brine solution to inhibit polyphenoloxidase enzyme activity that causes browning. The treated slices are filled into containers by volume. A precooked slurry mixture of water, corn syrup or sugar, starch, and spice is poured into the cans and rapidly occupies any air spaces in the container. Precooking of the slurry activates the starch, causing it to gel or set slightly as it cools. The container is closed and is conveyed to the retort cooker where it is cooked to render it commercially sterile, to tenderize the apples, and to set the starch slurry. The containers are cooled to about 37°C to allow evaporation of the water from the container and to avoid any continued cooking. The cooled containers are either labeled and cased or "bright" stacked on pallets to be labeled later.

18.6 DRIED APPLE PRODUCTS

Drying has been used for centuries to preserve food products. Dried apples are convenient to handle, store, and use (Somogyi and Luh, 1986). Under proper storage conditions they are almost immune to spoilage.

Dried apple products are prepared from sound, properly ripened fruit that has been peeled, sorted, trimmed, and cut into the desired piece size prior to drying. Most good processing cultivars are acceptable for drying. A desirable characteristic in apples for drying is a high sugar–water ratio (Smock and Neubert, 1950). Delicious apples, either Golden or Red, are generally recognized by industry as superior for drying. Sulfur dioxide (SO_2) is the primary agent used to control enzyme activity and preserve the color of dried apple tissue. A number of factors affect drying including size and geometry of pieces, temperature, humidity, air velocity and pressure within the drier, and wet-bulb depression. Hall (1989a) has presented a detailed description of equipment and methods for drying apples.

Evaporated apples and dehydrated apples are the two types of dried apple products recognized under U.S. standards. Evaporated apples, also called *regular moisture* and *dried,* are cut to desired size and dried to average not more than 24% moisture by weight. Evaporated apples are either cut to rings, pie pieces, or dices prior to drying; "fresh cut"; or sliced to rings then dried to 24% moisture prior to cutting to the desired "dry cut" dimensions. Unsulfured evaporated apples should average not more than 20% moisture. Packaging is usually in fiber board boxes of 40 lb net weight. Evaporated apples can be stored for short periods of time, less than three months, at ambient, room temperatures in a dry atmosphere. For prolonged storage, 7°C or less is required. Unsulfured evaporated apples require 4 to 5°C cold storage. The end usage, process, size, and style of cut will dictate the correct reconstitution ratio. Evaporated apples will generally fully reconstitute with one part apple in five parts water by weight.

Dehydrated apples, also called low moisture apples, are cut to desired sizes, pie pieces, dices, flakes, or granules prior to drying to not more than $3^1/_2$% moisture by weight. A variation of this is a flake powder prepared from pureed, sieved applesauce then dried to $3^1/_2$% moisture on a rotary drum drier. Only 300 ppm maximum SO_2 is necessary to prevent color deterioration in apple-flake powders. To prevent caking, 0.5% maximum calcium stearate may be added. Packaging is generally in fiber board boxes with a net weight from 15 to 40 lb, depending upon the product density. Dehydrated apples should be stored in a cool, less than room temperature, dry atmosphere. The end usage, process, size, and style of cut will dictate the correct reconstitution ratio. Dehydrated apples will generally fully reconstitute with one part apple in six parts water by weight.

Maximum allowable SO_2 level in dried apple products in the U.S. is 1000 ppm; maximum 500 ppm is allowed in the European Community (EC).

A unique method for producing dehydrated apples is "explosion puffing," developed by the USDA, Agricultural Research Service. In this process, partially dehydrated apple pieces are heated in a closed rotating cylindrical container called a "gun" until the internal pressure has reached a predetermined value. At this point the gun is discharged instantly to atmospheric pressure producing a highly porous piece of apple tissue. For more details see Eisenhardt et al. (1964) and Sullivan et al. (1980).

Evaporated and dehydrated apples are used in many baking, cereal, and snack applications. Low moisture apples also make an excellent substitute for other fruit and berries in dry products. The neutral flavored low moisture apple is color dyed then impregnated with the desired fruit or berry flavor. This apple product has gained wide acceptance in the breakfast cereal industry around the world.

18.7 SPECIALTY APPLE PRODUCTS

Specialty apple products usually require more time and hand labor than applesauce or apple slice products. Less than 1% of the processed apple volume is in this specialty category. Examples of specialty apple products are whole baked or glazed apples, spiced apple rings, spiced crabapples, apple butter, and apple jelly.

Baked and glazed apples require large, $2^3/_4$ to 3 in. firm, symmetrical fruit such as Rhode Island Greening, Rome, or Stayman. These apples are cored, partially peeled, and baked at 176.6°C either by the short method in the can or by the long method before canning (Wiley and Binkley, 1989). A 40 to 50° Brix syrup is used as a cooking or filling media. The canned, sealed product should be processed to a center temperature of 87.7 to 90.5°C, then cooled to about 37°C.

Spiced apple rings are used as a garnishment. The apples are cored and sliced on the apple peeler to about $^3/_8$ in. thick, and then smaller rings and end pieces are sorted out, prior to blanching, to remove the air. The apple slices are filled into jars and covered with a hot, 40 to 42° Brix seasoned syrup and processed at 87.7°C for 20 to 30 min, then cooled. A typical syrup formula for apple rings: to 80 gal of hot water in a steam kettle, add 7 to 8 oz of coloring (either FD&C 90% Lime Green Shade or FD&C Red 40); mix the color well and add 400 lb of sugar; add additional water to a volume of 100 gal and heat to 87.7°C; and finally add either peppermint or cinnamon flavoring. The flavoring mix can be obtained from any of the spice or flavor manufacturers.

Apple butter is processed much like applesauce except a slower batch cooking in swept-surface, steam-jacketed kettles is used to produce a thicker, carmelized, more stable product. Fresh, whole, small apples are usually used but "tailings" (peel waste) and lower quality fruit may also be used in making pulp for apple butter. More sugar is used in this process than in applesauce. A typical apple butter formula: to 100 gal of apple pulp, add 30 gal of 44° Brix apple concentrate, 150 lb of sugar and spice with 8 oz of ground cinnamon, 4 oz of ground cloves, and 4 oz of ground allspice. The final cooked down product should be about 45% solids. Fill into containers as with applesauce.

Apple jelly is made from apple juice concentrate. Federal regulations dictate the amount of fruit solids required. When concentrate is used, it is necessary to use sufficient concentrate to provide the amount of apple solids normally obtained from single strength juice. Example: for 165 lb of a 65% soluable solids "45 to 55" apple jelly, the basic formula would be 15.6 lb of 70° Brix apple juice concentrate, about 8 gal or 65 lb of water, 12 oz of 150 grade citrus pectin (slow set), and 100 lb of sugar. Adjust the pH to between 3.0 and 3.2 with a citric acid solution. The pectin should be dispersed in water. The water may be adjusted so very little cooking is needed to reach the desired jelly soluable solids.

18.8 QUALITY CONTROL

Good process quality programs are essential to provide assurance that a safe, sound, wholesome product is shipped to the consumer. These programs can provide both financial and other intangible benefits, such as improving operating efficiencies and reducing waste.

Quality control is maintained throughout processing, beginning with information on growers' pesticide programs and maturity of fruit, then blending as it relates to finished product specifications, on-line measurements such as trim and coring efficiency, filling volumes, and processing and cooling temperatures. Finally, there is the container condition for consideration, including closing, head-space, and labeling quality. Finished products are examined and tested to insure commercial sterility and buyers' specifications, plus maintenance of the U.S. standards for grades of canned apple products, when applicable.

The microbiology of apple products is generally restricted to yeasts, molds, and aciduric bacteria capable of growth at the low pH of apple products (Swanson, 1989). The previously mentioned micotoxin, patulin, can be avoided by using only whole, clean, sound fruit that has been carefully handled. The microorganisms found in apples are heat sensitive and usually destroyed when recommended processing times and temperatures are attained. Viability is further restricted by the reduced water activity of apple juice concentration and apple dehydration.

To conform to FDA standards, products should be filled to not less than 90% of the overflow capacity of the container. One exception is glass containers with an over-flow capacity of $6^1/_2$ fluid ounces or less, where the fill is not less than 85%. For a more complete description of the FDA Standards of Identity, Quality and Fill or the USDA Grade Standards, refer to the Almanac of the Canning, Freezing, and Preserving Industries.

There are several approaches to quality management available today. Statistical Quality Control (SQC), Total Quality Management (TQM), Hazard Analysis and Critical Control Points (HACCP), and, in international trade, International Organization for Standardization (ISO or ISO 9000).

18.9 NUTRITIONAL VALUE OF APPLES

Almost everyone has heard the expression "An apple a day keeps the doctor away," reflecting the notion that apples and apple products are nutritious. Fresh apples are considered moderate in energy value and low in protein, lipid, and vitamin content. There are about 242 cal/lb of apples as purchased. Carbohydrates are the principal nutrient of apples and apples are a good source of dietary fiber, while low in fat and sodium. It is evident from Table 18.5 that apples and apple products are sources of potassium, phosphorus, calcium, vitamin A, and ascorbic acid. Fructose, sucrose, and glucose are the most abundant sugars. The nutritive value of most processed apple products is similar to the fresh raw product. Dried or dehydrated apples have a higher energy value per gram tissue due to the concentration of sugars (Lee and Mattick, 1989). The USDA tabulated in *Composition of Foods,* Handbook No. 8, 1975, that apples are about 84.5% water, 1% fiber, 14.5% carbohydrates, 0.6% fat, and 0.2% protein.

In recent years there has been growing interest in the presence of polyphenolic antioxidants in various fruit and vegetable crops. Apples are a rich source of these beneficial phytonutrients that epidemiological studies have found to be associated with protection against aging diseases and cancers. Two recent publications (van der Sluis et al., 2001; van der Sluis et al., 2002) have highlighted the effects of apple cultivar, harvest year, storage conditions and apple-juice processing methods on the concentration of polyphenolics. Four apple cultivars (Jonagold, Golden Delicious, Cox's Orange, and Elstar) that can be utilized either fresh or as processed products were compared with regard to flavonol, catechins, phloridzin, and chlorogenic acid concentrations and antioxidant activity. Jonagold apples had both the highest polyphenolic concentration and antioxidant activity. There were no differences related to season in the 3-year study nor did long term storage under refrigerated air or controlled atmospheres affect either polyphenolic concentration or antioxidant activity.

Juice produced from Jonagold apples by either pulping or straight pressing had a significantly lower level of both polyphenolics and antioxidant activity. Polyphenolic levels were reduced to between 50% (chlorogenic acid) and 3% (catechins) of the concentrations in fresh apples. Antioxidant activity was reduced to only 10 to 13% of that in fresh apples by the juice-making process. It was determined that most of the polyphenolic antioxidants were retained in the pomace or press cake and were not extracted into the juice. These results have ramifications for apple juice processors interested in producing juice with higher nutritional value. It may be of interest to either market cloudy apple juice as a superior product or at least to utilize the pomace as a source of polyphenolic antioxidants.

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TABLE 18.5
Nutrients in the Edible Portion of 1 lb of Fruit as Purchased

Apples	Food Energy (calories)	Protein (grams)	Fat (grams)	Carbohydrate (grams)	Calcium (mgm)	Phosphorus (mgm)	Iron (mgm)	Sodium (mgm)	Potassium (mgm)	Vitamin A value (IU)	Thiamin (mgm)	Riboflavin (mgm)	Niacin (mgm)	Ascorbic acid (mgm)
Raw Fresh	242	0.8	2.5	60.5	29	42	1.3	4	459	380	0.12	0.08	0.3	16
Applesauce[a]	413	0.9	0.5	108.0	18	23	2.3	9	295	180	0.08	0.05	0.2	5
Unsweet	186	0.9	0.9	49.0	18	23	2.3	9	354	180	0.08	0.05	0.2	5
Apple juice	213	0.5	0.1	54.0	27	41	2.7	5	458	—	0.03	0.07	0.4	4
Frozen sliced[a]	422	0.9	0.5	110.2	23	27	2.3	64	308	80	0.05	0.14	1.0	33
Applebutter[a]	844	1.8	3.6	212.3	64	163	3.2	9	1143	0	0.05	0.09	0.7	9
Dried, 24%	1,247	4.5	7.3	325.7	141	236	7.3	23	2,581	—	0.26	0.53	2.3	48
Dehydrated 2%	1,601	6.4	9.1	417.8	181	299	9.1	32	3,311	—	0.02	0.26	2.9	47

[a] With sugar.

Source: USFDA, Composition of Foods, raw, processed, prepared, in *Agriculture Handbook No. 8*. U.S. Department of Agriculture. 1975.

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