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# 31
# Strawberries and Raspberries

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## Section 1: Strawberries

### INTRODUCTION

Strawberry is a member of Rosaceae (Rose) family and *Fragaria* (F) genus. The wild European strawberry is mainly from *Fragaria vesca* L., the cultivated varieties are hybrids from *F. chilosensis* and *F. virginiana*. The strawberry, *F. amanassa*, is cultivated worldwide (Menager et al., 2004) but grows well in a cool, moist climate. Fruits grow on stems in groups of three and are hand harvested at full ripeness. Strawberries are not true berries in the "botanical sense" but an aggregate fruit. Roots produce new plants that bear fruits. The flesh of strawberry is an enlarged receptacle and unlike other berries, seeds (achenes) are attached to the skin surface.

### STRAWBERRY VARIETIES

The three major classes of strawberries (Anon, 2004a, b, c; Hanson and Hancock, 2000) are (a) June-bearer or short-day, (b) Ever-bearer, and (c) Day-neutral. The differences are in the day length conditions that stimulate flower bud formation. June-bearers initiate flower buds in the fall when days are relatively short, and bear the following spring. Ever-bearers initiate flowers and fruits during the long days of summer. Day-neutrals can initiate flower buds during any day length. Fruit characteristics such as color, flavor, firmness, size, shape, yield, storage, transport, processing, and end use quality are considered while selecting a particular variety. Some of the key characteristics of selected varieties of strawberries are shown below.

(1) Annapolis: Early to midseason variety, large berries, light-red appearance, soft texture, mild flavor, suitable for freezing, and fresh consumption.
(2) Earliglow: Early to midseason variety, excellent flavor and color, fruit size tends to decrease as the season progresses, suitable for retailing and freezing.
(3) Hood: Developed from ORUS 2315 & Puget Beauty, early to midseason, medium to large fruit, round, conic, glossy, excellent internal and external color, medium firm, high solids and high acidity, low drip loss, suitable for retailing and processing.
(4) Totem: The predominant cultivar in Pacific Northwest, United States, developed from Puget Beauty & Northwest, early to midseason, large fruit, fully red internal and external color, high solids, good flavor, color, and firmness, suitable for retailing and processing.
(5) Jewel: Mid- to late season, developed from *Senga Sengana*, large berry, good flavor, bright and glossy red, good for freezing.
(6) Allstar: Mid- to late season, orange-red color, large conical, medium firm, mild sweet flavor, processing quality fair.
(7) Selva: A California variety, ever-bearer or a Day-neutral cultivar released in 1983, large berry, exceptionally firm but flavor is regarded as fair to poor unless fully ripened, skin is bright red and glossy, dessert and processing quality fair.
(8) Chandler: Ever-bearer, large berry, medium firmness, good dessert and processing quality.
(9) Camarosa: Large conical-shaped fruit, good color, excellent taste and firm texture, good for fresh market, slicing/dicing.
(10) Senga Sengana: Developed in 1954, deep red color, medium size, soft texture, round shape, excellent freeze–thaw stability. This variety is grown in Poland where the majority of strawberries are processed and sold as frozen.

## PRODUCTION AND CONSUMPTION

Food and Agriculture Organization (FAO) lists 71 countries where strawberries were grown in 2003 (FAO, 2004). Poland had the highest acreage (about 44,000 ha) under strawberry production, followed by the United States (20,000 ha). The total world production of strawberries in 2003 was approximately 3.2 million metric tons, of which the United States produced about 1.0 million metric ton. Spain was the second leading producer. During 1999–2003, the world production of strawberries expanded only slightly (less than 2%); however, in the United States, production increased by about 14%. Outside the United States, Mexico, Turkey, and Russia have also shown good growth in strawberry production (Table 31.1). In Poland, the production has declined perhaps because of lower yield compared to other major producers. However, Poland is still the leading frozen strawberry exporter, followed by Mexico, China, the United States, Spain, and Germany (FAS-USDA, 2004).

Strawberry is a popular dessert fruit (extensively used in ice cream and other desserts). It is also used in

**Table 31.1.** Strawberry Production in Leading Countries and World Aggregate

| | Production (Mt) | | | | |
|---|---|---|---|---|---|
| Country | 1999 | 2000 | 2001 | 2002 | 2003 |
| USA | 831,250 | 862,828 | 749,520 | 893,670 | 944,740 |
| Spain | 377,527 | 343,105 | 326,000 | 328,700 | 262,500 |
| Japan | 203,100 | 205,300 | 208,600 | 210,500 | 208,000 |
| Italy | 185,852 | 195,661 | 184,314 | 150,890 | 154,826 |
| South Korea | 152,481 | 180,501 | 202,966 | 209,938 | 209,938 |
| Poland | 178,211 | 171,314 | 241,118 | 154,830 | 131,332 |
| Russia | 115,000 | 128,000 | 125,000 | 130,000 | 145,000 |
| Turkey | 129,000 | 130,000 | 117,000 | 120,000 | 145,000 |
| Mexico | 137,736 | 141,130 | 130,688 | 142,245 | 150,261 |
| Germany | 109,194 | 104,276 | 110,130 | 110,000 | 95,278 |
| World | 3,159,062 | 3,274,341 | 3,178,752 | 3,248,840 | 3,198,689 |

*Source:* FAO (2004).

fruit fillings, jellies and jams, energy bars, breakfast cereals, etc. In the United States, it is the leading berry with per capita consumption of about 3.0 kg. About 75% of strawberries produced in the United States are utilized for fresh market, whereas the remaining 25% are frozen or processed into other products (USDA, 2003).

It is important to note that simply washing with water and freezing fruits do not ensure food safety. In the case of strawberries, hepatitis A (a viral liver disease) outbreak occurred in some parts of the United States in 1997, from consumption of sliced, frozen strawberries. However, washing strawberries with chlorinated water has been reported to significantly cut levels of bacteria, hepatitis A virus, and other viruses that indicate possible contamination by animal or human wastes (Williamson, 1998).

## PHYSICOCHEMICAL AND NUTRITIONAL QUALITIES

### SUGARS, ORGANIC ACIDS, AND FLAVORS

Flavor of strawberry is related to a balance between sugars and organic acids that are naturally present. Macias-Rodriguez et al. (2002) reported that the main soluble carbohydrates in strawberries are glucose, fructose, and sucrose, followed by myoinositol. However, among individual sugars, sucrose content decreases with storage time (Perez and Sanz, 2001; Castro et al., 2002). Among organic acids, citric acid predominates, although malic acid and ascorbic acid are also present. According to Perez and Sanz (2001), malic acid content decreases sharply during strawberry ripening. Table 31.2 gives quality-related data on Camarosa and Selva strawberries (Castro et al., 2002). The sucrose content of Camarosa strawberries is almost twice that of Selva. However, Selva strawberry has twice as much reducing sugars, glucose, and fructose than the Camarosa strawberry. In both varieties, the predominant sugar is glucose. In terms of acidity, Camarosa has more citric and malic acids than Selva. The ascorbic acid content was similar in both varieties. Sugars contribute to flavor and color development during fruit ripening and are the major nonvolatile flavor components in strawberries (Bood and Zabetakis, 2002). In a study of 24 strawberry cultivars (Azodanlou et al., 2003), correlation between overall acceptance and sensory attributes of aroma, sweetness, and juiciness were shown to be 0.94, 0.87, and 0.49, respectively. Although aroma showed highest correlation ($r = 0.94$) with overall acceptance, sweetness ($r = 0.87$) measured as Brix was also a good indicator of quality.

The fruity, green grass, and other flavor notes of strawberries emanate from esters, alcohols, and carbonyl compounds, which are biosynthesized from amino acid metabolism. Important flavor compounds in strawberries are methyl butanoate, ethyl butanoate, methyl hexanoate, cis-3-hexenyl acetate, and linalool. Menager et al. (2004) showed that in an immature strawberry fruit (cv. Cigaline), $C_6$ compounds, in particular (E)-hexen-2-al, was the main component; furanones and esters were not detected

**Table 31.2.** Characteristics of Selected Strawberries (without stem) 48 h after Harvest and Freezer Storage (−18°C) for 6 months

| | Camarosa | | Selva | |
|---|---|---|---|---|
| Characteristics | Harvest | Freezer Storage | Harvest | Freezer Storage |
| Total solids (g/100 g) | 9.12 ± 0.20 | 6.68 ± 0.05 | 12.69 ± 0.09 | 7.4 ± 0.59 |
| Sucrose (mg/g) | 9.09 ± 0.00 | 0.00 ± 0.00 | 5.83 ± 0.20 | 2.78 ± 0.02 |
| Fructose (mg/g) | 30.73 ± 0.03 | 16.75 ± 0.97 | 55.12 ± 4.25 | 32.83 ± 0.36 |
| Glucose (mg/g) | 35.37 ± 0.5 | 21.95 ± 0.67 | 67.58 ± 1.11 | 33.78 ± 0.36 |
| Citric acid (mg/g) | 7.65 ± 0.25 | 9.26 ± 0.85 | 5.19 ± 0.37 | 6.15 ± 0.14 |
| Malic acid (mg/g) | 1.17 ± 0.07 | 1.18 ± 0.02 | ND | 4.92 ± 0.45 |
| Ascorbic acid (mg/g) | 0.36 ± 0.01 | 0.06 ± 0.01 | 0.38 ± 0.05 | 0.17 ± 0.00 |
| Total phenolics (mg/g) | 6.35 ± 0.29 | 8.32 ± 0.05 | 9.83 ± 0.18 | 7.74 ± 0.10 |
| Anthocyanins (mg/100 g) | 48.19 ± 1.4 | 61.36 ± 1.66 | 29.98 ± 0.98 | 28.99 ± 0.21 |
| Ash (g/100 g) | 0.48 ± 0.01 | 0.52 ± 0.00 | 0.33 ± 0.01 | 0.34 ± 0.02 |
| pH | 3.66 | 3.50 | 3.73 | 3.52 |

ND = Not detected.
*Source:* Castro et al. (2002).

**Table 31.3.** Flavor Volatiles in Strawberries (Cv. Cigaline)

| Compound | Concentration (μg/kg) At Physiological Maturity (42 days After Anthesis) Mean | Range |
|---|---|---|
| *Furanones* | | |
| Mesifurane | 1917 | 1462–2435 |
| Furaneol | 6217 | 5707–6841 |
| *Esters* | | |
| Methyl butanoate | 755 | 625–887 |
| Methyl 2-methylbutanoate | 209 | 54–321 |
| Butyl acetate | 61 | 41–90 |
| Isoamyl acetate | 56 | 21–87 |
| Methyl hexanoate | 105 | 23–145 |
| Hexyl acetate | 48 | 41–57 |
| (E)-hex-2-enyl acetate | 210 | 96–321 |
| *Terpenes* | | |
| (E)-furan linalool oxide | 30 | 15–47 |
| (Z)-furan linalool oxide | 37 | 24–52 |
| $C_6$ *Compounds* | | |
| Hexanal | 43 | 19–71 |
| (E)-hex-2-enal | 370 | 299–462 |
| Hexanol | 211 | 39–410 |
| *Lactones* | | |
| γ-decalactone | 2887 | 2540–3279 |
| *Carbonyls* | | |
| Pentan-2-one | 704 | 558–812 |
| Acids | | |
| 2-methylpropanoic acid | 2130 | 1698–2562 |
| Butanoic acid | 4103 | 3905–4560 |
| 2-methyl butanoic acid | 9810 | 8750–10,450 |
| Hexanoic acid | 12,744 | 11,240–14,414 |
| Alcohols | | |
| Benzyl alcohol | 40 | 19–61 |

*Source:* Menager et al. (2004)

until the fruit was about half red in color. As ripening progressed, $C_6$ compounds decreased but furanones, acids, lactones, and esters increased. At full maturity, the concentration levels of furaneol and mesifurane were more than that of the other flavor compounds (Table 31.3). Organic cultivation practices had no effect on strawberry volatilities (Hakala et al., 2002).

## Color, Phenolic Compounds, and Antioxidant Capacity

The bright red color of fresh strawberries is due to anthocyanins, pelargonidin-3-glucoside, pelargonidin 3-rutinoside, and cyaniding-3-glucoside (Garzon and Wrolstad, 2002; Wang et al., 2002; Kosar et al., 2004). Strawberry varieties differ in their anthocyanin content. For example, the total anthocyanin content of Camarosa strawberries was about 60% more than that of the Selva varieties at the harvest. Freezing strawberries caused little loss in color, in fact the anthocyanin content of Camarosa strawberries increased by 27% after 6 months of frozen storage (Table 31.2). However, maintaining the natural color is a challenge in processed strawberries. About 20% of pelargonidin-3-glucoside was reported to be lost at refrigerated storage in 9 days (Zabetakis et al., 2000). Rwabahizi and Wrolstad (1988) reported lower anthocyanin concentration in strawberry juice clarified by ultrafiltration (possibly due to the removal of high molecular weight constituents) than those processed by conventional filtration. Similarly, strawberry concentrates made from juices clarified by conventional filtration were perceived better in appearance than those clarified by ultrafiltration. As would be expected, there were higher anthocyanin losses (from thermal processing) in strawberry concentrates than in juices (Garzon and Wrolstad, 2002).

Cano et al. (1997) investigated high-pressure treatment (50–400 Mpa) combined with heat (20–60°C) to inactivate color and flavor affecting enzymes polyphenol oxidase (PPO) and peroxidase (POD) in strawberry puree. The high-pressure treatments caused 60% and 25% loss of PPO and POD activities, respectively. However, Rwabahizi and Wrolstad (1988) indicated that browning during concentration and storage of strawberry juice was nonenzymatic. The pH optima of strawberry PPO were reported to be 5.5 with catechol and 4.5 with 4-methylcatechol (Wesche-ebeling and Montgomery, 1990). Since the pH of strawberry is generally below 4.5 (Table 31.2), PPO may not have a significant role in browning of strawberry products. Addition of ascorbic acid was shown to have a negative effect on the color of strawberry syrup (Skrede et al., 1992). It is believed that hydrogen peroxide produced as a result of ascorbic acid degradation affects anthocyanins.

Table 31.4 gives data on phenolic compounds (benzoates, ρ-coumaric acid, ellagic acid, anthocyanins, flavonoids, and myricetin) found in strawberries (Kosar et al., 2004). The concentration of anthocyanins, pelargonidin-3-glucoside was about 17 times higher than cyanidin-3-glucoside, and ellagic acid concentration decreased as the strawberries ripened. In a study on the effects of environmental factors and cultural practices on quality, it was shown that strawberries grown on a hill plasticulture had higher levels of soluble solids, total sugar, ascorbic acid, citric acid, flavonoids, and antioxidant capacities than those grown on a flat matted-row. The concentration of ellagic acid glucoside (believed to be better absorbed than ellagic acid) was slightly higher as well (Wang et al., 2002).

Wang and Lin (2000) reported antioxidant capacity, anthocyanins, and total phenolics of strawberries at different stages of fruit maturity, and in strawberry juices. Table 31.5 shows a typical data on these for Allstar strawberry variety. At full ripeness, antioxidant activity was the highest (12.0 μmole TE/g on wet basis). Wu et al. (2004) analyzed both lipids and water-soluble antioxidants and found more water soluble (35.41 μmole TE/g, as is basis; % moisture = 91.1) than lipid soluble (0.36 μmole TE/g) antioxidant activity in market samples of strawberries. The difference between maximum and minimum values of total antioxidant capacity was 12.51 μmole TE/g, which is close to 12.0 μmole TE/g reported by Wang and Lin (2000).

## Nutritional Quality

Besides, phenolic constituents and antioxidant properties, which have created interests in plant products, strawberries are a good source of potassium and vitamin C. However, in fresh strawberries, 26–50% ascorbic acid is lost when cut surfaces are exposed to air for 5 min. Even freezing strawberries did not stop loss of ascorbic acid (Table 31.2). A study of two important strawberry cultivars, Camarosa and Selva, showed that the latter variety not only had higher resistance to thawing, but also exhibited higher contents of ascorbic acid, protein, and total phenolics (Castro et al., 2002).

Table 31.6 shows nutritional values per 100 g in strawberries and its products. Fresh and frozen strawberries and strawberry juices are low calorie products. Even the sugar-infused and dried strawberries, which are used as snacks and as ingredients in various foods, on an ounce (28 g) serving size basis, contribute less than 100 calories. These products are also a good source of dietary fiber.

**Table 31.4.** Phenolic Compounds in Strawberries (mg/100 g Frozen Fruit)

| Compounds | Camarosa | Chandler |
|---|---|---|
| ρ-OH-benzoic acid | 0.15 ± 0.02 | 0.26 ± 0.02 |
| ρ-coumaric acid | 2.07 ± 0.04 | 1.38 ± 0.02 |
| Ellagic acid | 0.36 ± 0.02 | 0.42 ± 0.01 |
| Cyanidin-3-glucoside | 0.72 ± 0.01 | 0.95 ± 0.01 |
| Pelargonidin-3-glucoside | 11.72 ± 0.12 | 16.24 ± 0.08 |
| Myricetin | 0.69 ± 0.01 | 0.36 ± 0.03 |

*Source:* Kosar et al. (2004)

**Table 31.5.** Oxygen Radical Absorbance Capacity (ORAC), Anthocyanins, and Total Phenolics in Strawberry (Cv. Allstar) at Different Maturity and in Strawberry Juice

| Strawberry | ORAC[a] (μmole of TE/g) | Anthocyanins[b] (mg/100 g) | Total Phenolics[c] (mg/100 g) |
|---|---|---|---|
| *50% Red berry* | | | |
| Wet basis | 9.7 ± 0.2 | 16.2 ± 2.1 | 91.0 ± 1.9 |
| Dry basis | 81.8 ± 1.8 | 143.4 ± 18.6 | 916.0 ± 11.5 |
| *80% Red berry* | | | |
| Wet basis | 10.4 ± 0.3 | 23.6 ± 2.3 | 94.0 ± 0.8 |
| Dry basis | 95.4 ± 2.7 | 216.5 ± 21.1 | 971.0 ± 6.9 |
| *Full Red berry* | | | |
| Wet basis | 12.0 ± 0.5 | 38.9 ± 1.1 | 96.0 ± 0.9 |
| Dry basis | 118.8 ± 4.9 | 385.1 ± 10.9 | 946.0 ± 8.9 |
| *Strawberry juice* | | | |
| Wet basis | 12.2 ± 0.3 | 23.3 ± 1.3 | 95.0 ± 1.1 |
| Dry basis | 120.8 ± 2.9 | 230.7 ± 12.8 | 943.0 ± 10.4 |

*Source:* Wang and Lin (2000)

[a]μmoles of Trolox equivalent.

[b]As milligrams of pelargonidin-3-glucoside.

[c]As gallic acid equivalent.

**Table 31.6.** Nutritional Values of Strawberries

| Nutrients/100 g | Fresh Strawberry[a] | Frozen Strawberry[a] | Strawberry Juice[a] | Infused Dried Strawberry[b] | Dehydrated Strawberry[c] |
|---|---|---|---|---|---|
| Calories (Kcal) | 32.0 | 35.0 | 30.0 | 325.0 | 345.0 |
| Calories from fat (Kcal) | 2.7 | 1.0 | 3.60 | 9.36 | 38.34 |
| Total fat (g) | 0.30 | 0.11 | 0.40 | 1.04 | 4.26 |
| Saturated fat (g) | 0.015 | 0.01 | 0.02 | 0.10 | NA |
| Polyunsaturated fat (g) | 0.155 | 0.05 | 0.19 | 0.50 | NA |
| Monounsaturated fat (g) | 0.043 | 0.01 | 0.05 | 0.10 | NA |
| Trans fat (g) | 0.0 | 0.0 | 0.0 | <0.10 | 0.0 |
| Cholesterol (mg) | 0.0 | 0.0 | 0.0 | <0.10 | 0.0 |
| Sodium (mg) | 1.0 | 2.0 | 1.0 | 25.0 | 12.0 |
| Potassium (mg) | 153.0 | 148.0 | 166.0 | 382.0 | 1909.0 |
| Total carbohydrate (g) | 7.68 | 9.13 | 7.00 | 82.20 | 80.70 |
| Total fiber (g) | 2.0 | 2.10 | 0.10 | 10.20 | 6.10 |
| Soluble fiber (g) | 0.80 | 0.65 | 0.03 | 3.80 | NA |
| Insoluble fiber (g) | 1.20 | 1.45 | 0.07 | 6.40 | NA |
| Sugars (g) | 4.66 | 6.96 | 6.90 | 70.30 | 73.90 |
| Protein (g) | 0.67 | 0.43 | 0.60 | 3.16 | 7.02 |
| Calcium (mg) | 16.0 | 16.0 | 14.00 | 160.0 | 161.0 |
| Vitamin C (mg) | 58.8 | 41.20 | 28.40 | 95.0 | 652.10 |
| Vitamin A (IU) | 12.0 | 45.0 | 20.0 | 41.0 | 311.00 |
| Water (g) | 90.95 | 90.0 | 91.60 | 12.0 | 3.0 |

NA = Not available.

[a]USDA.

[b]Graceland Fruit Inc., Frankfort, Michigan, U.S.

[c]Esha Nutritional database, Salem, Oregon, U.S.

## STRAWBERRY PRODUCTS

Developments in storage, transportation, and processing have made possible the year-round availability of strawberries and strawberry products. As has been indicated before, about 25% of strawberries produced are frozen or processed into other products. There are several processed product options including juice, jelly, jam, fruit fillings, variegates, various dried strawberries, etc. Increasingly, consumers are looking for fresh fruit-like qualities (color, flavor, and texture) and nutritional values in processed products. Beginning with steps involved for frozen strawberries, selected processing methods and products are discussed here.

### Frozen Strawberries

Strawberries are generally frozen either block or individually quick frozen (IQF) after the removal of stems and cap at the point of production. The preparatory steps after harvesting consist of precooling (about 0–2°C) the harvested fruit to maintain color, texture, and flavor and to remove field heat; air classifying to remove leaves, field debris, etc.; removing berry caps, leaves, etc.; quick rinsing or washing, preferably with about 20 ppm chlorinated water; inspecting and grading for size and defects; quick freezing the fruit individually (at about −40°C) in a blast air freeze tunnel; and packaging and storing under frozen temperatures. Quick freezing helps in minimizing large ice crystal formation, which are believed to cause drip losses on thawing. The IQF strawberries are free flowing, and hold their color and shape better. Thus, they are preferred as raw materials for manufacturing value-added products like freeze dried or infused dried strawberries.

### Frozen Sugar Pack Strawberries

In this case, sugar is added to the strawberries after removing stems and caps, and the product is stored frozen at below −18°C. For example, 4 + 1 (80% fruit + 20% sugar) and 7 + 3 (70% fruit + 30% sugar) pack strawberries in a 30 lb pail will contain 24 lb strawberries and 6 lb sugar, and 21 lb strawberries and 9 lb sugar, respectively. These products are used in many applications. However, before using in dairy products such as yogurt and ice cream, they should be pasteurized.

### Strawberry Puree

Purees can utilize fruits, which are not sold as fresh or frozen. They generally form raw material for making fruit fillings, variegates, juices, jams, etc. For making strawberry puree, it is not critical to remove berry cap. The preparatory steps of precooling, washing, and grading are essentially the same as described for frozen strawberries. Subsequently, the berries are cut/chopped and passed through different dimension sieves, depending on whether the product contains seeds or not. For example, to make strawberry puree with and without seeds, the diameter of sieve opening would be, 1.33 ± 0.19 mm and 0.76 ± 0.076 mm, respectively. Then the puree is pasteurized by heating at 88°C for about 2 min and cooled to about 15°C. Following processing, the product is quality analyzed, filled in containers, and stored frozen. The single-pack strawberry puree will have almost the same Brix as that of the starting raw fruit. However, concentrated strawberry purees of about 28 Brix are also available. The puree may be treated with enzymes and filtered before concentration to provide better quality puree for use in jams, juices, etc. Sweeteners such as sucrose can also be added to the puree to adjust Brix as per the end use.

### Strawberry Juice and Concentrate

Garzon and Wrolstad (2002) described a process, which is similar to commercial production, to manufacture strawberry juice and concentrate. The processing steps are as below (it may be noted that a Bucher press or a centrifuge can also be used for separation of strawberry juice):

(1) Thaw IQF or block frozen strawberries overnight at room temperature.
(2) Crush with a hammer mill (Model D Commuting Machine; W.J. Fitzpatrick Co., Chicago, IL, USA) equipped with a circular pore mesh, 1.27 cm in diameter, at a speed of 182 rpm.
(3) Depectinize in a steam-jacketed kettle at 50°C for 2 h by adding Pectinase, Rapidase® Super BE @ 3 ml/kg (Gist-Brocades Laboratories, Charlotte, NC, USA). Conduct Alcohol test for pectin (1:1 juice–isopropanol + 1% HCl; incubate further until the test for pectin is negative).
(4) Press, after adding 1% rice hull as press aid, at 300 kPa for 30 min using a Willmes press bag, Type 60 (Moffet Co., San Jose, CA, USA).

(5) Filter at 27.6 kPa with 2% diatomaceous earth as filtering aid and using a multipad filtration unit (Strassburger KG, Westhofen, Worms, Germany); the unit equipped with a pad filter SWK supra 2600 (Scott Laboratories, Inc., San Rafael, CA, USA).
(6) Pasteurize at 88°C for 1 min using a tubular heater with screws, Wingear type (Model 200WU; Winsmith Co., Springville, NY, USA).
(7) Concentrate to 65 Brix using Centritherm evaporator, type CT-1B (Alfa Laval, Lund, Sweden). Two passes are needed to achieve the final concentration, and the juice can reach a temperature as high as 80°C.

### Strawberry Jelly, Preserve, and Jam

Among various fruit jelly and jams, strawberry jelly (45 parts by weight of fruit juice ingredients to 55 parts of sweeteners, see Code of Federal Regulations 2003: CFR 21, 150.140) and preserves and jams (47 parts by weight of fruit ingredient to each 55 parts by weight of sweeteners, see CFR 21, 150.160) are on the top of the list because of their unique color, flavor, and taste. The soluble solid contents of finished jelly and jam are not less than 65%.

### Stabilized Frozen Strawberries

Processed frozen products such as stabilized frozen (strawberry fruit pieces are combined with a syrup matrix containing sweeteners, pectin, starch, and carrageenan or other gums, and heat processed) or infused frozen strawberries for use in ice cream, sorbets, yogurts, and bakery products are made by infusing and pasteurizing whole or sliced strawberries (Sinha, 1998) in sugar syrup or other types of sweeteners. These products typically are about 35 Brix, so that they do not become hard at freezer temperatures. The products are pasteurized and can be added directly to the formulations.

### Infused Dried Strawberries

As the name implies, infused dried strawberries are produced by infusing strawberries to a range of sweetness level, prior to drying. These products have found better acceptance in the ingredient market than the traditionally dried strawberries. It has been reported that osmotic treatment of strawberries at atmospheric pressure had a positive effect on flavor (Escriche et al., 2000).

### Freeze Dried Strawberries

Freeze dried strawberries have found great success as fruit ingredients in ready-to-eat cereals. Freeze drying retains the typical bright red color of strawberries better than other drying methods. Besides, the freeze dried strawberries have crisp texture and their low bulk density (approximately about 0.1 g/cc) is closer to ready-to-eat cereals. Both whole and sliced strawberries can be processed as freeze dried. However, this product requires special laminated packaging to maintain the crisp texture.

## REFERENCES

Anon. 2004a. Strawberry Fact Sheet. California Strawberry Commission (http://www.calstrawberry.com).

Anon. 2004b. Strawberry Varieties. Oregon Strawberry Commission (http://www.oregon-strawberries.org).

Anon. 2004c. Strawberry Variety Information. Shasta Nursery, Inc. (http://www.rootstock.com/variety.html).

Azodanlou R, Darbellay C, Luisier J, Villettaz J, Amado R. 2003. Quality assessment of strawberries (Fragaria Species). J Agric Food Chem 51:715–21.

Bood KC, Zabetakis I. 2002. The biosynthesis of strawberry flavor (II): Biosynthetic and molecular biology studies. J Food Sci 67:2–8.

Cano MP, Hernandez A, De Ancos B. 1997. High pressure and temperature effects on enzyme inactivation in strawberry and orange products. J Food Sci 62:85–8.

Castro I, Goncalves O, Teixeira, JA, Vicente, AA. 2002. Comparative study of Selva and Camarosa strawberries for the commercial market. J Food Sci 67:2132–7.

Code of Federal Regulations (CFR). 2003. CFR 21. (http://www.cfsan.fda.gov).

Escriche I, Chiralt A, Moreno J, Serra JA. 2000. Influence of blanching-osmotic dehydration treatments on volatile fractions of strawberries. J Food Sci 65:1107–11.

FAO. 2004. FAO Crop Database. Food and Agriculture Organization (http://www.faostat.fao.org).

FAS-USDA. 2004. Foreign Agriculture Service, United State Department of Agriculture (http://www.fas.usda.gov).

Garzon GA, Wrolstad RE. 2002. Comparison of the stability of pelargonidin-based anthocyanins in strawberry juice and concentrate. J Food Sci 67:1288–99.

Hakala MA, Lapvetelainen AT, Kallio HP. 2002. Volatile compounds of selected strawberry varieties

analyzed by purge-and-trap headspace GC-MS. J Agric Food Chem 50:1133–42.
Hanson E, Hancock J. 2000. Strawberry varieties for Michigan. Michigan State University Extension (http://www.msue.msu.edu/vanburen/e-839.htm).
Kosar M, Kafkas E, Paydas S, Baser K. 2004. Phenolic composition of strawberry genotypes at different maturation stages. J Agric Food Chem 52:1586–9.
Macias-Rodriguez L, Quero E, Lopez MG. 2002. Carbohydrate differences in strawberry crowns and fruit (Fragaria x ananassa) during plant development. J Agric Food Chem 50:3317–21.
Menager I, Jost M, Aubert C. 2004. Changes in physicochemical characteristics and volatile constituents of strawberry (Cv. Cigaline) during maturation. J Agric Food Chem 52:1248–54.
Perez AG, Sanz, C. 2001. Effect of high-oxygen and high-carbon-dioxide atmospheres on strawberry flavor and other quality traits. J Agric Food Chem 49:2370–5.
Rwabahizi S, Wrolstad RE. 1988. Effects of mold contamination and ultrafiltration on the color stability of strawberry juice and concentrate. J Food Sci 53:857–61, 872.
Sinha NK. 1998. Infused-dried and processed frozen fruits as food ingredients. Cereal Foods World 43:699–701.
Skrede G, Wrolstad RE, Lea P, Enersen G. 1992. Color stability of strawberry and blackcurrant syrup. J Food Sci 57:172–7.
USDA. 2003. Fruit and Tree Nuts Outlook. United States Department of Agriculture, Economic Research Service (http://www.ers.usda.gov/publication/FTS/yearbook03/fts2003.pdf)
Wang SY, Lin HS. 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and development stage. J Agric Food Chem 48:140–6.
Wang SY, Zheng W, Galletta GJ. 2002. Cultural system affects fruit quality and antioxidant capacity in strawberries. J Agric Food Chem 50:6534–42.
Wesche-ebeling P, Montgomery MW, 1990. Strawberry polyphenoloxidase: Extraction and partial characterization. J Food Sci 55:1320–24, 1351.
Williamson D. 1998. Chlorinated Water Cuts Strawberry Contamination. http://www.clo2.com/reading/waternews/strawb.html
Wu X, Beecher GR, Holden JM, Haytowitz DB, Gebhardt SE, Prior RL. 2004. Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. J Agric Food Chem 52: 4026–37.
Zabetakis I, Leclerc D, Kajda P. 2000. The effect of high hydrostatic pressure on the strawberry anthocyanins. J Agric Food Chem 48:2749–54.

# Section 2: Raspberries

## INTRODUCTION

Raspberries (also termed "Brambles") belong to the genus *Rubus* and family Rosaceae (rose). Cultivated raspberries have been derived from the wild red raspberries (*Rubus ideaus*) and black raspberries (*Rubus occidentalis*). These soft and delicate fruits with small seeds and hollow core are made of aggregates of hairy drupelets, which adhere to one another. The origin of red raspberry dates back to 4th century A.D. at Mt. Ida, in the Caucasus Mountains of Asia Minor. The British are credited with popularizing and improving red raspberry cultivation throughout the Middle Ages. The black raspberry is indigenous to North America (Anon, 2004a).

Raspberry plants are a biennial, summer or autumn bearing, and grow on leafy canes (thus called caneberries) in temperate regions of the world. The root system of this plant is perennial and capable of living for several years where there is a good drainage system. All cultivars, especially new plants, are susceptible to root rots. Red and black raspberries dominate commercial production; however, purple and yellow raspberries are also grown for the fresh market.

## PRODUCTION AND CONSUMPTION

In recent years, studies linking antioxidative properties having beneficial effect against degenerative diseases have fueled demand for raspberries and other fruits. Raspberry production in the top 10 leading countries of the world is given in Table 31.7. During the last 5 years, the world production has increased by about 9%. Russia leads in raspberry production. In Serbia, where fruits are grown in valleys 400–800 m above sea level, raspberry production has increased by almost 60% during this period. The production has also doubled in Spain. In the United States, raspberry production is concentrated in the states of Oregon and Washington. In Washington State, the leading red raspberry variety is "Meeker," which is a late season, summer fruiting raspberry. In Oregon, "Willamette" an early fruiting, medium-small fruit, typically sold for processing is popular. It is also one of the few cultivars resistant to raspberry bushy dwarf virus infection that causes lower yield and crumbly fruits.

More than 80% of raspberries produced in Oregon and Washington are red raspberries and the remaining black raspberries, Oregon being a leader in

**Table 31.7.** Raspberries Production in Leading Countries and World Aggregate

| | Production (Mt) | | | | |
|---|---|---|---|---|---|
| Country | 1999 | 2000 | 2001 | 2002 | 2003 |
| 1. Russian Federation | 100,000 | 102,000 | 90,000 | 100,000 | 108,000 |
| 2. Serbia and Montenegro | 60,000 | 56,059 | 77,781 | 94,366 | 94,400 |
| 3. USA | 49,351 | 51,256 | 54,885 | 52,889 | 53,000 |
| 4. Poland | 43,195 | 39,727 | 44,818 | 45,026 | 45,000 |
| 5. Germany | 35,500 | 33,700 | 29,200 | 29,000 | 29,000 |
| 6. Canada | 15,650 | 16,247 | 11,658 | 14,291 | 13,900 |
| 7. Hungry | 22,277 | 19,804 | 13,306 | 10,000 | 10,000 |
| 8. France | 7020 | 8743 | 8549 | 7999 | 8000 |
| 9. Romania | 4287 | 2390 | 3990 | 4000 | 4500 |
| 10. Spain | 2000 | 2500 | 3200 | 4500 | 4500 |
| 11. World | 381,572 | 378,787 | 381,787 | 407,155 | 415,836 |

*Source:* FAO (2004).

**Table 31.8.** Red Raspberry and Black Raspberry Production in Oregon and Washington States of United States

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| | | | (1000 lb) | | |
| **Red raspberry** | | | | | |
| *Oregon* | | | | | |
| Production | 14,200 | 13,650 | 14,500 | 15,900 | 10,300 |
| *Utilization* | | | | | |
| Fresh | 800 | 700 | 1300 | 1300 | 1,700 |
| Processed | 13,400 | 12,950 | 13,200 | 14,600 | 8,600 |
| *Washington* | | | | | |
| Production | 60,300 | 69,350 | 71,250 | 75,050 | 74,100 |
| *Utilization* | | | | | |
| Fresh | 2300 | 4000 | 4000 | 3550 | 5200 |
| Processed | 58,000 | 65,350 | 67,250 | 71,500 | 68,900 |
| **Black raspberry** | | | | | |
| *Oregon* | | | | | |
| Production | 2600 | 2900 | 3800 | 3810 | 2920 |
| *Utilization* | | | | | |
| Fresh | 20 | 10 | 30 | 10 | 20 |
| Processed | 2580 | 2890 | 3800 | 3800 | 2900 |

*Source:* USDA (2003).

production of the latter. In the United States, about 85% of the raspberries produced are processed (Table 31.8). Generally, machine-harvested fruit is used for processing, and handpicked fruits are sold for fresh consumption or to premium quality market. Machine harvesting has become critical to enhance production; however, it requires coordination and synergies of efforts among fruit growers, plant breeders, and other researchers to develop new varieties and use of acceptable insect control practices suitable for machine harvesting of raspberries. Often, the machine-harvested fruits are used for fruit juice and puree/pulp market. There is a growing demand for superior quality whole IQF and frozen fruits in terms of color, shape, size, and freedom from diseases and insects for use as dessert fruit and other applications.

## PHYSICOCHEMICAL AND NUTRITIONAL QUALITIES

Raspberries are slightly tart but juicy fruits. Bushway et al. (1992) studied physical, chemical, and sensory characteristics of five red raspberry cultivars (Table 31.9). They indicated that titratable acidity, sucrose, and total sugar could serve as a predictor of flavor in frozen raspberries. The "Newburg" cultivar with highest concentration of sucrose and total sugars was most preferred by panelists, and the traditional red color in frozen raspberry cultivars was liked more than the deeper purple color of cultivar "Boyne."

Typical physicochemical properties of selected raspberry cultivars grown are given in Table 31.10 (Ancos et al., 2000a, b). Cultivars "Autumn Bliss" and "Heritage" are early season (harvested in May), "Zeva" and "Rubi," late season (harvested in autumn, October) berries. Generally, the late season cultivars have higher °Brix, anthocyanins, total phenolics, and ellagic acid content. The main color pigments found in the four raspberry cultivars were cyaniding-based anthocyanins (sophoroside, glucoside, glucorutinoside, and rutinoside) and pelargonidin derivatives (sophroside and glucoside). Late season cultivars showed greater anthocyanin content than early season fruits.

### COLOR PIGMENTS OF RASPBERRIES

Boyles and Wrolstad (1993) indicated average Brix of red raspberry cultivars "Willamette" and "Meeker" to be approximately 10.0; their average anthocyanin contents (mg/l cyanidin-3-glucoside) were 620 and 320, respectively. The high pigment concentration of "Willamette" is a desirable characteristic, which increased with ripeness. Approximately, 90–97% of anthocyanins were composed of cyanidin and 3–10% pelargonidin. Cyanidin-3-sophoroside (cyd-3-sop) was the pigment with highest concentration in red raspberry varieties "Willamette" and "Meeker." However, Polish cultivars "Veten" and "Norna" showed much lower concentration of cyd-3-sop.

Processing raspberries can change the quantitative distribution of pigments through partial hydrolysis of glycosidic substituents and/or anthocyanin polymerization. Low total anthocyanin and elevated levels of cyanidin-3-glucoside indicate degradation due to processing and storage. Black raspberries can be distinguished from red raspberries by xylose containing pigments, cyanidin-3-sambubioside, and cyanidin-3-xylosylrutinoside (Torre and Barritt, 1977). Recent studies (Wada and Ou, 2002) report 0.65 mg/g and 5.89 mg/g anthocyanins in red and black raspberries, respectively. These authors indicated that red raspberries anthocyanins were composed of cyanidin 3,5-diglucoside (89.25%) and cyanidin 3-glucoside (10.75%); black raspberries were made of cyanidin3-(6′-p-coumaryl) sambubioside (22%) and cyanidin 3-(6′-p-coumaryl) glucoside (77.0%).

### FLAVOR OF RASPBERRIES

Volatile components contributing to the fresh raspberry aroma are α-pinene, citral, β-pinene, phellanderrene, linalool, α-ionone, carryophyllene, and β-ionene. Freezing raspberries for 12 months had

**Table 31.9.** Sugar and Color Profiles of Selected Red Raspberry Cultivars from Maine in United States

| | Cultivars | | | | |
|---|---|---|---|---|---|
| Characteristics | Boyne | Festival | Latham | Newburg | Taylor |
| % Total sugar | 6.14 | 4.84 | 6.10 | 7.68 | 6.30 |
| % Fructose | 2.28 | 2.09 | 3.71 | 3.01 | 2.67 |
| % Glucose | 1.93 | 1.88 | 2.39 | 2.43 | 2.28 |
| % Sucrose | 1.93 | 0.87 | 0.00 | 2.24 | 1.35 |
| % Soluble solids | 9.6 | 10.0 | 10.6 | 12.3 | 11.1 |
| % Acidity (as citric) | 1.46 | 1.85 | 1.43 | 1.81 | 2.09 |
| pH | 3.04 | 3.02 | 3.05 | 3.13 | 2.98 |
| *Hunter color* | | | | | |
| L | 18.25 | 17.58 | 21.17 | 21.27 | 20.59 |
| a/b | 17.97 | 22.93 | 22.40 | 22.46 | 22.53 |

*Source:* Bushway et al. (1992).

**Table 31.10.** Physicochemical Characteristics of Selected Raspberry Cultivars

| Characteristics | Cultivars | | | |
|---|---|---|---|---|
| | Autumn Bliss | Heritage | Zeva | Rubi |
| Brix | 9.26 | 9.50 | 10.54 | 10.00 |
| Acidity (% citric) | 1.67 | 1.76 | 1.75 | 2.32 |
| pH | 3.65 | 3.87 | 2.88 | 2.65 |
| Total solids (%) | 15.23 | 14.69 | 16.33 | 17.98 |
| Moisture (%) | 84.77 | 85.31 | 83.67 | 82.02 |
| Total anthocyanin (mg/100 g) | 31.13 | 37.04 | 116.27 | 96.08 |
| Total phenolics (mg gallic acid/100 g) | 121.4 | 113.7 | 177.6 | 155.6 |
| Ellagic acid (mg/100 g) | 20.8 | 21.7 | 24.4 | 23.4 |
| Vitamin C (mg/100 g) | 30.2 | 22.0 | 29.6 | 31.0 |
| *Color* | | | | |
| L | 25.89 | 25.80 | 18.29 | 21.26 |
| a | 35.03 | 34.98 | 33.03 | 35.10 |
| b | 19.05 | 18.34 | 17.78 | 18.63 |
| 11. *Flavor volatiles (%)* | | | | |
| Caryophyllene | 37.7 | 15.0 | 25.9 | 20.8 |
| α-ionone | 33.5 | 32.8 | 43.1 | 23.9 |
| β-ionone | 20.7 | 19.3 | 13.3 | 17.3 |
| α-pinene | 2.9 | 13.2 | 2.9 | 17.0 |
| Citral | 0.4 | 0.7 | 0.7 | 1.6 |
| β-pinene | 0.5 | 1.2 | 0.5 | 1.7 |
| phellandrene | 2.4 | 11.4 | 12.9 | 10.4 |
| Linalool | 1.8 | 6.3 | 0.4 | 7.1 |

*Source:* Ancos et al. (2000a, b).

little affect on flavor volatiles; however, color pigment cyanidin 3-glucoside decreased by about 26.0% in late season raspberry cultivar "Zeva" (Ancos et al., 2000b).

## Phenolic Components and Antioxidant Capacity

Liu et al. (2002) reported that the color of raspberry juice correlated with the total phenolic, flavonoid, and anthocyanin content of raspberry. The "Heritage" variety contained the highest total phenolic content (512.7 ± 4.7 mg/100 g), followed by "Kiwigold" (451.1 ± 4.5 mg/100 g), "Goldie" (427.5 ± 7.5 mg/100 g), and "Anne" (359.2 ± 3.4 mg/100 g). Similarly, the "Heritage" had the highest total flavonoids (103 ± 2.0 mg/100 g), followed by "Kiwigold" (87.3 ± 1.8 mg/100 g), "Goldie" (84.2 ± 1.8 mg/100 g), and "Anne" (63.5 ± 0.7 mg/100 g). Raspberry extracts equivalent to 50 mg of "Goldie," "Heritage," and "Kiwigold" fruits inhibited the proliferation of HepG2 human liver cancer cells by 89.4% ± 0.1%, 88% ± 0.2%, and 87.6% ± 1.0%, respectively. Variety "Anne" had the lowest antiproliferation activity of the varieties measured (70.3% ± 1.2%). The antioxidant activity of these raspberry varieties showed significant positive correlation ($P < 0.05$) with the total phenolics and flavonoids found in raspberry. However, there was little significant correlation ($P > 0.05$) between antiproliferative activity and the total phenolics/flavonoids, suggesting that other phytochemicals (such as anthocyanins and ellagic acid) may have a role in the antiproliferative activity of raspberries.

Wang and Lin (2000) measured oxygen radical absorbance capacity (ORAC) of juices from black raspberry and red raspberry at different maturities (Table 31.11). As expected, juice made from ripe fruits had higher antioxidant activity than that from green or pink berries; and black raspberry juice had higher antioxidant activity than red raspberry juice. Moyer et al. (2002) reported very high anthocyanin content of 627, 607, and 464 mg/100 g and ORAC values of 104.6, 146.0, 110.3 μmol TE/g in black raspberries cultivars "Munger," "Jewel," and "Earlysweet," respectively.

**Table 31.11.** Average Antioxidant Activity (ORAC), Anthocyanin Content, and Total Phenolic Content in Raspberry Juice of Different Maturity Raspberries (on a Fresh Weight Basis)

| Raspberry | ORAC (μmol of TE/g) | Anthocyanin (mg/100 g) | Total Phenolics (mg/100 g) |
|---|---|---|---|
| *Red raspberry* | | | |
| Green | 16.5 ± 0.8 | 1.0 ± 0.2 | 181 ± 5.0 |
| Pink | 10.9 ± 0.6 | 7.2 ± 1.2 | 99 ± 1.5 |
| Ripe | 18.2 ± 0.8 | 68.0 ± 3.0 | 234 ± 5.1 |
| *Black Raspberry* | | | |
| Green | 33.7 ± 4.0 | 1.7 ± 0.6 | 338 ± 7.1 |
| Pink | 16.1 ± 0.6 | 22.8 ± 1.4 | 190 ± 3.5 |
| Ripe | 28.2 ± 1.4 | 197.2 ± 8.5 | 267 ± 4.3 |

*Source:* Wang and Lin (2000).

## Ellagic Acid

Phenolic compound ellagic acid, a dimeric derivative of gallic acid, is suggested as an anticarcinogenic/antimutagenic compound. It is present in plants in the form of hydrolyzable tannins called ellagitannins. Ellagitannins are esters of glucose with hexahydroxydiphenic acid and when hydrolyzed ellagic acid and dilactone of hexahydroxydiphenic acid are produced. Initial studies of ellagic acid in rodents at Ohio State University have shown significant prevention and reduction of certain cancers (Funt et al., 2004). When added to cultured cancer cells *in vitro*, ellagic acid is shown to stop cell division and cancer cells eventually die by apoptosis, while sparing normal cells (Anon, 2004b). However, currently, the role of ellagic acid on human cancer patients is inconclusive. A study at Ohio State University (Anon, 2004c) indicated "Heritage" red raspberry with highest amount of ellagic acid in the pulp among several raspberry cultivars. Raspberry seeds generally had higher ellagic acid content than the pulp (Table 31.12).

Wada and Ou (2002) showed total ellagic acid ranging from 47 mg/g in red raspberries to 90 mg/g in black raspberries grown near Salem, Oregon. They indicated that free ellagic acid level was 40–50% of the total ellagic present. Rommel and Wrolstad (1993) reported an average concentration of ellagic acid and its derivatives in experimental and commercial raspberry juice samples as 30 ppm (0.003%) and 52 ppm (0.052%), respectively. Raspberry juice produced by diffusion extraction (where the berries were exposed to high temperature [63°C] for several hours, thus releasing ellagic acid from the cell walls) contained about twice as much ellagic acid as juice made by high-speed centrifugation. The ellagic acid derivatives

**Table 31.12.** Ellagic Acid Content of Raspberries (μg/g Dry Weight)

| | 1997 | | 1998 | |
|---|---|---|---|---|
| | Pulp | Seed | Pulp | Seed |
| *Red cultivars* | | | | |
| Caroline | 36.0 | 173.4 | 52.5 | 799.2 |
| Autumn Bliss | 22.3 | 98.9 | 42.0 | 263.6 |
| Heritage | 40.5 | 105.8 | 39.2 | 467.2 |
| Ruby | 39.7 | 176.4 | 10.0 | 85.6 |
| *Yellow cultivar* | | | | |
| Anne | 11.1 | 177.7 | 7.8 | 60.5 |
| Black cultivar | | | | |
| Jewel | 17.0 | 240.0 | | |

*Source:* Anon (2004c).

(4-arabinosylellagic acid, 4-acetylxylosylellagic acid, and 4-acetylarabinosylellagic acid) with the exception of ellagic acid itself remained quite stable with processing and during 6 months of raspberry jam storage. The initial free ellagic acid content of 10 mg/kg increased twofold with processing into jam, and it continued increasing up to 35 mg/kg after 1 month of storage. Thereafter, a slight decrease was observed until 6 months of storage. The increase in ellagic acid was possibly due to the release of ellagic acid from ellagitannins with heat treatment (Zafrilla et al., 2001).

### Nutritional Quality

Besides having potential antioxidant and anticancer containing components, raspberries and its products are good sources of dietary fiber and potassium. Typical nutritional profile of raspberries and its products according to National Educational and Labeling Act (NELA) is given in Table 31.13.

## RASPBERRY PRODUCTS

Availability of raspberries in IQF, bulk frozen, puree, jam, jelly, juice, concentrated syrups, and dried form enable consumers to enjoy this fruit year round. The postharvest handling, storage, and processing of this fruit generally follow procedures similar to strawberries. Frozen seedless raspberry puree forms a base for many products including stabilized processed products for use in ice cream and sorbet. The raspberry puree, with or without seeds, can be made using sieves of about 1.5–3.2 mm, and 1.1 mm, diameter openings, respectively. Pasteurization and other steps are similar to strawberry puree processing. Single strength seedless raspberry puree is about 10 Brix. However, concentrated raspberry puree of about 28 Brix is also commercially produced for various applications.

Raspberry juice is blended in many beverages where it lends its characteristic flavor, color, and a balance of sweetness and tartness. Essentially similar steps (Boyles and Wrolstad, 1993), as in the case

**Table 31.13.** Nutritional Values of Raspberries

| Nutrients/100 g | Red Raspberry | Black Raspberry | Fresh Raspberry Juice | Infused Dried Red Raspberries[a] | Dehydrated Raspberries |
|---|---|---|---|---|---|
| Calories (Kcal) | 49.00 | 73.00 | 30.0 | 309 | 354 |
| Calories from fat (Kcal) | 5.00 | 13.00 | 0.0 | 14.0 | 35.73 |
| Total fat (g) | 0.55 | 1.42 | 0.00 | 1.52 | 3.97 |
| Saturated fat (g) | 0.02 | NA | 0.00 | 0.2 | NA |
| Polyunsaturated fat (g) | 0.31 | NA | 0.00 | 0.4 | NA |
| Monounsaturated fat (g) | 0.02 | NA | 0.00 | 1.0 | NA |
| Trans fat (g) | 0.0 | 0.00 | 0.00 | <0.10 | 0.00 |
| Cholesterol (mg) | 0.0 | <0.10 | 0.00 | <0.10 | 0.00 |
| Sodium (mg) | 0.0 | 0.00 | 3.00 | 17.0 | 0.00 |
| Potassium (mg) | 152.00 | 199.20 | 153.00 | 162.0 | 1097 |
| Total carbohydrate (g) | 11.60 | 15.67 | 7.14 | 84.0 | 83.50 |
| Total fiber (g) | 6.80 | NA | 0.00 | 16.2 | 21.70 |
| Soluble fiber (g) | 1.22 | NA | 0.00 | 2.1 | NA |
| Insoluble fiber (g) | 5.58 | NA | 0.00 | 14.1 | NA |
| Sugars (g) | 4.80 | NA | 7.14 | 62.0 | 61.80 |
| Protein (g) | 0.91 | 1.49 | 0.31 | 4.0 | 6.57 |
| Calcium (mg) | 22.0 | 29.85 | 18.00 | 72.0 | 159.0 |
| Iron (mg) | 0.57 | 0.90 | 2.60 | 1.82 | 4.12 |
| Vitamin C (mg) | 25.00 | 17.91 | 25.00 | 98.0 | 180.50 |
| Vitamin A (IU) | 130.0 | NA | 66.70 | 76.0 | 939.0 |
| Water (g) | 86.60 | 81.02 | 89.40 | 8.3 | 3.00 |

NA: Not available.

*Source:* Esha Nutritional database, Salem, Oregon, U.S.

[a]Graceland Fruit Inc., Frankfort, Michigan, U.S.

of strawberry juice, are followed to make raspberry juice and concentrates. Raspberry juice concentrates of about 65 Brix, with an acidity of as high as 12%, are commercially available.

Raspberry drying process requires proper handling and use of smaller size IQF fruits because the large fruits have a tendency to breakdown during the process. The drying techniques are essentially similar to that of strawberries and other fruits presented elsewhere in this book.

## REFERENCES

Ancos B, Gonzalez EM, Cano MP. 2000a. Ellagic acid, Vitamin C, and total phenolic contents and radical scavenging capacity affected by freezing and frozen storage in raspberry fruit. J Agric Food Chem 48:4565–70.

Ancos B, Ibanez E, Reglero G, Cano MP. 2000b. Frozen storage effects on anthocyanins and volatile compounds of raspberry fruit. J Agric Food Chem 48:873–9.

Anon. 2004a. Blackberries and Raspberries—Rubus spp (http://www.uga.edu/fruit/rubus.htm).

Anon. 2004b. Ellagic Research (http://www.ellagic-research.org/clinical_studies.htm).

Anon. 2004c. Evaluation of Ellagic acid Content of Ohio Berries—Final Report (http://www.ag.ohio-state.edu/~sfgnet/eacid_final.html).

Boyles MJ, Wrolstad RE. 1993. Anthocyanin composition of red raspberry juice: Influences of cultivar, processing, and environmental factors. J Food Sci 58:1135–41.

Bushway AA, Bushway RH, True RH, Work TM, Bergeron D, Handley DT, Perkins LB. 1992. Comparison of the physical, chemical and sensory characteristics of five raspberry cultivars evaluated fresh and frozen. Fruit Variety J 46:229–34.

FAO. 2004. FAO Crop Database. Food and Agriculture Organization (http://www.faostat.fao.org).

Funt RC, Bash WD, Schwartz SJ, Stoner GD. 2004. Research and Education on Phytochemicals and Neutraceutical Foods. Ohio State University (http://www.ag.ohio-state.edu/~sfgnet/ellagic.htm).

Liu M, Li XQ, Webber C, Lee CY, Brown J, Liu RH. 2002. Antioxidant and antiproliferative activities of raspberries. J Agric Food Chem 50:2926–30.

Moyer RA, Hummer KE, Finn CE, Frei B, Wrolstad RE. 2002. Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: Vaccinium, rubus, and ribes. J Agric Food Chem 50:519–25.

Rommel A, Wrolstad RE. 1993. Ellagic acid content of red raspberry juice as influenced by cultivar, processing, and environmental factors. J Agric Food Chem 41:1951–60.

Torre LC, Barritt BH. 1977. Quantitative evaluation of rubus fruit anthocyanin pigments. J Food Sci 42:488–90.

USDA. 2003. Fruit and Tree Nuts Outlook. United States Department of Agriculture, Economic Research Service (http://www.ers.usda.gov/publication/FTS/yearbook 03/fts2003.pdf).

Wada L, Ou B. 2002. Antioxidant activity and phenolic content of oregon caneberries. J Agric Food Chem 50:3495–500.

Wang SY, Lin H-S. 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry and strawberry varies with cultivar and developmental stage. J Agric Food Chem 48:140–46.

Zafrilla P, Ferreres F, Tomas-Barberan FA. 2001. Effect of processing and storage on the antioxidant ellagic acid derivatives and flavonoids of red raspberry (Rubus idaeus) jams. J Agric Food Chem 49: 3651–55.