CHAPTER 1
Overview of pineapple production, postharvest physiology, processing and nutrition

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1.1 Introduction

Pineapple, Ananas comosus (L.) Merr., is the only species in the Bromeliaceae family grown commercially for its greatly appreciated and nutritional fruit. Production occurs both in the tropics and subtropics. After banana and citrus, it is the third most important fruit in world production. Asia (Thailand, Philippines, Indonesia, India and China), South Central America (Costa Rica and Brazil) and Africa (Nigeria and South Africa) are the main producers. In 2012, Thailand was the world’s largest producer of pineapple, followed by Costa Rica, Brazil and Philippines.

Cultivated types of pineapple are called ‘clones’, since they are vegetatively propagated. The many named clones are classed in 4–5 groups that include ‘Cayenne’, ‘Spanish’, ‘Queen’ and ‘Pernambuco’. Pineapples as non-climacteric fruits should be harvested when ready to eat. Changes in the skin color from green to yellow at the base of the fruit, a minimum soluble solids content of ~12% and a maximum acidity of 1% will assure a baseline flavor that is acceptable to consumers. This delicious tropical fruit is consumed fresh, dehydrated, canned, in juice and jams and contains fiber, bromelain, manganese, copper, vitamin C, vitamin B complex, calcium, zinc and β-carotene. The flesh is free of cholesterol and fat, and low in sodium and calories. Pineapple is the only source of bromelain, a proteolytic enzyme complex used in the pharmaceutical market, beer making and as a meat-tenderizing agent. The consumption of this fruit offers great benefits as it supports the immune system, aids digestion of proteins, alleviates symptoms of the common cold, and strengthens bones. Because of its nutritional properties, texture, and juiciness its use is appropriate at all stages of life.
As with many tropical fruits, pineapples are susceptible to chilling injury and exposure of pineapples to temperatures below 12°C can cause this physiological disorder, depending upon the duration of storage. Therefore, ripe fruit should be stored at 7–10°C, as they are less susceptible than unripe or partially ripe fruit that should be stored at 10–13°C for no more than three to four weeks. Symptoms of chilling injury include dull green wilting and discoloration of leaves (the greening of the properly ripened), translucent or water-soaked flesh, darkening of the heart tissue, increased susceptibility to decay, and wilting and discoloration of the crown leaves.

The stems and leaves of pineapple plants are also a source of fiber which can be processed into paper and cloth with remarkable qualities of thinness, smoothness and pliability. Parts of the plant are used for silage and hay for cattle feed. Processing wastes (shell or core material) and centrifuged solids from juice production are also used as animal feed. Alcoholic beverages can also be made from the juice or nutrient-rich fruit core.

1.1.1 History and origin

Pineapples originated from South America, particularly in the region around Brazil and Paraguay. Laufer (1929) reported that the Native Americans in the lowland tropics consumed this fruit and it was widely distributed in the Americas and the Caribbean prior to the arrival of Columbus (Collins 1960). In 1493 Columbus found the fruit on the island now known as Guadaloupe and called it ‘piña’, due to its resemblance to a pinecone, and brought the ‘exotic’ fruit back to Spain. The antiquity of this fruit, even at that time, is evidenced by the presence of distinct types, all of which were nearly or completely seedless. Its wide use as food, wine and medicine at the time of Columbus’ arrival in the Americas and the absence of recognizable wild progenitors of the cultivated pineapple are further evidence of the pineapple’s antiquity (Collins 1960). Pineapple fruit was a staple of South American Indian feasts and rites related to tribal affirmation. The fruit was spread around the world on sailing ships that carried it for protection against scurvy. The Spanish introduced it into the Philippines early in the 16th century. The pineapple reached England in 1660 and began to be grown in greenhouses in the early 1700s for its fruit and as an ornamental feature. Portuguese traders introduced pineapples into India from the Moluccas in 1548, and also into the east and west coasts of Africa. The plant was growing in China in 1594 and in South Africa about 1655. In 1819 the ‘Cayenne Lisse’ variety (‘Smooth Cayenne’) from French Guyana (South America) was introduced into Europe and spread over the world in the 19th and 20th centuries (Collins 1951) with other varieties; ‘Queen’ and ‘Singapore Spanish’.

Early commercial trade was limited to relatively short transportation routes due to the short shelf life of fresh pineapple. Thus, Florida, the Bahamas, Cuba and Puerto Rico supplied the North American market, and the Azores the European market. In the early 19th century, fresh pineapples were sent from the West Indies to Europe attached to the entire plant (Loudon 1822).
Canning industry started at the beginning of 19th century in South-East Asia, Australia, South Africa, the Caribbean and Kenya. The South-East Asian industry was devastated during the Second World War, and Hawaii gained importance at the end of the 1960s superseded by Côte d'Ivoire, the Philippines and Thailand (Rohrbach et al. 2003). The fresh-fruit market started expanding after the Second World War, because refrigerated sea transport developed and the need for proximity to the market was reduced (Anonymous 2003).

1.1.2 Ecology and regional distribution

Pineapples are tropical plants that can grow in most warm climates with temperatures between 20°C and 36°C. Frost is not well-tolerated, but mild cool weather in winter improves fruit quality and induces flowering. Pineapples can grow up to 1800 meters above sea level, although at the higher elevation the fruit is more acidic (Morton 1987).

Pineapples should be watered regularly to ensure quality fruit production, but they can be harmed if too much water accumulates in the soil due to poor drainage. Because of their stomata and use of the CAM pathway for photosynthesis, pineapples withstand droughts very well for a tropical plant, although fruit mass and yields are reduced (Min & Bartholomew 2005). A well distributed annual rainfall of 839–1742 mm and high relative humidity is important for optimal growth. Pineapple grows well in partial shade. Acidic soil with pH between 4.5 and 5.5 and good internal drainage is ideal, as soil-borne diseases are reduced and iron in the soil become more readily available to the roots of plants. In areas where soil pH is close to neutral, foliar application of FeS_2O_4 is necessary to support normal growth. Inability to obtain iron from an iron-rich soil under certain conditions is a peculiarity of the pineapple not shared by other plants.

Pineapple is one of the most cultivated tropical fruits introduced into warm climates worldwide because of the sweet, desirable fruit. It is believed that the Guarani Indians were the first growers in Brazil and Paraguay, and introduced the pineapples into the Caribbean islands. Christopher Columbus introduced the pineapple to Europe, where it was grown in greenhouses and became a favorite fruit of kings and the wealthy. Charles the II of England had his picture painted receiving a pineapple in 1677.

1.2 Production, trade and consumption trends

1.2.1 World production and leading producers

The world production of pineapples in 2012 was 23.33 million metric tons (MT) and the area planted has similarly increased from 1990 to 2012 (Figure 1.1). From 1990 to 2012, pineapple production almost doubled (97.04% increase, compared to 11.84 million MT in 1990). This increase in production has been consistent over the long-term, with a 27.87% and 34.61% increase during
The area under pineapple cultivation from 1990 to 2012 increased by only 62%, demonstrating that significant increases (about 35%) in production resulted from varietal improvement and adoption of better agricultural practices. Regionally, Asia leads in pineapple production with 10.88 million MT, followed by 8.68 million MT in the Americas (North, Central, and South America), and 3.65 million MT in Africa; these figures accounted for 46.62%, 37.18%, and 15.65% share of the total world production, respectively.

The global demand for pineapple, according to a market survey, is projected to grow, which will result in further increases in its production (CBI 2008). The large agro-multinationals will capture most of the projected growth since they are the major suppliers to the large supermarkets in the EU and North America, the main outlets of pineapple marketing (CBI 2008; Perez & Plattner 2013). In recent years, organic pineapple production has also increased globally due to increased demand for organically grown fruit. For the EU markets, most organic pineapples are produced in Ghana, with an increasing share coming from Costa Rica (CBI 2008). It is to be noted that organic pineapples are still a niche market and organic pineapples must be produced according to organic standards, i.e., without the use of most synthetic chemical pesticides and fertilizers (CBI 2014). Weed control is a major issue in organic pineapple production.

The top-ten pineapple producing countries in 2012 were Thailand, Costa Rica, Brazil, Philippines, Indonesia, India, Nigeria, China, Mexico, and Colombia (Table 1.1). The leading five countries contributed about 50% of
Table 1.1 Leading pineapple producing countries for selected years since 1990 (million metric tons).

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2012</th>
<th>% Share¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>1.865</td>
<td>Thailand</td>
<td>2.248</td>
<td>Brazil</td>
<td>2.206</td>
</tr>
<tr>
<td>Philippines</td>
<td>1.422</td>
<td>Brazil</td>
<td>2.004</td>
<td>Philippines</td>
<td>2.169</td>
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<tr>
<td>Brazil</td>
<td>1.104</td>
<td>Philippines</td>
<td>1.560</td>
<td>Costa Rica</td>
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<tr>
<td>India</td>
<td>0.881</td>
<td>India</td>
<td>1.020</td>
<td>Thailand</td>
<td>1.966</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.763</td>
<td>Nigeria</td>
<td>0.912</td>
<td>Nigeria</td>
<td>1.487</td>
</tr>
<tr>
<td>USA</td>
<td>0.522</td>
<td>Costa Rica</td>
<td>0.903</td>
<td>Indonesia</td>
<td>1.406</td>
</tr>
<tr>
<td>Vietnam</td>
<td>0.468</td>
<td>China</td>
<td>0.857</td>
<td>India</td>
<td>1.387</td>
</tr>
<tr>
<td>China</td>
<td>0.463</td>
<td>Kenya</td>
<td>0.607</td>
<td>China</td>
<td>1.000</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.455</td>
<td>Mexico</td>
<td>0.522</td>
<td>Mexico</td>
<td>0.702</td>
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<tr>
<td>Costa Rica</td>
<td>0.424</td>
<td>Indonesia</td>
<td>0.399</td>
<td>Viet Nam</td>
<td>0.522</td>
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<tr>
<td><strong>World total²</strong></td>
<td><strong>11.84</strong></td>
<td><strong>15.14</strong></td>
<td><strong>20.38</strong></td>
<td><strong>23.33</strong></td>
<td></td>
</tr>
</tbody>
</table>

¹ For 2012 world production; ² including all other countries not listed here.

Source: FAO (2014).
the total pineapple production globally. Costa Rica, ranked 10th in 1990, and rose to second position in 2012, thereby exhibiting a six-times increase in production. The USA, which was the 6th leading producer of pineapples in 1990, was not among the top-ten producers in 2012. Thailand, the Philippines, and Brazil are the countries with sustained production among the top-five producers.

1.2.2 Trade and commerce

The top-ten pineapple exporting and importing countries for 2011 are listed in Table 1.2. Costa Rica led the total world pineapple exports with a 55.60% share or 1,749,360 MT. The predominant position of Costa Rica is supported by the fact that second leading exporter, the Philippines, exported 263,019 MT or 8.36% share of the total world exports. The United States, though not in the top-ten producers, was the fifth largest pineapple exporter. Among pineapple importers, the United States led with 817,131 MT, followed by the Netherlands, Belgium, Germany, and the United Kingdom. As reported by the CBI (2008), the export prices of pineapples are determined mainly by the supply and demand on the world market, making price fluctuation considerable over time. In addition, fruit variety, quality and country of origin are some of the other important factors that affect price.

In the USA, imports are a key component of the domestic market for fresh pineapples, maintaining about 90% of market share annually in recent years. USA fresh pineapple imports showed a continued increase from 1996 through 2012, fulfilling the ever growing demand for fresh pineapples aided by the availability of newer low acid hybrid clones (Perez & Plattner 2013). Costa Rica,

<table>
<thead>
<tr>
<th>Exporters</th>
<th>Metric tons</th>
<th>% Share</th>
<th>Importers</th>
<th>Metric tons</th>
<th>% Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costa Rica</td>
<td>1,749,360</td>
<td>55.60%</td>
<td>USA</td>
<td>817,131</td>
<td>28.00%</td>
</tr>
<tr>
<td>Philippines</td>
<td>263,019</td>
<td>8.36%</td>
<td>Netherlands</td>
<td>232,850</td>
<td>7.98%</td>
</tr>
<tr>
<td>Belgium</td>
<td>217,359</td>
<td>6.91%</td>
<td>Belgium</td>
<td>232,054</td>
<td>7.95%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>184,464</td>
<td>5.86%</td>
<td>Germany</td>
<td>191,956</td>
<td>6.58%</td>
</tr>
<tr>
<td>USA</td>
<td>103,300</td>
<td>3.28%</td>
<td>United Kingdom</td>
<td>167,513</td>
<td>5.74%</td>
</tr>
<tr>
<td>Ecuador</td>
<td>88,632</td>
<td>2.82%</td>
<td>Japan</td>
<td>152,864</td>
<td>5.24%</td>
</tr>
<tr>
<td>Panama</td>
<td>65,613</td>
<td>2.09%</td>
<td>Italy</td>
<td>151,300</td>
<td>5.18%</td>
</tr>
<tr>
<td>Cote d’Ivoire</td>
<td>64,116</td>
<td>2.04%</td>
<td>Spain</td>
<td>135,915</td>
<td>4.66%</td>
</tr>
<tr>
<td>Ghana</td>
<td>45,999</td>
<td>1.46%</td>
<td>Canada</td>
<td>108,672</td>
<td>3.72%</td>
</tr>
<tr>
<td>Honduras</td>
<td>42,578</td>
<td>1.35%</td>
<td>France</td>
<td>99,477</td>
<td>3.41%</td>
</tr>
<tr>
<td>World total</td>
<td>3,146,211</td>
<td></td>
<td>World total</td>
<td>2,918,151</td>
<td></td>
</tr>
</tbody>
</table>

1 Latest data available; 2 for 2011 world total; 3 including all other countries not listed here. Source: FAO (2014).
Overview of pineapple production

Mexico, and Honduras are the main exporters of pineapples to the USA. Besides fresh pineapples, USA imports processed pineapple products as well (frozen, canned, juice, and juice concentrate).

The market for pineapples is growing in all EU countries, with Germany, Italy and the UK being the largest markets (CBI 2008). Between 2002 and 2008, EU pineapple imports doubled in volume, though the increase in value was only about 50%. The fresh fruit quality requirements vary greatly, but are generally high in most EU markets. The market survey also noted that there is an extensive pineapple trade within the EU, with some countries such as the Netherlands and Belgium being the leading pineapple importers and distributors in the EU. Exports through import/retail market channels, as reported by CBI (2014) are depicted in Figure 1.2.

1.2.3 Consumption trends

Traditionally, pineapples grown in developing countries was mostly consumed fresh, whereas in developed countries processed pineapple (juice, canned, dried) products were predominantly marketed and consumed in addition to fresh fruit. Pineapple was once a favorite fruit for processing (FAO 2009) but it has been increasingly marketed as fresh with the emergence of the extra sweet varieties in the mid-1990s. This trend in the market for fresh pineapple is closely associated with expansion of ready-to-eat fresh-cut (minimally processed) fruits.

In the USA, total per capita consumption of pineapple (fresh and processed) was 6.16 kg/year in 2012 (Table 1.3). While the total consumption since 1990 has remained fairly flat, a greater portion of this consumption in recent years has been in the fresh or fresh-cut form, which showed over three-fold increase in 2012 as compared to 1990 consumption. Given consumers’ preference for fresh versus processed products, the fresh-cut pineapple market is expected to grow further in coming years. Pineapple juice consumption has decreased significantly with ~57% decrease as compared to 1990 levels. Similarly, canned pineapple consumption also decreased from 2.36 kg per capita in 1990 to 1.80 kg in 2012. In European countries, Germany, Spain, the United Kingdom, and Italy are the...
largest consumer markets for pineapples. Based on FAO’s production and trade data, CBI (2014) reported that Germany accounted for about 20% of the total pineapples consumption in the EU countries. The total market volume was estimated about 800,000 metric tons, which equals about 1.5 kg per capita in 2011 (CBI 2014).

### 1.3 Postharvest handling and storage

Pineapple is a non-climacteric fruit; therefore, for optimum quality and sweetness, this fruit should not be harvested until at least one-third or more of the peel or shell has turned from green to yellow. After harvest the fruit does not continue to ripen or sweeten significantly.

Full ripe yellow mature fruit are often unsuitable for transporting to distant markets due to their shorter shelf-life and high susceptibility to mechanical damage; therefore slightly less mature fruits are selected (Akamine 1963). Immature fruit should not be shipped, since they do not develop a good flavor, have low soluble solids, high acidity and are more prone to chilling injury (Rohrbach & Paull 1982).

Pineapples are picked by hand and using a conveyor belt, the fruit are transferred into the truck or field baskets when possible. To reduce fruit temperature at harvest it is recommended to pick in the morning or evening.

Generally, the physical appearance of the fruit often provides several key clues as to its readiness for eating. When your pineapple fruit turns almost entirely yellow and gives off a sweet aroma, it is usually ready to eat. The ripe pineapple has a yellow to golden yellow pulp, is juicy and has a sweet flavor. The crowns should not have a withered appearance, which may be due to insufficient irrigation, mechanical injury, extensive refrigerated storage, storage <7°C, low relative humidity, delays during marketing and incorrect application of ethephon. Peduncles should have a clean cut and be 5–20 mm long, especially when fruit have to be transported in a vertical position.
After washing the fruit in chlorinated water, fruit are graded based upon certain characteristics: degree of skin coloration, size (weight), absence of defects and diseases, and in keeping with other market requirements. Some buyers require green fruit (color 0) which means soft green color near the peduncle, with 12°Brix, porosity of 1.5 and translucency 0 to 0.5. Other buyers demand ripened or off-green fruit with a minimum of 12°Brix, porosity of 1.5 and translucency of 1 to 1.5 (de la Cruz Medina & García 2005). Crown size relative to the fruit is also another criterion.

After grading, pineapples are often treated with a fungicide to control postharvest fruit rot, known as black rot or water blister, and waxes can also be applied to reduce postharvest water loss and improve fruit appearance. Frequently, ethephon is applied a few days before harvest to fruit with the desired levels of sugars and acids, to enhance shell degreening. Postharvest use of ethephon if allowed by regulations, can result in uniform skin degreening, but this can also lead to a shortened shelf-life. The need to degreen is related to the consumer’s perception that a ripe pineapple must have a full yellow skin. Once the fruit is packed in a horizontal position, careful transportation has to be done to avoid fruit bruising.

The optimum storage temperature for pineapple fruit is 7–10°C when ripe and 10–13°C when partially ripe, and 90–95% relative humidity (Kader 1992; Paull 1992). Refrigeration is the main tool used to slow undesirable quality changes and to increase the shelf-life of freshly harvested pineapples, but the response of different varieties varies towards low temperatures. The application of refrigeration for pineapples is limited due to the development of chilling injury symptoms at temperatures of below 13°C (Brown 1986). At 0–5°C, fruits may store for weeks, but upon transfer to non-refrigerated conditions, the fruit would not ripen and severe chilling injury symptoms would appear (Abdullah & Atan 1983). At 10°C, blackheart symptoms have been observed in the flesh of ‘Smooth Cayenne’ fruit (Stewart et al. 2002), whilst almost no blackheart was observed in the flesh of ‘Queen’ fruit (Abdullah et al. 1985). Susceptible fruits are generally lower in ascorbic acid and sugars and are opaque. Partial to complete control of chilling injury symptoms has been achieved by waxing, heat treatment, modified atmosphere packaging, ascorbic acid and application of the ethylene inhibitor 1-methylcyclopropene (1-MCP). Liu & Liu (2014) observed that elevated temperatures used in postharvest, triggered pineapple fruit to mature in the cool season to a more red and yellow color and with better physicochemical quality and aroma.

### 1.4 Value-added processing and products

Pineapples after harvest are transported in large bins or in trucks with the crowns down to serve as cushions to minimize fruit bruising. At the processing facility, fruit are graded for size and quality followed by washing or/and sanitizing treatments. Gentle handling is recommended to avoid tissue impact damage that can accelerate quality loss, compromising the final quality of processed products. To avoid such
Handbook of Pineapple Technology

quality loss, it is desirable to process the fruit within 24 hours of harvest or sooner. The details regarding the fruit source, date of harvest, field number and grade need to be carefully recorded in order to ensure traceability (Paull & Lobo 2012).

The processed pineapple products include: canned (slices, rings, dices, chunks), frozen (slices, rings), juice and nectar (single strength, concentrate, blends with other juices), and dried (dices, chunks) (Figure 1.3). Other processed products include jam, jelly, and candies (Paull & Lobo 2012). Since the 1990s, the minimally-processed or fresh-cut fruit market has seen an exceptional growth. Fresh-cut pineapples ranked the highest of all tropical fruit in quantity and dollars sold in the value-added category for USA fresh fruit in supermarkets (Cook 2007). Fresh-cut pineapple is usually marketed as slices or cubes.

In the pineapple processing industry, Good Manufacturing Practices (GMPs) and food safety systems such as Hazard Analysis and Critical Control Points (HACCP) are used to assure a high quality and the safety of the finished product. HACCP are designed to prevent, reduce to acceptable levels, or eliminate the microbial, chemical, and physical hazards associated with food production. The USA Food and Drug Administration (FDA) has promulgated GMP regulations that apply to all food processing facilities, including fresh-cut operations and complements FDA’s Current Good Manufacturing Practice regulations ‘21 CFR 110’ (Paull & Lobo 2012). Over the past two decades, food safety has become and continues to be the number one concern of the fresh produce industry and regulatory agencies (Fan et al. 2009; Kader & Siddiq 2012). The International Fresh-cut Produce Association (IFPA) has developed guidelines, which incorporates GMPs as well as other food safety standards such as a model HACCP plan, sanitary facility design, and proper use of antimicrobials (Paull & Lobo 2012).

1.5 Processing waste and by-products

Processing pineapple generates significant quantities of waste, namely skin, leaves/crowns, and residual pulp. These wastes can cause disposal and potential environmental pollution problems if not utilized to produce other products (Paull & Lobo 2012). Pineapple leaf fibers have a high cellulose content and are

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Figure 1.3 A schematic of processing different pineapple products.
mechanically strong. They can be used as reinforcement in thermoplastic and thermostetting resins for developing low-cost and lightweight polymer composites (Mishra et al. 2004; Mohamed et al. 2009). Tongsumrith and Netpradit (2005) produced pineapple leaf paper for use as an alternative print paper. Pineapple leaf fiber is also used to make traditional embroidered formal shirts in the Philippines.

Pineapple peel is rich in cellulose, hemicellulose and other carbohydrates. It can be dried for use as an animal feed or ensilaged. Ensilaging of pineapple peels produces methane which can be used as a biogas. Anaerobic digestion takes place and the digested slurry may find further application as animal, poultry and fish feeds (Rani & Nand 2004). The utilization of dehydrated pineapple by-products increases the coefficients of apparent digestibility of the nutrients, resulting in satisfactory weight gains in goats (Costa et al. 2007). Biomass from pineapple is a renewable energy resource with a high potential fuel source for the creation of steam and electricity, transportation fuel, medicinal manufacturing industries as well as a solvent in the laboratory (Hossain et al. 2008). Peel and other pineapple by-products from processing can be used as raw materials to prepare natural vinegar by acetic fermentation of alcohol solutions derived from sugar or starchy materials (fermentable sugar content of 8–20%). Vinegar must be pasteurized once it is prepared and bottled. It is stable at ambient temperature (COVECA 2002). Hebbar et al. (2008) reported that bromelain can be extracted and purified from pineapple wastes (core, peel, crown and extended stem) using reverse micellar systems.

1.6 Nutritional composition and health benefits

Pineapples are low in calories (2% Daily Values, DV), saturated fat, cholesterol and sodium. The fruit is a good source of fructose, dietary fiber, vitamin B₁, vitamin B₆, and copper and a very good source of manganese (46% DV) and vitamin C (80% DV) (Paull & Lobo 2012). Pineapples contain antioxidants, namely flavonoids and pro-vitamin A. Table 1.4 shows proximate composition of raw pineapples and its processed products (canned chunks, juice, and frozen juice concentrate). Pineapple has relatively lower content of minerals and most vitamins, with the exception of vitamin C. Chapter 12 on Pineapple Composition and Nutrition provides more detailed information.

During processing, the nutritional quality of pineapple and sensorial attributes such as color, texture and flavor can be negatively affected. Thus, thermal treatments (blanching, drying, and sterilization) used to produce dried pineapple, chips, juice, and puree reduces vitamin C, carotenoids, and anthocyanin content (Sian & Ishak 1991). Also there is solubilization/degradation of pectic polysaccharides, with a notable decrease in the degree of pectin esterification (Femenia et al. 2007). Bioactive compounds of fresh-cut products (vitamin C, phenolics,
carotenoids, etc.) also decrease during storage (González-Aguilar et al. 2005; Gil et al. 2006).

Pineapple is a dietetic and healthy fruit. Pineapple contains bromelain, a major cysteine proteinase that has several therapeutic properties as it is effective in the treatment of albuminuria. Pineapple reduces the appetite and is used for weight control (Coveca 2002). It also aids in digestion by facilitating protein breakdown (Roxas 2008). Due to the fiber content of the pulp, pineapple prevents and corrects constipation, regularizes the intestinal flora and is also used in the control of diarrhea (Báez et al. 2007). There is evidence that bromelain has a broad spectrum of activity against intestinal helminths (both nematodes and cestodes), a quality that reinforces its suitability for development as a much needed novel treatment against gastrointestinal helminths of humans and livestock (Stepek et al. 2007).

### 1.7 Conclusion

The pineapple, *Ananas comosus* (L.) Merr., is a member of the Bromeliaceae family, and is the third most important tropical fruit in the world after banana and citrus. It is a non-climacteric fruit that is consumed as a fresh product, or canned, in juice, nectar or concentrate, frozen or dehydrated. Successful marketing depends on the proper maturity of fruit at harvest, development of uniform color and shape of the variety, and fruit without injury. Proper wrapping of individual fruit in transport, and careful handling with no exposure to moist conditions help in maximizing the profit margin. It is important to extend the shelf-life of the fresh product in order to reach long distance markets through adequate refrigeration that slows the product deterioration in terms of consumer

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Raw¹</th>
<th>Canned²</th>
<th>Juice³</th>
<th>Juice concentrate⁴</th>
</tr>
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<tbody>
<tr>
<td>Water</td>
<td>g</td>
<td>86</td>
<td>83.51</td>
<td>86.37</td>
<td>53.1</td>
</tr>
<tr>
<td>Energy</td>
<td>kcal</td>
<td>50</td>
<td>60</td>
<td>53</td>
<td>179</td>
</tr>
<tr>
<td>Protein</td>
<td>g</td>
<td>0.54</td>
<td>0.51</td>
<td>0.36</td>
<td>1.3</td>
</tr>
<tr>
<td>Total lipid (fat)</td>
<td>g</td>
<td>0.12</td>
<td>0.11</td>
<td>0.12</td>
<td>0.1</td>
</tr>
<tr>
<td>Carbohydrate, by difference</td>
<td>g</td>
<td>13.12</td>
<td>15.56</td>
<td>12.87</td>
<td>44.3</td>
</tr>
<tr>
<td>Fiber, total dietary</td>
<td>g</td>
<td>1.4</td>
<td>1.3</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Sugars, total</td>
<td>g</td>
<td>9.85</td>
<td>14.26</td>
<td>9.98</td>
<td>43.6</td>
</tr>
</tbody>
</table>

¹ Average, all varieties.
² Chunks/dices, juice pack, drained.
³ Unsweetened canned juice.
⁴ Frozen, unsweetened.

perception and nutritional value. Nevertheless, some varieties are more sensitive to chilling injury than other clones. An awareness program on the importance of harvest maturity of pineapple, the storage temperature, and postharvest treatments that can alleviate chilling injury must be conducted to improve the overall quality of pineapple in the market. The demand for value-added pineapple products, due to their unique flavor and a wide range of applications, continues to grow worldwide.

References


