17 Fruit Processing

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17.1 Introduction

Processing is a value-adding step that fills the gap between farm production and marketing. The objective of processing is to convert highly perishable but prime quality farm commodities to more stable forms. When the process is accomplished with the least alteration in the nutritional value and aesthetic properties of the food, high consumer acceptance is assured. Completely new product lines can likewise be created out of fresh raw materials through processing. In other instances, the raw material may undergo such extensive physical alteration during processing that the product is used differently by consumers. Culinary experts devise new uses for these products to fit the changing lifestyles of present-day consumers. The availability in the market, for example, of pre-mixed condiments and various meat powders used for flavouring foods such as instant noodles and similar convenience
foods, has simplified the life of working women who do not have the time or the skill to prepare food the way their mothers and grandmothers did at home. The products are affordable and easy to prepare; hence, consumer acceptance is high. In addition, these foods are found everywhere, from neighbourhood stores in the suburbs and countryside to supermarkets in urban centres. The product and process research and development work of food scientists and food technologists, the business acumen of entrepreneurs and the marketing expertise of product distributors ensure the availability of the food products.

The global competitiveness of agricultural produce of a country can be considerably enhanced by utilizing appropriate technologies to produce high-quality processed foods. Research focusing particularly along the areas of processing equipment, product design and packaging has made the latest techniques available for the manufacture of new generations of food products. Tropical fruits have had an excellent record of breaking into the world market because of their exotic flavours (Plate 83). When processed into purée, juice, nectar or simply dried fruit slices, they can be shipped long distances with only minimum changes in quality.

The popularity of fruits may be attributed to consumer perception of their health benefits. In the case of fruit juices, many consumers are now looking for healthy alternatives to the traditional carbonated beverages. Fruits are rich in dietary fibre as well as phytonutrients, especially antioxidants, and have no cholesterol. The availability in the market of natural fruit juices derived from fresh fruits is a welcome alternative to synthetic juices that are being passed off as fruit juices but are, in reality, sugar-based, fruit-flavoured beverages prepared from artificial ingredients.

Mango fruits are usually eaten fresh as dessert or as relish depending on their stage of maturity when picked. In the Philippines and elsewhere, fresh mangoes are available throughout the year because the flower-induction technology first described by Barba (1974) allows growers to produce fruit out-of-season. The off-season fruits, however, are still expensive. Most mango growers have not put the technology into practice due to the high cost of additional farm inputs necessary for its successful implementation during the rainy season.

At the peak of the harvest season, on the other hand, oversupply of fresh mangoes depresses the market price to the detriment of the growers. Moreover, high temperatures combined with high relative humidity (RH) and intense sunlight during the harvest season accelerate the metabolic processes associated with ripening in fresh mangoes, rendering them susceptible to microbial attack, particularly by Colletotrichum gloeosporioides Penz., the cause of anthracnose. The physico-chemical changes that occur during ripening also lead to fruit deterioration and loss of quality. Thus, fresh mangoes are processed to facilitate better distribution and to stabilize prices.

Mango processing was previously reviewed by Nanjundaswamy (1997), who described the status of processing technologies and products in India. This review discusses current trends in mango processing.
17.2 Dehydrated Mango Products

Dehydration works on the principle that by lowering the water (H₂O) content of foods below a certain threshold level, growth of many spoilage microorganisms is prevented, thus preserving the food. As more and more H₂O is removed from the material, its solids content becomes concentrated, further making the food less suitable for microbial growth.

The choice of the most appropriate drying system is determined largely by the cost-effectiveness of the process. Sun drying is the most inexpensive method for drying foods. The products, however, are rather susceptible to contamination by dirt, insects, rodents, faecal matter and microorganisms. The process also requires several days to dry each load or batch of raw materials since it relies on the availability of sunlight. Temperature control is virtually impossible. Other systems have been designed that are more hygienic and equally cost-effective compared to sun drying. The use of solar dryers practically eliminates most of the inherent defects of sun drying. However, the reliance of solar dryers on sunlight as the source of energy for evaporating H₂O from the material being dried makes the system commercially unreliable. Solar panel collector-equipped dryers with provision to store energy from sunlight can operate continuously and efficiently.

A mechanical dryer such as the convection oven provides the processor with control over the system that is essential for a successful drying operation. It eliminates most of the problems mentioned above. Although the initial investment cost is high due to the acquisition of the dryer, in the long run it is more economical than sun drying because the drying time per load is much shorter.

Oil-, steam-, liquid propane gas- or electric-powered air heaters are the alternative sources of energy for the dryers. Dryers have also utilized a wood-fired furnace that heats the air entering the drying chamber. Its main advantage is that trimmings from raw materials, packing materials and other trash can be burned in the furnace, keeping the compound clean.

Dried mango

Dehydrated or dried mango slices are among the first products manufactured commercially from ripe mango fruits that caught the attention of consumers in the international market for processed tropical fruits (Plates 83 and 84). The product was developed in Cebu, the Philippines, from where it spread to the neighbouring islands of Panay and Negros. It is now produced in many regions of the Philippine archipelago where mango is abundant. In addition, it is a popular product in Thailand and elsewhere in South and South-east Asia.

In the Philippines, the ‘Carabao’ mango is the preferred variety for dehydration or drying. The fruit should be at the firm-ripe stage. When over-ripe fruit is used as raw material, a dark-coloured product will invariably result. Although the dried pieces from over-ripe mangoes have a more distinct ripe mango flavour that attracts customers, the shelf life is considerably shorter.
The fruit is washed thoroughly. The cheeks are sliced with a sharp stainless-steel knife. Each slice is then cut into two or three pieces lengthwise. The flesh is scooped from the skin with a stainless-steel scoop or ladle. These operations are done manually; however, a simple and novel peeling and slicing machine for ripe mangoes has been developed and patented in Australia (as cited by Nanjundaswamy, 1997).

Sugar syrup is prepared by adding 175 kg sugar, 1.7 kg citric acid and 0.85 kg sodium metabisulfite in 175 l $H_2O$ to make a 45 Brix sugar concentration and heating to $90^\circ C$ to dissolve the metabisulfite. The prepared mango slices (1 t) are added to the syrup. The preparation is heated to $90^\circ C$ and then allowed to stand for at least 6 h. Subsequently, the sugar concentration of the syrup is adjusted by dissolving more sugar until the concentration reaches 50 Brix using a hand refractometer. After 6 h, the mango pieces are again removed from the syrup and the sugar concentration is adjusted to 60 Brix using a hand refractometer for the ‘plumping’ stage. The syrup is reheated to $90^\circ C$; the mango slices are added to the syrup and soaked for a further 6 h.

The final step in the process involves the removal of mango pieces from the syrup. They are lightly rinsed with $H_2O$ to remove the excess sugar that may crystallize on the surface of the mango during drying. The slices are then loaded in drying trays and dehydrated at 40–50$^\circ C$ in a convection dryer. Drying time usually requires 18 h. The dried mango pieces are unloaded from the dryer and reconditioned at room temperature overnight. Each piece is coated with confectioner’s sugar. The product is then packed in aluminium-foil-laminated pouches and sealed. Recent improvements in dryer design can reduce drying time to 8 h. As a result, up to three batches of prepared mango slices can be processed daily instead of only two batches every 36 h. The process for the production of dried mangoes has been described by Raymundo et al. (1999).

**Mango fruit bar**

The product is also commonly referred to as mango ‘leather’ (Plate 83). The processing of mango fruit bar has also been described previously by Amoriggi (1992) and Raymundo et al. (1999, unpublished work, 2006). Purée processed from ripe ‘Carabao’ mango is the preferred raw material for the manufacture of mango fruit bar in the Philippines, although ‘Pico’ is also suitable because of the orange colour of the purée.

The total solids content of 1 t of mango purée is adjusted to 25 Brix with the use of a hand refractometer by adding sugar to the purée. The amount of sugar required depends on the initial total solids content of the mango purée. Then 2 kg each of citric acid and sodium metabisulfite are blended into the purée. Juice of calamansi, also known as the Philippine lemon ($\times Citrofortunella microcarpa$ Wij. (Bunge); *Citrus mitis* Blanco) may be used instead of citric acid at the rate of c.20 kg per batch, although the resulting cost of the product will be slightly higher. There is no real difference in the appearance
and flavour of the finished product. Citrus juice is generally utilized if the client prefers an all-natural product.

The prepared purée is heated for 2 min at 80°C with constant stirring to avoid scorching. The hot mixture is carefully transferred to stainless-steel drying trays. The trays are loaded into the dryer and dried for 14 h at 55°C. At the end of the drying operation, the dried sheets of mango should be pliable and should not stick to the fingers when touched.

The sheets of mango are removed from the trays. Six layers of the dried mango leather are stacked on top of each other. The edges are trimmed and bars measuring 2 × 4 cm are cut from the stack. Each bar is coated with confectioner’s sugar, wrapped in cellophane then packed in labelled plastic bags.

**Mango fruit roll**

The processing of mango fruit roll has been described previously (UPLB, 1996; Raymundo et al., 1999, unpublished work, 2006). The product and process are similar to mango fruit bar, and they only differ in the presentation. The total solids content of 1 t of mango purée is adjusted to 25 Brix using a hand refractometer by adding sugar to the purée. The amount of sugar needed depends on the initial total solids content of the mango purée. Then 2 kg each of citric acid and sodium metabisulphite are blended into the purée. As with mango fruit bar, citric acid may be replaced by calamansi juice at the rate of 0.20 kg per batch without affecting the overall sensory quality of the fruit roll, if the client specifies an all-natural product.

The prepared purée is then heated for 2 min at 80°C with constant stirring to avoid scorching. The hot mixture is carefully transferred to stainless-steel drying trays. The trays are loaded into a convection dryer and dried for 12–16 h at 55°C.

The dried sheets of mango are removed from the trays. Confectioner’s sugar is sprinkled over a stainless-steel-topped table to avoid sticking of the sheets on subsequent rolling. Each sheet is rolled manually into 1 cm diameter pieces. The ends are trimmed; and each roll is sliced into 5 cm long pieces. The pieces are coated with confectioner’s sugar and wrapped with cellophane. The rolls are then packed in appropriate containers.

**Vacuum-puffed dried mango**

The use of vacuum for puffing and drying mango and similar food materials is not as widespread as explosion puffing (Eskew et al., 1963), high temperature short time (HTST) pneumatic drying and centrifugal fluidized bed (CFB) drying (Brown et al., 1972), because the vacuum-puff dryer is still expensive. With the increasing consumer demand for high-quality processed foods and their willingness to pay a higher price for such products, vacuum-puff dehydration could become an economically viable investment opportunity for entrepreneurs, particularly in the mango processing industry.
Vacuum-puffed mango pieces will readily rehydrate due to the porosity created during the puffing and drying stages of the process. The significantly shorter drying time (Candelaria and Raymundo, 1994b) also makes possible the drying of four loads of prepared mango slices in 24 h.

The ripe mangoes are washed thoroughly in chlorinated H₂O, then sliced either mechanically or with a stainless-steel knife. The flesh is scooped from the skin with a sharp stainless-steel ladle (Candelaria, 1993; Candelaria and Raymundo, 1994a). The fruit pieces are then heated to 90°C in 30 Brix syrup containing 1% sodium metabisulfite, and steeped in the syrup for 4–6 h. The mango slices are removed from the syrup, rinsed briefly in H₂O, arranged in stainless-steel trays and loaded into the vacuum oven.

The mango pieces thus prepared are initially heated at a positive pressure of 40–50 kPa until the maximum tissue temperature of 100°C is reached, usually within 8 min. The pressure is released and the hot mango pieces are dried at −70 to −80 kPa vacuum at a temperature of 45–50°C. Total dehydration time under vacuum is 6 h. The above pressure-temperature combinations provide the most desirable puff and rehydration characteristics (Candelaria and Raymundo, 1994b).

With the present technology, vacuum-puffed dried mango from a 1 t batch of prepared mango slices is more expensive to produce than convection oven-dried mango (Table 17.1). The production cost needs to be reduced for the product to be market competitive. Research that focuses on devising a system to assure a continuous supply of mango fruits is required. The plant must operate on a year-round basis in order to optimize the use of its equipment and facilities.

The facilities can be used for the production of other vacuum-puffed fruits (i.e. bananas and muskmelon) as well as vegetables (i.e. white potato and maize kernels) (Candelaria, 1993; Candelaria and Raymundo, 1994b) among others, which can be used as raw materials in the manufacture of instant foods.

Table 17.1. A comparison of the profitability of different mango product lines.

<table>
<thead>
<tr>
<th>Product</th>
<th>Volume (kg)</th>
<th>Cost of goods sold (US$)</th>
<th>Gross profit (US$)</th>
<th>Net profit before tax (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango powdera</td>
<td>124,800</td>
<td>251,460</td>
<td>966,540</td>
<td>439,983</td>
</tr>
<tr>
<td>Instant mango juicea</td>
<td>202,890</td>
<td>467,355</td>
<td>1,560,645</td>
<td>965,088</td>
</tr>
<tr>
<td>Green mango powdera</td>
<td>141,221</td>
<td>245,226</td>
<td>1,166,984</td>
<td>600,216</td>
</tr>
<tr>
<td>Instant green mango shakea</td>
<td>124,800</td>
<td>209,468</td>
<td>1,308,532</td>
<td>473,975</td>
</tr>
<tr>
<td>Vacuum-puffed dried mangob</td>
<td>124,800</td>
<td>1,141,807</td>
<td>730,193</td>
<td>246,588</td>
</tr>
<tr>
<td>Dried mangoe</td>
<td>67,392</td>
<td>398,492</td>
<td>140,644</td>
<td>84,386</td>
</tr>
<tr>
<td>Mango fruit barc</td>
<td>115,200</td>
<td>921,600</td>
<td>461,816</td>
<td>277,090</td>
</tr>
<tr>
<td>Mango fruit rollc</td>
<td>115,200</td>
<td>921,600</td>
<td>461,816</td>
<td>277,090</td>
</tr>
</tbody>
</table>

a US$10/kg powder.
b US$15/kg.
c US$8/kg.
17.3 Spray-dried Mango Powders

Spray-drying is a process in which a liquid feed is finely dispersed or atomized to form droplets, which are eventually sprayed into a heated air chamber. The process facilitates the rapid evaporation of H₂O from the feed droplets, thereby forming the powder particles. The product obtained using the technology is a free-flowing powder that may or may not be instantly soluble in H₂O, depending on the formulation of the liquid feed that has been used. By modifying the formulation and adjusting the process parameters, a plain powder is obtained that can be dry-mixed with sugar, modified starches or similar components. The powder is used for flavouring confectioneries and pharmaceutical preparations as well as in the manufacture of baby foods and tropical fruit drinks fortified with nutrients to replace those portions lost during processing.

Tropical fruit juice powders that are rapidly soluble in H₂O are produced directly by spray-drying fruit juices and purées. By dry-mixing spray-dried plain fruit powder with sweeteners, a ready-to-drink juice is made. The latter method has the added advantage in that it allows formulation of exclusive blends of fruit drinks. As a result, consumers have a wider range of products from which to choose that will suit their individual preferences.

By converting fruit pulps into powder or by instantizing them, their shelf life is prolonged. Consequently, this value-adding step simplifies exportation since many of the restrictions normally imposed on fresh produce by importing countries are offset by the process. Transportation cost is also reduced by at least 85%, which reflects the amount of H₂O removed from the fresh juice. Instant juices are more convenient for consumers since they can be reconstituted easily. In the pharmaceutical and cosmetics industries, there is a large demand for natural tropical fruit powders as flavouring and colouring agents to add to their usual line of fruit-flavoured products. Powders are also more convenient to handle during the manufacturing process.

Spray-drying is by far the most cost-effective method for transforming fruit pulps into powder. Fruit pulp is very heat-sensitive and requires special treatments to produce competitively priced powders of superior quality. Furthermore, because of the rapid drying cycle and simplicity of operation, continuous production is achieved which contributes to the low operational cost. The short holding time of the powder inside the drying chamber reduces the risks of powder burn. Human contact with the liquid feed and powder is also minimized as a result of the short holding time. The processes are, therefore, very hygienic and the product is ready for packaging as it leaves the dryer. Unlike other drying systems, including convection oven-drying and drum-drying, there is no need to purchase a hammer mill for grinding the dry flakes into a powder. The main drawback of spray-drying, however, is the relatively high initial investment cost.

Spray-dried mango fruit powder and instant mango juice

Khalid and Sial (1974), Anonymous (1998) and Diaz (2000) have discussed the recovery of fruit powder and production of instant mango juice powder.
using the technology. Both products use mango purée as the raw material. They differ only in the composition of the liquid feed. The liquid feed is mango purée with the total solids adjusted to the right consistency, thereby allowing the purée to be discharged through a high-speed nozzle in the form of fine droplets into the drying chamber that quickly dries to a yellow free-flowing powder. The patent application for the manufacture of spray-dried mango powders is still pending at the Philippine Patent Office. The process parameters used, therefore, cannot be discussed in detail in this chapter. The parameters used are the same as reported previously, namely, the inlet temperature, the feed rate, air speed and the outlet temperature (Welti and Lafl uente, 1983; Liang and King, 1991; Anonymous, 1998). The powder of instant mango juice is comparatively dense so that it gets wet easily, enabling it to sink immediately during reconstitution. The plain mango fruit powder, on the other hand, does not disperse as readily; it has a tendency to clump on the H₂O surface. However, it will dissolve quickly in hot H₂O or with the use of an ordinary household blender.

A modest capacity spray-drying plant equipped with a NIRO SD 12.5R model spray-dryer made in Denmark, valued at approximately US$207,860, with an evaporative capacity of 25 kg H₂O/h will require an initial investment of about US$313,860 to make it operational. In addition, if fresh mangoes are be used as raw materials, a purée processing facility will cost around US$98,000. The figure represents expenses for buying and installation of equipment, and does not include the costs of the building, land and ancillary expenses such as environmental pollution control system and spray-dryer accessories.

At the evaporative capacity rate of 25 kg H₂O/h, the facility can produce 124.8 t/year of plain mango powder and 202.8 t/year of instant mango juice at a total cost of US$251,460 and US$467,355, respectively (Table 17.1). The net profit for plain mango powder is US$439,983 and US$965,088 for instant mango juice before taxes.

**Spray-dried green mango powder**

The purée of green mangoes can be converted to a powder (UPLB, 2005) just like the purée of ripe mangoes by spray-drying (Plate 85a). The spray-dried powder can be mixed with other condiments and used as a souring agent for exotic or native dishes, or as the raw material in the manufacture of instant green mango shake (see below). The powder may be dry-mixed with sugar, powdered honey, caramel powder or powdered sugar syrup to instantize it. During this process, the mixture can be fortified with vitamins (e.g. ascorbic acid) and other nutrients.

The estimated cost of goods sold using a commercial spray-dryer with an evaporative capacity of 25 kg H₂O/h is US$245,226/year (Table 17.1). At the rated capacity of the spray-drying plant of 141,221 kg/year, the net profit before taxes for green mango fruit powder is US$600,216 at a selling price of US$10/kg of powder.
Green mango shake on cracked ice is a very popular thirst quencher in Southeast Asia and elsewhere (Plate 85b). Its origin can be traced back to the countryside where finely diced fresh green mango pieces are mixed with H₂O, sugar and ice to make a cheap, wholesome summer drink during the mango season. The practice has since been modified and upgraded to cater to upscale domestic markets and abroad.

The beverage is an excellent source of vitamin C. When the green mango purée is spray-dried, a free-flowing white to greenish-white powder is produced that will dissolve instantly even in cold H₂O. The powdering process offers unprecedented convenience to the consumer, especially when the powder is packed in sachets. Since no artificial or synthetic colours and flavouring agents are included in the liquid-feed formulation, the natural taste and aroma of green mango is retained in the powder.

Using a commercial spray-dryer with an evaporative capacity of 25 kg H₂O/h, the estimated cost of goods sold is US$209,468/year. At the rated capacity of spray-drying plant of 124,800 kg, the net profit before taxes for instant green mango shake is US$473,975/year at a selling price of US$10/kg of powder (Table 17.1).

The technology for the production of instant green mango shake and green mango powder was developed at UPLB (2005). If the proper feed formulation and process parameters are applied, spray-drying is an efficient and hygienic method for producing cheap but high-quality mango fruit powder and instant mango juice. Table 17.2 demonstrates that the spray-dried mango powders have much lower microbial load, i.e. 2.8–10.4 × 10² colony forming units (cfu)/g, compared to the industry standard of 1 × 10⁴ to 5 × 10⁵ cfu/g total plate count. Except for mango powder, the mould and yeast counts are within the limit of 1 × 10² cfu/g. Locally refined sugar and imported modified starch, on the other hand, have much higher mould and yeast counts than the Heinz standard for powdered products (Shapton and Shapton, 1991).

<table>
<thead>
<tr>
<th>Material</th>
<th>Total plate count</th>
<th>Mould count</th>
<th>Yeast count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango powder</td>
<td>2.8 × 10²</td>
<td>2 × 10²</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Instant mango juice</td>
<td>3.6 × 10²</td>
<td>0.4 × 10²</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Green mango powder</td>
<td>10.4 × 10²</td>
<td>0.95 × 10²</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Instant green mango shake</td>
<td>9.8 × 10²</td>
<td>0.85 × 10²</td>
<td>1 × 10²</td>
</tr>
<tr>
<td>Mango purée</td>
<td>0.5 × 10²</td>
<td>0.2 × 10²</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Green mango purée</td>
<td>0.8 × 10²</td>
<td>0.1 × 10²</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Sugar, refined</td>
<td>11 × 10²</td>
<td>43 × 10²</td>
<td>20 × 10²</td>
</tr>
<tr>
<td>Modified starch</td>
<td>63 × 10²</td>
<td>7.5 × 10²</td>
<td>5 × 10²</td>
</tr>
<tr>
<td>H.J. Heinz standard (Shapton and Shapton, 1991)</td>
<td>1 × 10⁴ to 5 × 10⁵</td>
<td>1 × 10²</td>
<td>1 × 10²</td>
</tr>
</tbody>
</table>
and Shapton, 1991) at $11 \times 10^2$ and $63 \times 10^2$ cfu/g total plate count, respectively. These materials are essential ingredients of the liquid-feed formulation used for the production of the spray-dried powders.

The formulation and processing of numerous mango products popular in South Asian countries were reported previously (Nanjundaswamy, 1997).

### 17.4 Capital Investment Costs

An initial investment of approximately US$100,000 is needed for the establishment of a mango dehydration plant. The facility can also be used for drying other farm commodities such as vegetables, spices and other high-value crops. The cost of acquiring the land, building construction and ancillary costs such as environmental pollution abatement as well as quality assurance laboratory facilities are not included in the estimate.

A commercial dryer such as that manufactured by Tsung Hsing Food Machinery Co. Ltd of Taiwan with a loading capacity of 500–600 kg prepared mango slices costs c.US$11,000. At the rated capacity of the plant of 1 t per batch, 67,392 kg of dried mango pieces can be produced annually. The cost of goods sold is US$398,492 with a net profit before taxes of US$84,386/year. If the facility is used for the manufacture of mango fruit bar and mango fruit roll, the annual production is 115,200 kg of either fruit bar or fruit roll with a net profit before taxes of US$277,090/year (Table 17.1).

The total cost of equipment for the vacuum-puffing plant with a loading capacity of 1 t is approximately US$122,000, broken down as US$100,000 for fabrication of the dryer and US$22,000 for other plant equipment. The total capitalization, which includes the cost of raw materials, salaries and equipment per year, is US$648,240 excluding interest on capital.

Spray-dryers come in various capacities ranging from NIRO SD Micro Spray-dryer ideal for powdering small quantities of raw materials for research and development to units that produce powders at evaporative rates in excess of 500 kg H$_2$O/h. The investment cost for equipment increases with the capacity of the dryer (Table 17.3). For a small-scale operation producing powders or flours from commercial purée, the initial investment is US$182,000 for a 5 kg H$_2$O evaporative capacity dryer while a plant equipped with a 12 kg evaporative capacity dryer requires US$262,000 for equipment. On the other hand, an investment of US$313,860 is needed to equip a medium-scale drying plant with a 25 kg H$_2$O/h evaporative capacity such as NIRO SD 12.5R.

The estimates do not include land, building and construction costs as well as the cost of pollution statement facilities. The cost of land is dependent on where the plant will be located while building and construction costs are determined by the capacity of the spray-dryer unit to be acquired.

Total capitalization is US$317,200, US$535,947 and US$806,265 for the 5 kg, 12 kg and 25 kg H$_2$O/h evaporative capacity units, respectively. The estimate includes the cost of raw materials, salaries and equipment per annum. Interest on capital is not included.
1.5 Raw Material Requirements of the Mango Processing Plant

The amount of mango purée, mango slices and fresh mango required monthly and annually to run the plant continuously varies with the product line (Table 17.4). In general, more raw materials are needed to process dried mango, mango fruit roll and mango fruit bar compared to the spray-dried mango powders. As a result, the net income is lower than that derived from the production and sale of spray-dried mango powders (Tables 17.1 and 17.4).
The spray-drying facility requires 187.2–218.4 t/year of green mangoes and 468–504 t/year of ripe mango fruits at the evaporative capacity of 25 kg H₂O/h to produce the volume of powders in Table 17.1. On the other hand, 576 t/year of ripe fruits are required to produce mango fruit roll or fruit bar. For dried mango, 832 t/year of fresh fruits are needed to produce 67.4 t/year of the product while to produce 124.8 t/year of vacuum-puffed dried mango, 2496 t/year of fresh fruits are necessary.

In terms of area, c.38–48 ha can supply the green mango requirement of the spray-drying facility. Approximately 100 ha are needed to produce 124.8 t of ripe mango powder or 202.9 t of instant mango juice from fresh ripe mango fruits. The fresh fruit requirement for the manufacture of fruit roll and fruit bar can be supplied by 115 ha of mangoes. The 832 t and 2496 t of fresh fruit are equivalent to the annual harvest from 166 ha and 500 ha of mangoes to produce 67.4 t and 124.8 t of dried mango and vacuum-puffed dried mango, respectively. The estimates are based on a yield of 5 t from 100 trees/ha as well as the biennial fruiting habit of mango.

17.6 Conclusion

Processing of mango is a profitable business venture once economies of scale are attained, i.e. when the processor has the proper proportions of raw materials, labour and machinery to meet a given market demand. Fresh mangoes are now available year-round. But the supply is still insufficient to satisfy the demand by the fresh fruit market and the mango-processing sector. It is, therefore, essential that a farming system for mango be designed in order to minimize the cost of production of off-season fruits and ensure the sustainable operation of mango processing facilities. Since raw material sourcing is the primary cause of the difficulties encountered by processors of dried mangoes, mango in syrup and similar products, growers need more assistance for them to adopt the technology for off-season mango flower induction. The problem is not as serious for product lines utilizing mango purée as starting material since the purée can be processed during the peak of the harvest season and held in cold storage for later use. Once the system is in place, the processed mango industry is expected to develop further and become a major revenue generator.

In the near future, with the advances in the field of genetic engineering, it may be possible to eliminate the biennial fruiting habit of many current mango cultivars or, at the very least, minimize its influence on the performance of the crop. Species of *Mangifera* and some non-cultivated, wild types of mango can be the source of desirable traits that may be incorporated in the next generation of mango cultivars, such as their innate ability to bear fruits during the rainy season (see Bompard, Chapter 2, this volume).

The technologies for processing mangoes are readily available. Others are being developed in research laboratories to cope with the changing needs of consumers. The main problem is to ensure a continuous supply of high-quality fresh mango fruit in order to produce the prime quality commodities that consumers expect from the industry.
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