COLEAD

SECTOR STUDY
PROCESSED MANGO

4. Frozen mango (IQF)

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This document is part of the mango sector study. This study explores the technical and economic feasibility of different processing and waste valorisation activities. The other chapters are available here: resources.colead

Contents

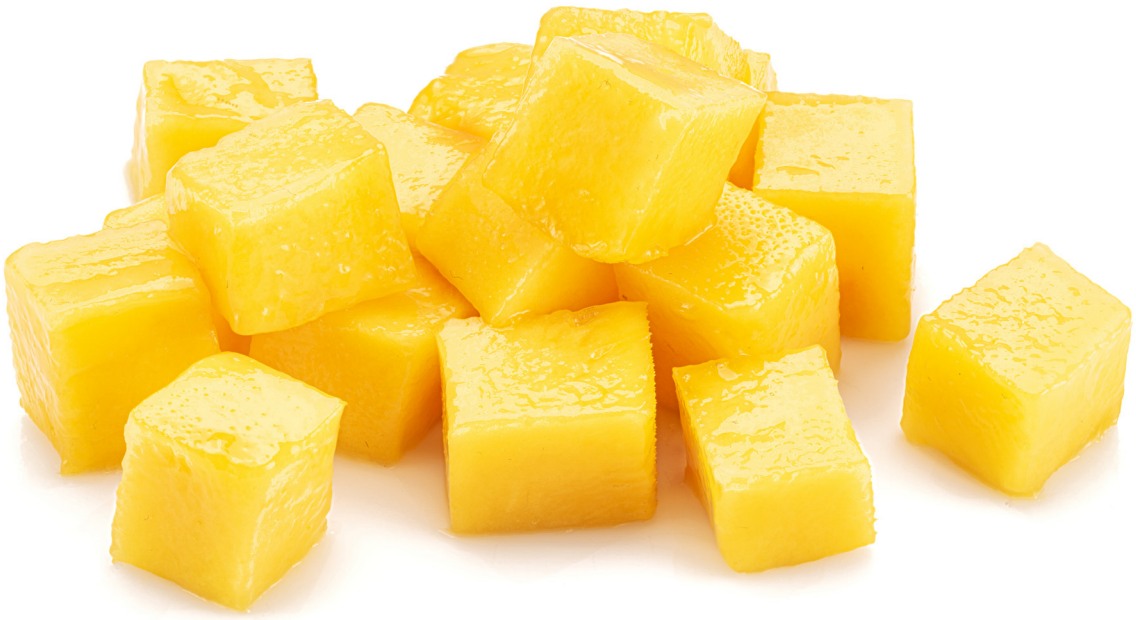
1. What is IQF mango?

The term individually quick-frozen (IQF) refers to the fact that the cubes are frozen in a way so they do not stick to each other and retain their original shape.

Because the freezing process is quick, small ice crystals form, which do not damage the tissue or cellular structure of the fruit. This means that on defrosting the fruit is firm and resembles fresh cut fruit.

Boxes of mango cubes are sold in supermarkets and via wholesalers and other stores that service restaurants.

Frozen mango comes in two main forms: frozen cubes used in the food industry and for smoothies, and longer chunks used for fresh fruit salads and baked goods. The standard size for cubes is 10 mm, but 15 mm and 20 mm are also used.



2. Demand

The demand for IQF fruits has been growing in most regions of the world. The total market is expected to grow to €5.9 billion by 2029. About 53% of the global frozen fruit volume globally is berries, while citrus and tropical fruits have a significantly smaller market share. Nevertheless, tropical fruits are growing in popularity in North America and Europe. As a result, frozen pineapple, mango, dragon fruit, papaya, banana, etc., can be found in more supermarkets and are being supplied by companies that supply hotels, restaurants, caterers, bakeries, etc. Mango is a particular favourite. One importer can easily buy 3,000 tonnes per year.

Frozen fruits are used in the home, industrially and in the hospitality industry. At home people use frozen mango to prepare smoothies, as toppings for breakfast yoghurts or for desserts. The hospitality industry (restaurants, hotels, catering, smoothie bars) uses frozen mango cubes and slices in fruit salads, on desserts and in smoothies. Home consumption and hospitality account for roughly one third of frozen fruit consumption, including mango. In this segment frozen mango competes with fresh fruit.

Two thirds of frozen mango globally is used in the food industry in baked goods, as pie filings, in toppings, in desserts, in baby foods and to flavour dairy products. It is in competition with mango purée and used to produce premium products that require some "fruity structure". The products might also need to have pieces of fruit in them. Often, frozen mango is preferred over purée or dried as it gives a more suitable texture and an appearance that cannot be delivered by pulp. Chunky yoghurts, smoothies, jams and ice creams are some examples of where frozen mango cubes are sometimes selected. Sometimes food manufacturers use frozen mango directly, but in many cases a supplier will use it to make a preparation where it is blanched, and other ingredients are added.

Figure 1. A range of products that use frozen mango as a key ingredient
Source: Authors from trade visits

Finally, the fresh cut salad market has an interesting interplay with the frozen cube market. The producers of these salads sometimes use frozen fruit as a substitute for fresh cut fruit. This has the distinct advantage of allowing them to source fruit all year round and to balance their ingredient prices. When fresh cut fruit is expensive, they can substitute it with frozen fruit and vice versa.

Berries make up the biggest share of IQF fruit traded around the world, because they have a short shelf life and are very seasonal. Most berries need to be consumed within a few days of harvesting, and they are very easily damaged. This requires careful handling, packaging, and refrigerated transport and storage. Having sufficient fresh berries for deserts, smoothies and salads is very difficult for restaurants. Furthermore, fresh berries are quite expensive and most restaurants cannot afford to throw away berries if there is a lack of demand. Finally, labour for production and fruit picking is one of the main cost factors in berry production, and the cost can be greatly reduced if berries are produced in, for example, Morocco or Mexico. Many of these characteristics are shared with tropical fruits. But frozen berries were perhaps more familiar in the premium markets where the technology was developed.

Frozen fruit offers great advantages for restaurants or food manufacturers. It is easier to prepare and cheaper than fresh fruit. Sourcing of fresh fruit is not needed, there is little waste from unused fruit, and it cuts out labour-intensive cutting of fresh fruit. Frozen mango cubes can be much cheaper to transport than fresh mango, as there is no wasted space in the container and no transport of skins and pips. In addition, second and third grade fruit unsuitable for fresh export can be used for frozen chunks.

2.1 Market size in Europe and the USA

By 2019, the European frozen tropical fruit market was €145 million, with steady growth (>7%). Some growth came directly from developing countries, while a good deal of growth came from EU countries[1]. The specific volumes of frozen mango cubes being traded in Europe are unknown. However, industry experts' estimates suggest that there could be as much as 20,000–25,000 tonnes of IQF mango being imported per year.

Mango contributes a large volume to frozen fruit imports. Demand for IQF mango is growing in the USA (see Figure 2).

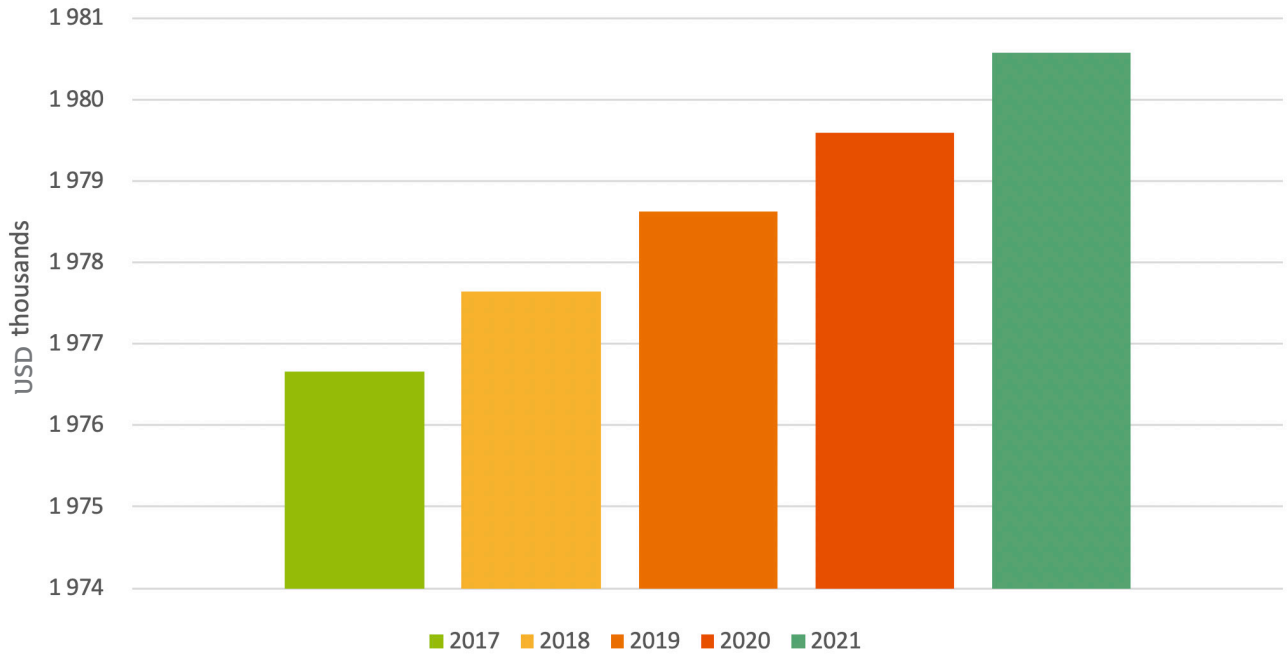


Figure 2. Value of IQF mango imports into the USA, 2017–2021 (USD thousands)

Given the growing demand and frequent shortage of supply, importers are very interested in finding new suppliers of mango. The product must meet their definition of the market standard, Kent. This specific variety is in great demand. Importers are willing to provide advice and invest time in working together to develop new producers. However, good samples are crucial to convince them, particularly for varieties other than Kent. The reason is that all their clients like Kent and they do not need to explain to them what kind of product it is; it is thus an easy sell. Nevertheless, they are willing to consider other varieties after some persuasion.

1 Autentika Global (2020) The European market potential for tropical frozen fruit. CBI. "http://www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts/tropical-frozen-fruit/market-potential"www.cbi.eu/market-information/processed-fruit-vegetables-edible-nuts/tropical-frozen-fruit/market-potential

2.2 Market trends

Smoothies

Figure 3. Smoothie market
Source: (left) www.alberts.be (right) www.unsplash.com

The smoothie market is thriving in both established and emerging markets. The increasing number of health-conscious clients, changing lifestyles and eating patterns, and the health advantages associated with smoothies are all important factors driving interest in enjoying smoothies. Customers are shifting away from high-carbohydrate meals, towards protein-rich alternatives and ingredients that are free of gluten.

People are also drinking more functional beverages, such as smoothies, to meet their daily nutritional needs. Furthermore, since people lead busier lifestyles and work longer hours, there is a greater desire for more convenient eating alternatives.

Smoothie bars and health restaurants have been innovating to bring new concepts to market. These include smoothie bowls, vegetable and fruit blends, adding herbs and spices, and offering home delivery of a week's or even a month's supply of smoothies.

This has inspired home preparation, which often relies on fresh and frozen products to add flavour and nutrition in smoothie recipes. The rapid growth of at-home preparation has perhaps prevented prepared bottled smoothies from truly taking off. Many food manufacturers have had to withdraw product from shelves as they have not been able to get people to regularly buy their packaged smoothies. This does not mean that smoothies are not a growing market. It means that getting a share of that market might require reaching shoppers through IQF, or via juice bars and other specialised health food outlets.

Confectionary and bakery

Mango has become so popular that it is becoming a regular ingredient in desserts, salads, breakfast bars, etc. Frozen mango cubes are available for most of the year and so give food outlets access to a desirable ingredient all year round. The tidy, pre-sliced format makes it convenient to use and reduces waste in the kitchen. It is an ideal format for restaurants, hotels and confectioners who are looking for ways to simplify their ingredient lists, reduce labour and better manage waste.

Figure 4. A mango dessert
Source: unsplash.com

Labour shortages

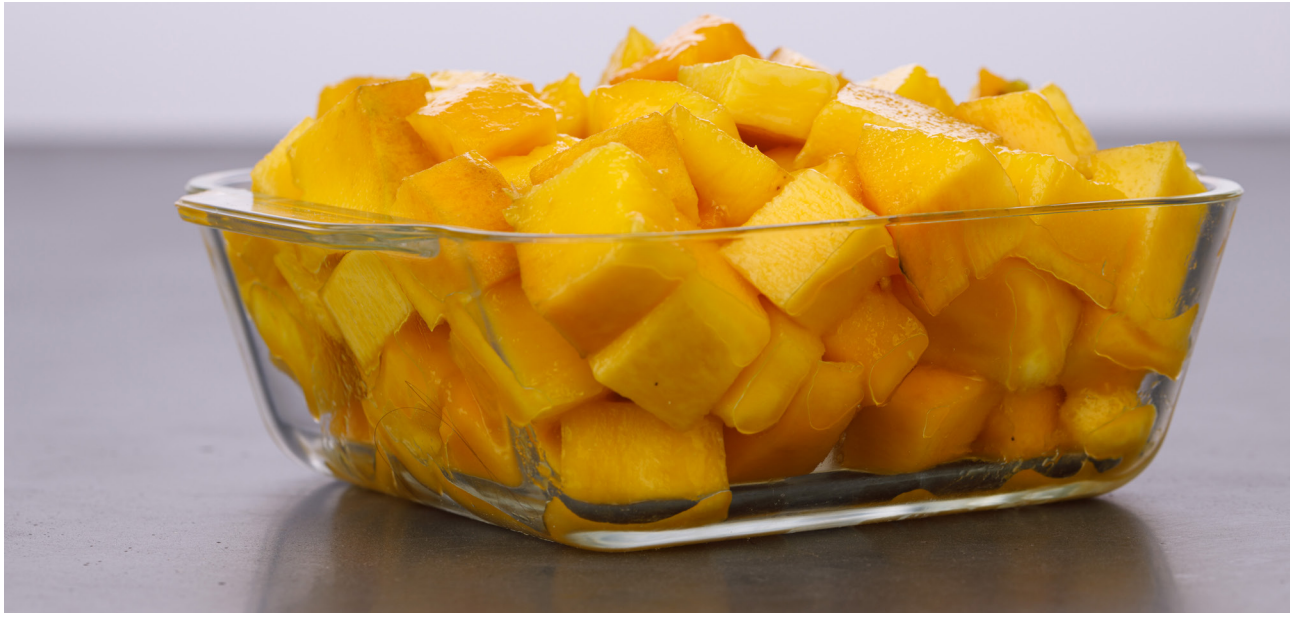
The COVID-19 pandemic has created significant shifts in the labour market. The hospitality sector has experienced difficulties, with labour shortages now common in all major economies. This creates far greater pressure on restaurants to manage more with fewer people. Using products that are prepared and do not need much handling is one strategy that could help in this. Frozen mango cubes can deliver these benefits, while helping companies to simplify management of the shelf life and seasonality of ingredients.

2.3 Certifications, quality standards, etc.

Each client has different specifications for their product, in terms of colour, sweetness, flavour, size and hardness of the cube. Nevertheless, most prefer a dark yellow–light orange colour with a typical ripe mango flavour, low fibre and a cube that is still soft enough to eat but hard enough that it keeps its shape and structure once it is defrosted. The required hardness also depends on how the product is processed: the more machines are used, the harder it needs to be. In terms of cuts, the two dominant preparations are hand-cut chunks (mainly used in fruit salads) and cubes (most 10 mm, though 15 mm and 20 mm are also sold). Certification (hazard analysis and critical control points [HACCP], etc.) is increasingly demanded by clients. The most important buying criteria are described in Table 1.

Table 1. Buying specifications for IQF mango

Maturity cut	Mangoes have matured sufficiently to be full fleshed, tender and well ripened. 11–14 °Brix. The target cut is 25 mm ± 5 mm, uniform cut.
Freezing technique organoleptic	Acceptable freezing variety and manufactured in accordance with good manufacturing practices.
Product specification	Tolerance of 30% by weight for pieces smaller than 20 mm or greater than 30 mm.
Colour, flavour and aroma	Typically dark yellow–light orange colour. Product possesses a good characteristic normal flavour, aroma and appearance of mangoes. Free from objectionable flavour and odours of any type.
Storage and handling shelf life	Transport and store at 0°F (–17.8°C) or colder. 24 months at 0°F or colder.



2.3.1 Varieties

Kent (extensively grown in Peru) seems to be the preferred variety because it corresponds best with most client specifications.

Prior to 2018, importers were mostly looking for Kent, because they were happy with the colour, flavour and structure, and it was basically the only variety they knew (apart from Ivory from China). Today there is more space for other varieties. Many new countries have entered the market and brought with them different varieties. Anything that resembles Kent will work, such as a Keitt, Hayden, Edwards or Palmer; for the industry that reworks mango cubes into preparations less premium varieties such as Totapuri are also acceptable.

Tommy Atkins is accepted by the market but has more fibre and is therefore not a premium product. Varieties Amélie, Lippens and Brooks grown in West Africa are unknown on the market, and it will take serious marketing efforts and some discounts to move importers to them – unless the product is organic, in which case it is much easier to sell.

2.3.2 Organic

The organic market for frozen tropical fruit is relatively small, but growing. Baby food in particular is shifting to organic. Supplying countries often see organic tropical fruits as too niche and no countries have carved out a space for themselves as true organic specialists. This opens an interesting opportunity to enter the market.

Organic frozen fruit is, however, a specialist product, with specific importers focussing on the product. Organic frozen mango fetches a 10–15% premium over conventional frozen mango. There is a clear demand for organic IQF mango and a shortage of supply, as with other processed mango products. Thus, it is worthwhile exploring, particularly since West Africa still has many organic producers, and organic product can always be sold as conventional in case demand is limited.

3. Supply

3.1 How do these products reach the market, what is the value chain structure?

The value chain for IQF fruit is very similar to that of fruit purées and concentrates. Producers in the tropics export to an importer or compound house/prep house. Many importers of frozen fruits also import purées and concentrates, but there are also companies that specialise in frozen products.

Some prep houses make fruit preparations for the food industry. Importers sell to prep houses, but also to wholesalers for the hospitality industry, to supermarkets, to food companies directly and on some occasions to fresh cut fruit salad producers.

In Europe, most importers are located in Belgium, the Netherlands, France and Germany. With companies such as ARDO, CROPS and DIRAFROST, Belgium plays a disproportionally large role in the frozen fruits and vegetables market and is a major exporter of frozen fruits to the rest of Europe. The Netherlands has a similar role, for example with importers such as Netra Agro and Rolin. However, vertical integration is also a trend in frozen fruit, with more products being sourced directly by food producers themselves in the tropics.

Importers are increasingly looking to reduce food safety risks, to secure volumes all year around and to encourage better product handling. These are essential in Europe and the USA where these are important terms of doing business with large manufacturers and retailers.

As a result, strategic partnerships down the value chain as well as mergers and acquisitions are more common than before. Many importers have strategic partnerships with producers or are investing in factories. Importers might themselves be involved in mergers or buyouts to get better efficiencies down the value chain. A key example is the ARDO–VLM merger, which gave the Belgian firm, ARDO, greater access to US markets as well as a controlling stake in Compania Frutera, Costa Rica's largest frozen pineapple manufacturer.

The largest challenge for importers and processors prior to the COVID-19 pandemic was the lack of reliability of suppliers when it came to fulfilling contracts. Importers close contracts ahead of the season with their clients, and on the supply side with factories and/or other traders. When the harvest is poor producers often do not have enough to sell, and what they do have they often sell to other traders who offer a higher price than those they have signed contracts with. They then make excuses as to why they cannot deliver, leaving the importer with the need to dishonour the contract or buy mango elsewhere on the spot market.

Strategic partnerships and increased vertical integration, which were emerging pre-pandemic, are often attempts to avoid these issues. In this model, the businesses in the value chain work together to build their joint business in the sector. Prices are a negotiation between the growers, processors and importers, and might at times be higher or lower than the spot market prices. Over the long term this shared value for the actors in the chain is beneficial as it reduces risk and uncertainty, and allows them to build the category and their reputation within the category together.

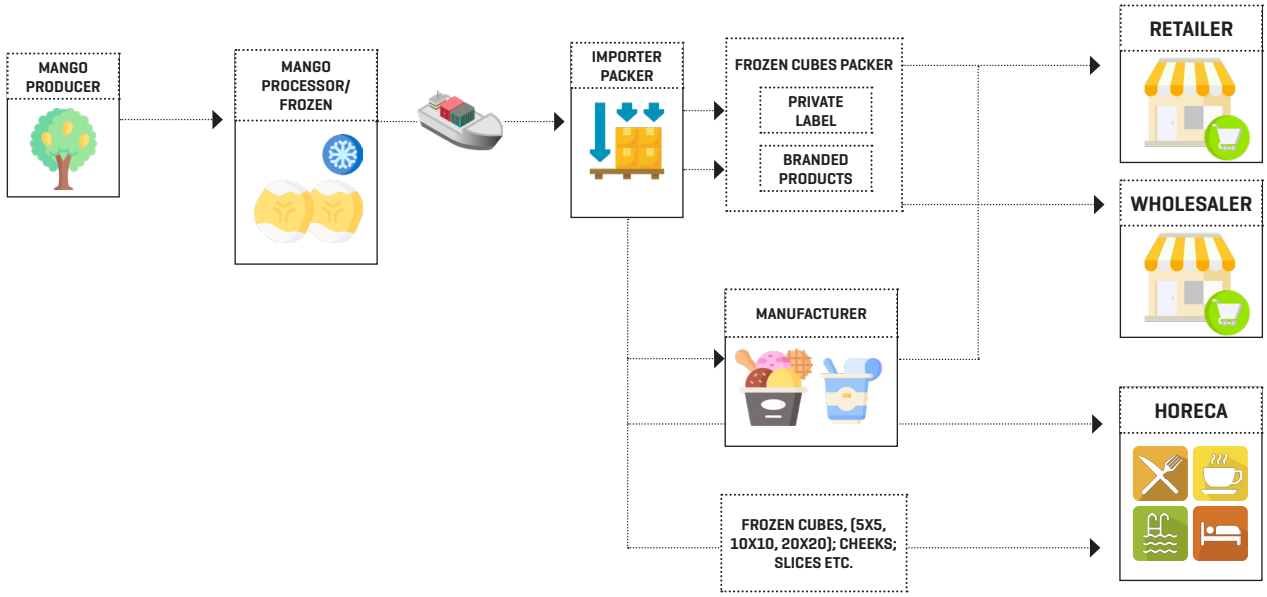


Figure 5. Market structure for frozen tropical fruit
Source: Authors' own illustration based on interviews and desk research.

3.2 Main suppliers of IQF mango

The three largest suppliers of IQF mango globally are currently India, Mexico and Peru. Historically, China was an important supplier of cheap frozen mango cubes for industrial use, while India did not produce IQF. However, since the mid-2010s the role of China has been taken over by India. Historically, importers have had food safety concerns that makes them more hesitant to import frozen mango from China. More recently being able to export Kent has meant that China has become more competitive again, but uses more of its product domestically.

Pre-COVID demand for frozen mango sparked interest in production. New factories were opened across the world in countries such as Guatemala, Chile, Vietnam, the Philippines and Madagascar. While still small, their contribution to global IQF mango has been growing rapidly (CBI). Guatemala, Vietnam and Chile together supplied €7 million worth of IQF mango cubes to the USA in 2021.

Table 2. Origin of IQF mango imported into the USA, 2021 (€ millions)

Mexico	Peru	Guatemala	Vietnam	Chile	Canada	Ecuador
72.2	47	4	1.5	1.5	1	0.77

There are some regional differences in where products are sourced. Frozen mango cube for the US market is almost entirely supplied by exports from Latin America. Mexico and Peru deliver 91% of all frozen mango to the USA. In contrast, the top two suppliers to Europe are Peru and India.

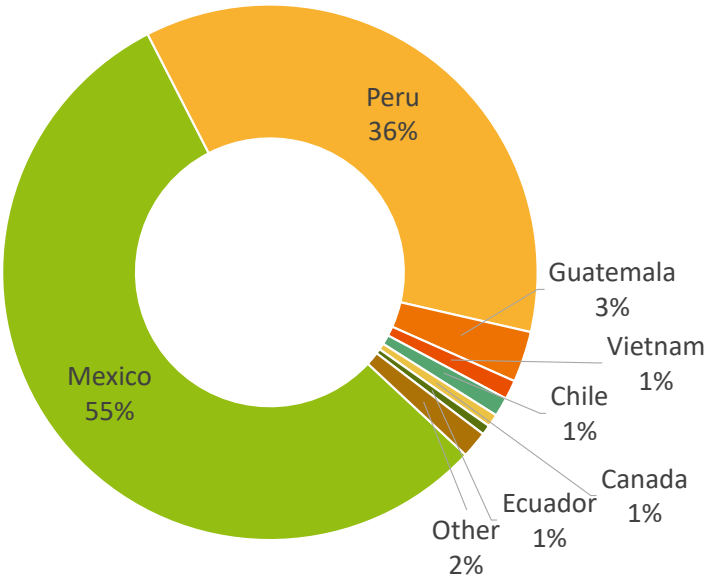


Figure 6. Contribution to US imports of frozen mango, 2021
Source: ITC Trade Map,

3.2.1 Producers – China

China is a large producer of IQF mango, but most production is used in the country itself. The dominant variety is Ivory. The product they produce is a very hard and light-coloured cube, which is not very popular on the international market, and only in demand by specific industrial processors. However, western companies try to avoid Chinese food products as much as they can because of concerns of chemical contamination and food adulteration.

3.2.2 Producers – India

India is a traditional producer of processed mango products such as pulp, but was not formerly a dominant player in IQF. They supply two products: Alphonso cubes and Totapuri cubes. Alphonso has an attractive orange–yellow colour with a sweet flavour. Totapuri is a lighter yellow with less flavour, but still relatively soft. Alphonso is very expensive and often in short supply. Because of its high price it is not imported in large quantities. Totapuri is much cheaper and imported in larger quantities, despite its shortcomings. Totapuri is only sold in machine-diced cubes for further processing into food products.

3.2.3 Producers – Peru

Peru is a relatively new player in mango processing, but they managed to obtain a dominant position in just a few years and have been the main supplier to Europe since about 2016. Despite growing competition, they are still dominating the market. The two main varieties from Peru are Kent, but Keitt, Edwards and Hayden are also used. Importers estimated in 2016 that there were about 10–15 factories in Peru, with an annual production of between twenty and sixty 40-foot containers (at 24 tonnes per container this means between 480 and 1,440 tonnes per year). Production has undoubtedly grown since then.

Figure 7. Frozen Peruvian mango in a German retail outlet
Source: authors from trade visits.

Factories do not seem to produce many other frozen products, which indicates that even with a four-month production season a factory can be profitable.

Hand-cut chunks of Kent and Keitt for fruit salads and other premium uses is an important market segment for Peruvian producers.

3.2.4 Producers – Mexico

Mexico also produces mainly Kent for frozen fruit cubes, but it is generally more expensive than Peruvian frozen mango cubes on the European market. Most Mexican produce goes to the nearby US market that can afford to pay more because the transport costs are lower. Europe only sources from Mexico if Peru cannot deliver the quantities it requires.

3.2.5 Producers – Thailand and others

Thailand is a traditional producer of IQF mango but seems to have stagnated in development and its position in the market has been lost to Peru. Ecuador is a new player, with Kent as the main variety. When supply of mango in Peru is short, Peruvian producers may source in Ecuador to fill their contracts. Some importers import directly from Ecuador. Vietnam is a new player, about which there is little information; it seems to lack the specific varieties that are currently in demand. There are also rumours of importers looking at Sierra Leone and Nigeria as possible suppliers.

3.3 Prices

The prices for IQF are considerably higher than for purée. Prices vary according to the variety and the supply volumes on the market at that moment. Totapuri from India and Ivory from China are the least desirable products and the cheapest (€1,840 per tonne for Totapuri, 2022). They are bought because of their low price. Alphonso is usually more expensive than Totapuri (as is its purée) and is currently available on the market for around €3,400 per tonne to Europe. In South Africa, Kent is available at €2,060 per tonne; however, retail prices in supermarkets equate to €8,350 per tonne, showing the huge margins.

The regular market price for Kent when there is a normal to good harvest in Peru, is around US$1,400 per tonne CIF Rotterdam; prices seldom drop much below this level. However, in a year of poor harvest in Peru, India or Mexico prices can increase rapidly to US$1,600 and even US$1,800 per tonne.

In such years, importers scramble to obtain enough mango to fulfil at least most of their existing contracts. This naturally drives the price up. Given the fact that in most producing countries the mango harvest is disappointing each second year, this is a situation that occurs frequently.

Table 3. IQF mango spot market prices in the USA by variety and origin

	Totapuri India	Alphonso India	Kent South Africa	Kent Peru	Ivory China
2018	€922	€2,000	–	€1,550	€920
2022	€1,840	€3,400	€2,060	€2,600	€3,750 *

* Mixed according to availability – 3 variants.

There is very little organic IQF on the market, and therefore we do not have a good overview of the price premium. Interviews suggest it is 10–15% as in the purée market.

3.4 Technology, processes and techniques

IQF mango is made by peeling the mango and removing the pip, which is usually done by hand. The large pieces are then cut by machine into cubes or cut into chunks by hand.[2] It may be blanched and cooled to preserve colour and juiciness. The mango is then put on a transport conveyor that moves through a freezer tunnel. The belt in the freezer has holes in the bottom through which frozen air is blown, moving the pieces while they freeze so that they do not freeze together in clumps. They are then packed in a plastic bag in 10 kg cardboard boxes (industry) or in smaller boxes for the consumer market.

3.4.1 Step 1: Reception and sorting of fruit

Fruit is received from the suppliers and weighed, and the quality is checked. Fruit is then sorted on ripeness and quality. Rejected mangoes are either returned to the client or used elsewhere – in any case, they are subtracted from the payment to the supplier. After sorting, the mango is stored in different cold stores. Depending on the maturity and supply needed in the factory, these stores can be switched on to delay the ripening process of a batch or left switched off. Water may be sprayed on the floor and ethylene gas used to accelerate ripening.

The equipment used at this stage consists of plastic crates for reception and sorting of mangoes, scales for weighing, and cooling rooms like those used by fresh fruit exporters (see Figure9).

Figure 8. Mango reception at a factory in Burkina Faso
Source: authors from factory visits.

2 Chunks are usually cut by hand or pressed by hand through a mould. It is also possible to use a running belt with knives on the end as used in mango drying plants.

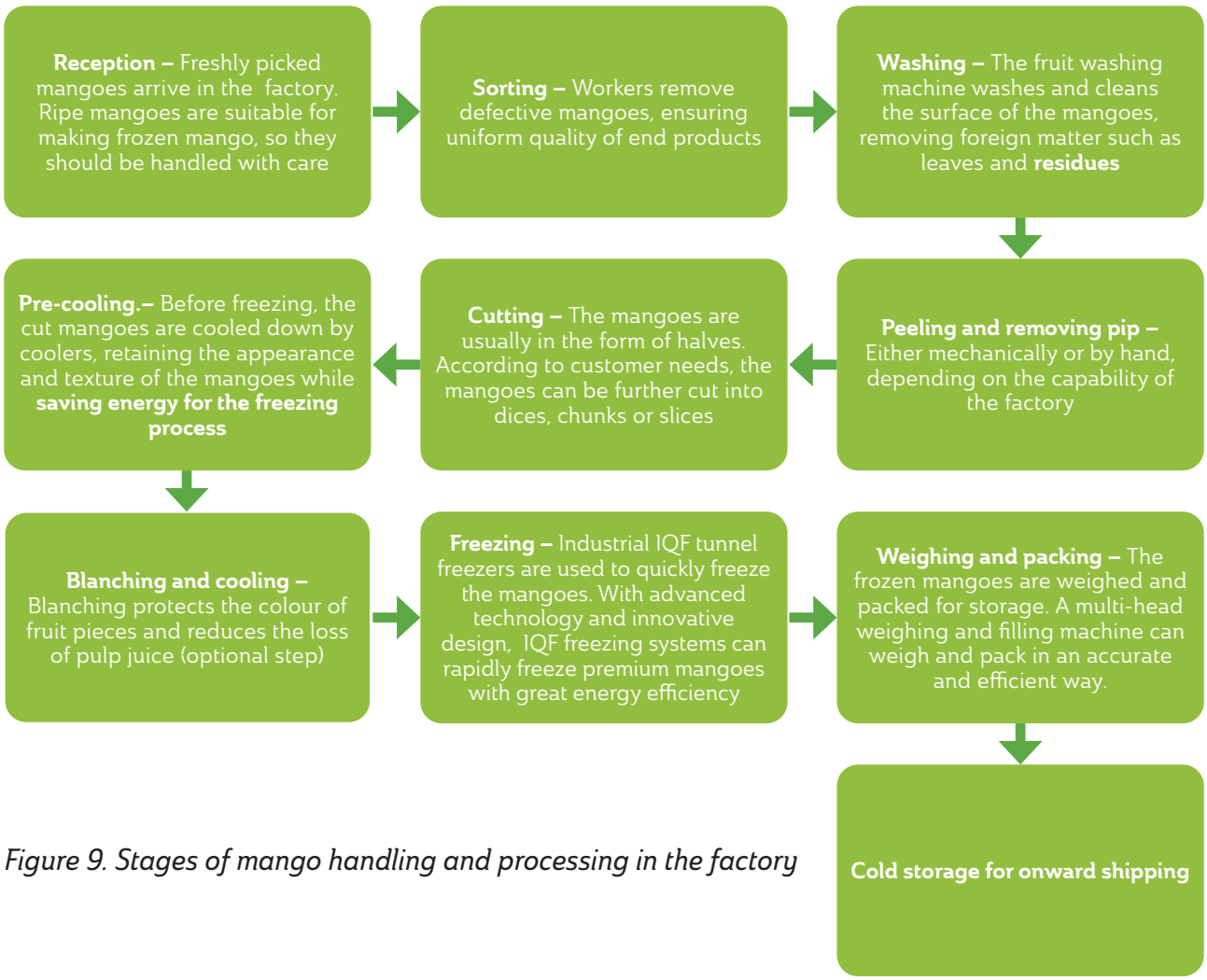


Figure 9. Stages of mango handling and processing in the factory

3.4.2 Step 2: Washing, disinfection and pre-cooling

Sufficiently ripened fruit is taken from the cold stores, weighed, and washed in a bath with a mild disinfectant to remove bacteria from the skin and thus reduce the risk of infection of the final product. The equipment used is a simple fruit washer similar to those used by fresh fruit mango exporters (see Figures 11 and 12). There are two types, those where mangoes float free in a bath and those where the crate is simply placed on a rail in the water and is transported by belt though the water. The advantage of the latter is reduced handling, as the crates can be lifted and supplied to the peelers working on simple tables.

We suggest at this stage you put a cooling element in the water, as the cold water will help to lower the temperature of the mangoes that at this stage may be 40°C if they do not come from a cold store. A reduced temperature also reduces the energy usage during the freezing stage and makes cubing easier.

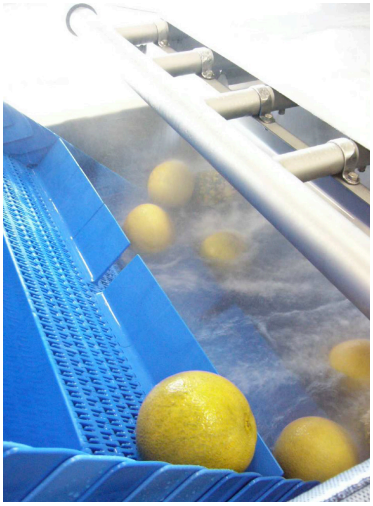


Figure 10. Mango fruit washer
Source: authors from factory visits.

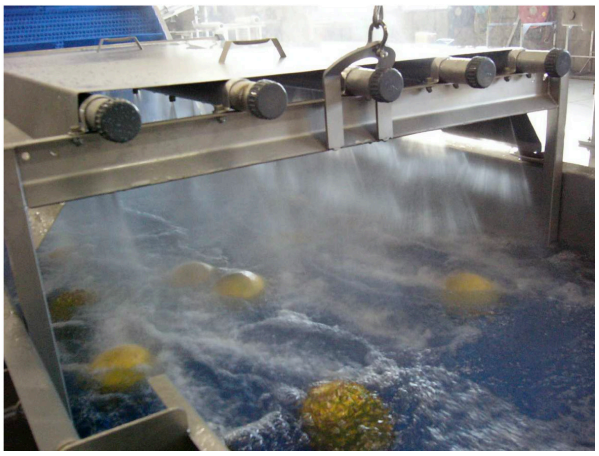


Figure 11. Mango washing machine
Source: authors from factory visits.

3.4.3 Step 3: Peeling and slicing–destoning

The peeling and slicing–destoning of the mango can be done manually or by machine, depending on the factory. If by hand, dried mango factories of LVA in South Africa show that this is most efficiently done in groups of two. The first person peels off the skin with a potato peeler, while the second person cuts off the two cheeks and short sides and places these onto a conveyor belt.

Figure 12 Peeling and cutting of mango at an LVA factory
Source: authors from factory visits.

The only machinery used at this stage is a simple food-grade conveyor belt and elevator to transport the mango slices to the cubing machine and feed them into the top of it.

Equipment used here are stainless-steel peelers and knifes, and stainless-steel tables.

Most of the waste in the production process occurs at this stage – in the form of individual mangoes that are too ripe for processing after the ripening process, parts of mangoes that are too ripe and need to be removed, and the flesh of the mango that remains on the pip after cutting off the cheeks.

Experience of LVA in South Africa has shown that in a well-managed sorting, ripening and handling process, 65% of the weight of a fresh mango can be converted into slices, suitable in this case for dicing. The flesh stuck on the mango pip and (parts of) mangoes that are too ripe can be recovered and made into a pulp for juice or dried in the form of mango rolls. Generally, 10–15% of the fresh mango weight can be recovered into pulp.

3.4.4 Step 4: Cubing and sieving

Figure 13 Cubing and sieving mango in a factory
Source: authors from factory visits.

Cubing is a relatively simple process then can be carried out by one small but very efficient machine. The mango slices are fed into the top and cut by a series of knives into perfect 10 mm cubes that leave the machine at the bottom. The most used machine is the multi fruit dicer by the US firm Urschel. The cost of the machine is relatively modest (around US$35,000) and there is currently an Urschel dealer for North and West Africa. The same machine can be used to slice, dice and pulp a large variety of fruits and vegetables, by simply changing the cassette of knives. There are two basic mechanisms, one is slightly slower but treats the product more gently, which is needed to prevent brown marks on sliced apples. The other is faster but uses more force. It will be necessary to test these knife sets to decide which mechanism is optimal for mango, but tests with the latter gave little problems. By exchanging the knives, the size of the cubes can also be changed to 15 mm or 20 mm, and mango can even be pulped.

We initially assumed considerable loss at this stage in the form of juice. When you cut mango by hand you lose weight in the form of juice that leaks away because of the pressure applied with the hand and knife. However, during the machine test there was no juice or weight loss.

That said, tests do show a considerable loss in the form of half and quarter cubes and small end slivers after cubing. Because the mango cheeks have a round side, and the length, breadth and height of a piece is never precisely in whole centimetres there were always smaller parts after cubing. Clients tend to tolerate a maximum of 10% imperfect cubes, so a percentage needs to be sieved out. A simple screen sieve can be added after the cubing. We estimate a loss of 5–10% at this stage.

Figure 14. The Urschel Diversacut Sprint, suitable for cubing, slicing and pulping a large variety of fruits and vegetables
Source: Urschel.

3.4.5 Step 5: Precooling, dewatering and freezing

It is very important to cool the mango immediately after dicing. It is recommended that you use cooling water close to the freezing point, since the mango's temperature will slightly increase while it is transported on the conveyor belt to the freezer. If you want to obtain high-quality IQF mango, its temperature should be lower than 5°C (41°F) before entering the freezer.

This might seem like an additional effort but is necessary for a good freezing result.

Figure 15. Mango packaging
Source: www.saluzzocr.com

Efficient dewatering: it is important to make sure the mango is properly dewatered after cooling if you want to obtain a superior IQF mango. The maximum surface water should not exceed 2%.

The mango is now entering the freezer. Experienced IQF mango processors consider the optimal choice for the freezer infeed to be vibrating conveyors. The positioning of the infeed conveyor is of crucial importance as too high a drop can damage the surface of the product. And the feeding must be done at a constant rate.
Because of its complex technology, the fluid bed freezer is one of the most expensive machines in the process. Technology has progressed a lot, however, and we obtained quotes from both China and one of the original producers of IQF lines, Octofrost. China prices for a capacity of 3 t/hour upwards range from €223,110 and Octofrost costs around €450,000.

A refrigeration plant is required as the cold store for fresh mango. The refrigeration plant is an expensive part of the factory in terms of investment cost. A diesel generator supplies the energy of the refrigeration plant; this is a simple and inexpensive part of the factory, as second-hand, refurbished generators are readily available.

3.4.6 Step 6: Packaging

IQF mango is normally packaged in cardboard boxes in batches of 10 to 20 kg. After freezing, the cubes are transported by conveyor belt and fall into the boxes. A simple packaging machine is needed that divides the flow of cubes into pockets of 10 or 20 kg and then fills each box. The boxes are normally transported completely flat and will need to be folded; it is easiest and probably cheapest to do this manually.

It is important to obtain quality boxes, otherwise they
may collapse during transport and the final product will be damaged and rejected upon arrival. Most likely the boxes will need to be imported from Europe, Asia or South Africa.

3.4.7 Step 7: Storage and transport

Ample storage space is necessary, as transport to final clients may not be available regularly and some clients do not want to receive the full order at once. Because the cooling runs on diesel, there is no risk of loss of stock because of frequent power outages. Nevertheless, it will be important to negotiate rapid shipments with clients because storage under the high West African temperature using the expensive local fuel is more expensive than storage in

Europe.

3.5 Technology and total investment cost

Table 4 gives an overview of the investment cost of the plant and its energy usage.

Table 4. Investments in building and machinery for a 1-tonne/hour IQF production plant and energy requirements

Item	Estimated cost, Europe	Quoted cost, China	Power required (Europe/China)
Production hall of 500 m2, cold storage, office, and toilet/ changing room	€400,000	€400,000	
Multi fruit washer, capacity c. 3 t/hour	€30,000	€14,200	6.0 kW / 2.2 kW
6 Stainless steel tables for 38 cutters and peelers, plus conveyor belt for transport to cutters	€15,000	€12,000	1.5 kW / 0.75 kW
Mango dicer, capacity 2–3 t/hour, comprising 3 groups of adjustable knives	€35,000	€14,700	1.1 kW/ 2.2 kW
Freezer, capacity 3 t/h (start-up capital and on-site training)	€450,000	€223,110	Chinese line: ▪ 220 V/50 Hz single phase; 11.2 kW ▪ 380 V/50 Hz three phase; 62 kW
2 Screw elevators, including collection hoppers and adjustable-speed gear drives	€15,000	€12,300	4 kW / 1 kW
Separation vibrator for rejection of slivers	€13,500	€3,900	1 kW / 0.5 kW
Plant service, comprising water treatment plant, control panel, air compressor, set-up sundry items	€27,000	€27,000	5,0 kW
Automatic 20 kg packaging machine, manual tools for box sealing and labelling	€35,000	€39,500	1,0 kW / 1 kW
Refrigerated container storage	€15,000	€15,000	
Two diesel-electric generator sets, 350 kVA (new from South Africa)	€60,000	€60,000	
Ammonia refrigeration plant	€300,000		10 kW
2 x 40 ft Freezer rooms and 4 x 20 ft fridge rooms		€38,000	8 kW
Spare parts	€40,000	€30,000	
Shipping cost from	€34,000	€30,000	
Cost of erection, commissioning of equipment on site	€30,000	€30,000	
Total	**€1,499,500**	**€1,029,710**	
Various cost and unexpected 10%	€149,950	€102,971	
Total estimated cost	**€1,649,450**	**€1,132,681**	
Total power installed			334.6 kW / 110.8 KW

Source: Various independent suppliers.

The most uncertainty exists around the quote for the refrigeration plant, which seemed greatly inflated by an opportunistic supplier; the figure given in Table 4 has been revised downwards. The same can be said from the quote for the fruit washer, which has also been revised downwards. A quotation was obtained for a pre-cooling tunnel, but according to various experts this will not be needed.

The total estimated investment costs are around €1.15 million for a line from China, commissioned and with training provided. A line from Europe would cost approximately €1.65 million.

A smaller-scale machine from China with an input of 500 kg per hour and output of 300 kg per hour would cost €168,415 for the same set-up as in Table 4.

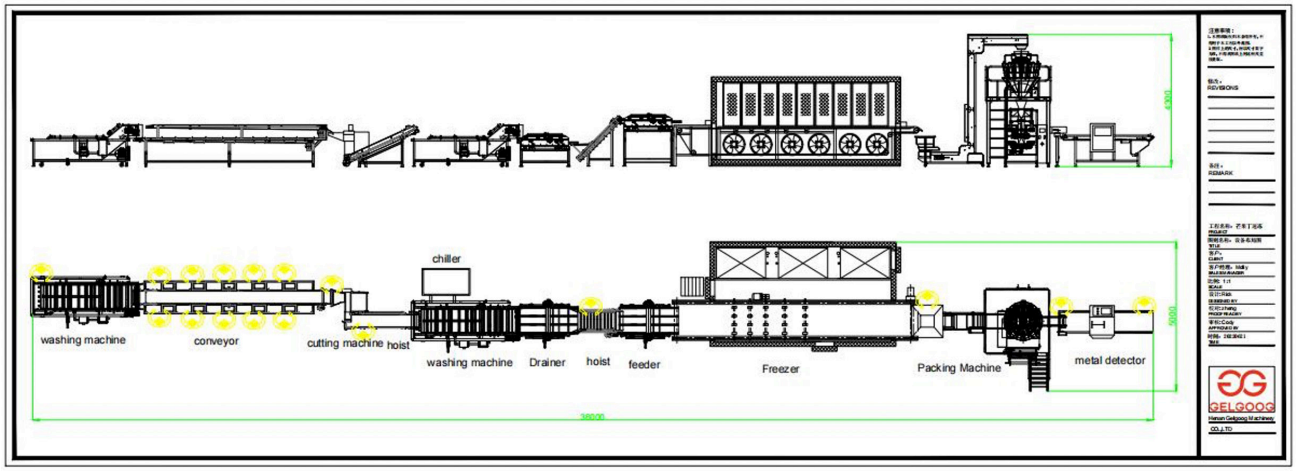


Figure 16. Gelgoog's technical drawing of the IQF processing line
Source: Gelgoog machine suppliers image.

3.6 Energy usage and power supply of the factory

The total energy usage of the factory for the line from China is estimated at 110.8 kW, compared to the line from Europe requiring 334.6 kW. This excludes the cold storage for ripening mango and finished product. The majority of this energy is used by the freezer fluid. If we include cold storage, which may not always be running, it is safe to assume a maximum of about 250 kW will be needed at peak production time (for the Chinese line).

One of the most critical parts of the production is the supply of the energy. In principle it is cheaper to run most equipment on locally provided electricity than on electricity generated by a diesel generator. However, the electricity needed for the refrigeration plant may exceed what can be supplied locally. Power outages of several hours up to half a day are frequent in Burkina Faso, and this would lead to unacceptable losses. Mangoes in cold chambers would ripen too soon, leading to riper mango than can be processed and thus a loss of product, valuable production time would be lost, and finely finished product would be lost because it would defrost. Therefore we allowed for the refrigeration plant run on its own diesel generator that has sufficient power to also supply the rest of the machines in the factory if needed. Furthermore, a backup generator is needed to allow for maintenance and service of the main generator.

Figure 17. Production of IQF samples: cutting and weighing of the cheeks (top left), cubing by machine (bottom left), collection of freshly diced cubes (bottom right) and freezing of the cubes (top right) Source: authors from factory visits.

3.7 Ingredients for success

3.7.1 Investment capital

Setting up IQF is both complicated and costly. The equipment is large, specialised plumbing is required, and creating and managing separate HACCP plans for each IQF product requires significant staff support. More importantly, to ensure the costly IQF system is utilised efficiently may require additional equipment or reconfiguration of production processes and storage space.

3.7.2 Technical control

One of the most difficult challenges processors face in IQF freezing is keeping the individual cubes separated. They can become quite sticky after being diced or sliced. The stickiness of processed product is the primary cause of lumps and blocks in the final product.

Another challenging issue for is retaining the flavour, aroma and texture of the goods while minimising dehydration of the product. This is essential for managing profitability. A natural looking and tasting product can fetch higher prices on the market. Excess dehydration negatively affects the final appearance, aroma, texture and taste.

The degree of dehydration also affects how much liquid is lost in processing. All of the moisture lost during the IQF freezing process translates into a decrease in product weight, which results in financial losses for IQF processors. This can be prevented by a blanching step, which locks in the juices and colour.

3.7.3 Location

The plant must be located where key raw materials, electric power, water, skilled labour and modern communication facilities are reliably available.

Although the general rule is to process close to your raw material source, in the case of IQF, it is preferable to be located close to the shipping location. With backup generators, you have control of storage facilities of raw and finished product. It makes better business sense to process at the shipping port, which eliminates the possibility of a break in cold chain during transport of finished goods. You can confidently deliver consistent quality at the point of onward shipping.

3.7.4 Range of products

In the long run, it is difficult for an IQF plant to be competitive by producing only during one season of typically 4 months per year. To remain competitive, processors need to look for opportunities to diversify out of mango.

Tropical fruits (passion fruit and pineapple) as well as vegetables are all possibilities that could be considered.

3.7.5 Reliable equipment, spares and repairs

Equipment should be reliable, made of food-grade material and suitable for the hot climate in Africa. The equipment should be robust enough to survive rough handling by unskilled staff and not too technologically complex.

It is especially important that servicing and maintenance are simple and easy to carry out. Ideally, spares would be easy to source and should be standard items available from various technology suppliers. Furthermore, it should be possible to use the essential pieces of equipment to produce other frozen fruits and vegetables. Any business that can use the equipment for only one product and only for a few months in the year will struggle to remain competitive in the long run.

3.7.6 Cold chain

Maintenance of cold chain at –20°C is essential till the product is delivered to the consumer.

The existing infrastructure used for refrigerated transport of fresh produce can also be used for transport of frozen produce. Surprisingly, transport of frozen produce should be cheaper and easier than that of fresh produce because a frozen state is easier to maintain than a temperature of 10–12° used for fresh mango. For fresh produce the cooling unit attached to the container needs to run continuously, as opposed to a frozen product where it only needs to run for a while if the temperature starts to exceed a threshold of –17°C.

Processors that supply fresh cut salad mangoes must be experts at local sourcing and logistics, to ensure that cold chain is well managed.

3.7.7 Utilisation of waste

Fruit processing plants always have waste or by-products, and few can afford not to process and sell this. Mango waste products that can be processed into valuable products are:

1. The flesh of the mango that remains on the pip after cutting off the cheeks
2. (Parts of) mangoes that are too ripe for processing into cubes
3. The small slivers sieved out after cubing.

We estimate that to arrive at 1 kg of cubes we need 2 kg of fresh mango. From the 1 kg of waste, 20% is usable as mango pulp. Table 5 provides the calculations of usable product per stage.

Table 5. Estimates of yields and waste during IQF mango production

		Percent-age	Weight (kg)
Fresh mango			**2.0**
Peeling and cutting of fresh mango	Slices	55%	1.1
	Pulp	15%	0.3
	Waste	30%	0.6
Cubing and saving of slices	Slices		1.1
	Cubes	90%	1.0
	Pulp	10%	0.1
Totals	Cubes	50%	1.0
	Waste	30%	0.6
	Pulp	20%	0.4

During the selection of mangoes, cutting and peeling, 55% of the mango is turned into cheeks and slices that can be diced; 30% is waste in the form of peels and pips and mango that is too ripe or diseased, and 15% is mango flesh that can be pulped. In dicing the slices, 10–20% of the total weight may be slivers and half or quarter cubes. Given a tolerance of

10% for imperfect cubes, we can safely assume that if we take out at least 10% of these by weight, the final product will be acceptable to the client. All of this can be turned into pulp, and added to the pulp obtained in the first step.

Assuming a total production of 1,664 tonnes of IQF mango, for which we need 3,328 tonnes of fresh mango, we end up with 665.6 tonnes of pulp.

There are three possible products that can be made with the mango pulp:

1. Mango juice for the local market, by adding sugar and water, and bottling
2. Mango pulp for export
3. Dried mango rolls for export or local market.

3.8 Issues and opportunities summary

Table 6. Issues and opportunities

Issues	Opportunities
▪ Expensive technology ▪ Challenging to manage cold chain ▪ Operationally demanding	▪ The processing technology preserves colour, texture and flavour ▪ Food trends and challenges with labour in the hospitality sector are positive trends for IQF ▪ Opportunities to use waste

SECTOR STUDY: PROCESSED MANGO

1. Fresh cut mango
2. Dried mango
3. Mango puree
4. IQF mango
5. Mango pickle
6. Mango vinegar
7. Mango butter
8. Mango briquettes
9. Mango based compost

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