CHAPTER VI PROCESSING

DEVELOPMENTS IN TECHNOLOGY FOR PROCESSING OF MANGOES

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INTRODUCTION

Mango (Mangifera indica L.) is the king among tropical fruits. It occupies relatively the same position in the tropics as is enjoyed by the apple in temperate regions. It is very much relished for its succulence, exotic flavour, delicious taste and nutritive value. It is recognised as one of the best fruits in the world market. Mango is now being cultivated in many countries of the world. However, India is the largest producer, accounting for 63% of world production (124). A fruit with many versatile properties has naturally found application for processing into various products. Starting from salt, pickled green mango slices and chutneys and going on to many products derived from ripe fruits, mango provides a wide range of products unparalled by any other fruit. Mango processing has earlier been briefly reviewed by several authors (17, 20, 40, 53, 105, 121, 129).

This review covers exclusively the technological developments in processing of mango including waste utilisation. Processing of mangoes present many problems to the industry. They are also summarised and presented.

BACKGROUND

World Production

World production of mango in 1983 is estimated to be 13.95 million metric tonnes. Of this India's share is 8.7 million metric tonnes. Other countries with notable production are Tanzania, Madagascar and Zaire in Africa; Mexico, Haiti and Dominican RP in North Central America; Brazil and Venuzuela in South America; Pakistan, Philippines, China and Indonesia in Asia. It is also now being grown in Florida and several Latin American countries. It is significant to note that almost all the production comes from developing countries. The mangoes grown in these countries are mainly consumed locally with only a small percentage being exported. The fruit therefore serves an important role in the diet of these people as a source of calories, vitamins and minerals.

Production in India

In India mango accounts for 40% of area and 39% of production of fruit crops. While the area increased by about 20%, production increased by about 13%.

Varieties

The names of varieties of mangoes grown in various countries are given in Table 1. A little over a thousand varieties are recorded in the literature of which 30-35 grafted varieties are cultivated in India on a commercial scale. Ten of the cultivars are popular for fresh trade as well as processing and Alphonso among them is the choicest variety. Baneshan, Totapuri, Neelum, Mulgoa, Dashehari, Fazli, Langra and Chousa are the other principle varieties. Non-fibrous pulpy varieties are largely used for processing. Seedling varieties and premature and preharvest drops are used for pickles (17). The season in many tropical countries starts around March/April and lasts till August/September with the exception of Kenya where cropping occurs throughout the year.

Table 1. Important Mango Varieties of Selected Countries

Country	Varieties
Australia	Kensington
Brazil	Bourbon, Carlota, Extrema, Haden, Non-Plus-Ultra
Cuba	Bizcochuelo, Haden, Macho
Egypt	Mabroka
India	Alphonso, Bombay Green, Bangalora (Totapuri), Bangana pally, Chausa Dashehari, Dushri, Fazli, Gulabi Khas, Himsagar, Kesar, Langra, Malda, Malkurad, Mulgoa, Neelam, Pairi, Raspuri, Rumani, Safeda Lucknow, Schooli Shah Pasand, Suvarnarekha, Zardaloo
Indonesia	Aroomanis, Gadoong, Golek, Wangi
Israel	Haden, Maya, Mabroka, Nimrod, Sarafend
Haiti	Madame Francis
Mexico	Ataulfo, Diplomatico, Esmeralda, Haden, Irwin, Keitt, Kent, Manila, Manzana, Naranja, Oro, Pina Canario, Sensation, Tommy Atkin
Philippines	Carabao, Pico
Pakistan	Sindhri and several Indian varieties
Puerto Rico	Colombo, Kidney, Haden, Mangotino, Mayaguezano
United States	Gouveia, Haden, Irwin, Keitt, Kent, Momi K, Palmer Pope, Sensation, Smith, Tommy Atkin

Source: Malo (1970), Malo (1972), Singh (1972), Wiltbank (1977), Lakshminarayana (1980) and Valmayor (1972).

International Trade

Total international trade in fresh mangoes is placed at around 23,000 tonnes per year valued at US $ 30 million, the major areas of import being Western Europe, West Asia and North America. Major suppliers of fresh mangoes include the Philippines and India, the two together supplying about 63% of world requirement of this fruit. Other notable suppliers are Mexico, Mali, Kenya, and South Africa. Nearly 65% of world imports of fresh mangoes is accounted for by Western Europe and West Asia. In India mango exports account for less than 0.1% of total production, the reason being that Alphonso variety, which accounts for only

2% of total production, is the single largest variety that is exported and hence there is scope for increasing the export by introducing other varieties (124).

Chemical Composition

The range in chemical composition of commercial varieties of mangoes grown in various countries is given in Table 2. Mango is a fairly good source of carbohydrates, vitamin C and a very rich source of provitamin A (28,38,40,108). Sixteen carotenoid pigments were identified in the Alphonso mango, 60% of which was β-carotene. Luteoxanthin and Violaxanthin which are seldom found in fruits, are reported to be present in significant quantity in this fruit (43).

World Production and Trade of Mango Based Products

India also dominates the world production and trade of processed mango products. It is reported that India accounted for 80% of the world total production of 20,000 tonnes in 1975 (124). The world total for processed mango products is not known exactly. However, it may be assumed that it does not exceed say 60,000 tonnes since the total production of India, the world's leading producer, reached only about 43,600 tonnes in 1980. India is estimated to have produced 43,583 tonnes of mango products valued at Rs.257 million in 1980. The major products in descending order are mango pulp, mango juice, mango pickle, mango RTS (Ready to Serve) beverage, mango slices in brine, mango chutney, canned mango slices, mango jam and mango squash. Production of dehydrated products and frozen products have just begun. Export from India increased from around 9,000 tonnes in 1971-72 to 27,000 tonnes in 1981-82. The value of export and unit value realised have increased over the years. The breakdown of export of products is given in Table 3.

India is dependent upon Gulf Countries and European export markets and now to some extent on the USSR. Hence, there is need for diversification of markets.

Table 2 Proximate Chemical Composition of Ripe Mangoes

Variety	Moisture %	TSS °Bri	Titratable acidity %	pH	Vitamin C mg/100 g	Sugars			Carotenoids ug/100 g	
						Red. %	Non-Red. %	Total %	Total	Beta
Alphonso	81.95	17.6	0.15	4.7	60.7	3.23	12.33	16.22	8344	4764
Bangenapalli	82.10	17.0	0.40	4.3	-	6.80		16.6		
Cherukurasam	79.80	19.0	0.29	4.2	-	4.10		15.3		
Haden	82.80	18.9	0.22	4.9	32.1	3.50		16.22		
Irwin	83.10	16.7	0.12	4.5	45.7	6.00		13.71	9212	4617
Keit	79.46	18.4	0.11	4.8	13.9	4.46		13.60	5902	2292
Kent	-	21.0	0.12	-	23.5	5.50		20.90	927	277
Pairi	84.2	15.0	0.14	5.8		5.40	7.7	13.50	5729	2613
Peddarasam	81.9	18.0	0.57	4.2		5.60		16.0	927	277
Sensation	-	15.7	0.15	4.4	55.0	4.30	9.0	13.30		
Suvarnarekha	80.7	18.7	0.45	4.5		5.3		17.9		
Totapuri		16.8	0.80	3.8	19.5	5.3	6.0			
Zill		15.9	0.16	4.6	14.0	3.2	10.9	14.1		

Source: Lakshminarayana (1980).

Table 3 Export of Processed Mangoes (Quantity: Tonnes, Value Rs. X 000)

Fruit/Product	1976-77		1977-78		1978-79		1979-80		1980-81		1981-82	
	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
Mango slices (dried)	37	220	343	1918	307	2169	738	4471	542	4660	21	247
Mango slices Brine	885	3754	832	4652	2213	12790	2049	12210	2769	17662	1096	7547
Mango Flour	116	887	42	395	16	197	-	-	12	138	24	331
Mango chutney pickle	352	1988	3895	21722	4819	29978	-	-	5081	42090	4961	46289
Mango juice	9632	46094	6295	31790	5743	34028	5728	37299	9647	58929	18478	74800
Mango puree paste etc.	3015	17472	3438	23038	2569	15715	1981	13724	3767	29910	7037	59727
Mango squash	-	-	-	-	-	-	37	310	65	628	18	374

Source: Monthly statistics of the foreign trade of India, Vol. 1 (Exports and re-exports) Mar. 1977, 1978, 1979, 1981 and 1982. Directorate General of Commercial Intelligence and Statistics, Calcutta, Govt. of India. Figures in each year represent for the period April to March.

PROCESSING OF MANGOES

In most mango growing countries the fruit is generally consumed in its fresh state. It is estimated that about 0.22% of mangoes produced in the world are processed (17). Mangoes are processed, at both raw and ripe stages of maturity, for conversion into a wide range of products as shown in Table 4.

Table 4. Utilisation of Mangoes for Processing (Products Range)

Green mangoes	Ripe mangoes	Mango waste	
		Peel	Stone
Mango pickle	Mango slices in syrup	Pectin	Starch
Mango chutney	Mango juice	Mango syrup	Fat
Mango slices in brine	Mango nectar		
Dehydated slices or powder	Mango squash		
Raw mango beverage	Mango RTS beverage		
	Mango syrup		
	Mango jam		
	Mango fruit bar		
	Mango powder		
	Strained baby foods		
	Mango cereal flakes		
	Mango concentrate		
	Mango aroma concentrate		

I. TECHNOLOGY FOR PROCESSING GREEN MANGOES

Mango Slices in Brine

Raw and unripe mango slices are preserved with salt for later conversion into pickles, chutneys, or as salt stock for export. The method consists of adding 15-20% salt to prepared slices, draining the liquid formed therein and replacing it with fresh salt. An improved method consists of steeping the slices in 10% brine containing 200 ppm of SO_2 for primary salting for 20 hours and 5% powdered salt with 200 ppm SO_2 for storage (6). Addition of black mustard powder (0.5% level) or 0.1% sodium benzoate in 20% salt solution has also been suggested (41). The fibrous varieties are ideally suited for brine curing. Table and grafted varieties tend to become soft and mushy during storage. To overcome this defect, firming, using calcium chloride, alum after salt curing is recommended (67,125). Alternatively, the cured slices could be dried in the sun or in a cross flow air drier. Drying reduces bulk and results in economy.

Mango Pickles

This is an important product prepared from unripe green mangoes in some countries. Pickles are classified as salt pickles or oil pickles. The oil used is either mustard or gingelly oil. Cured slices are drained of the brine. Salt powder, spice mix (containing fenugreek, mustard powder, turmeric powder, red chilli powder, aniseed, etc.) and oil are shaken in a vessel. To this the slices are added, mixed well, packed into containers (glass jars or glazed jars) and properly sealed. Extra oil is added to form a 1-2 cms layer over the pickle to prevent the entry of air (17). Microbial spoilage due to moulds is common and could be checked by proper addition of salt and spices or 200 ppm of benzoic acid. Addition of a preservative emulsion is also suggested (7). Several recipes used in India and Pakistan have been reported (3,120).

The best stage of harvest for pickling is just after the endocarp starts hardening (37). Pickles made from 6-10 week old Amlet mangoes were of good quality but those from 8-9 week old fruit were superior in colour and flavour. High acid mangoes (5-6%) were found to produce the best quality pickles (100,101,102). For preparing pickle the following recipe is recommended (100): Mango slices - 250 gm, salt - 60 gm, mustard powder - 24-40 gm, chilli powder - 20 gm, turmeric powder - 2-4 gm, fenugreek seed - 2-4 gm, Bengal gram seeds - 2-4 gm, Gingelly oil - 20-30 gm.

Pickles are generally packed in glass jars. Salt pickle may be packed in polythene containers. Curing of pickles before canning, polythene lining inside the can, and the use of lacquered cans are measures suggested for packing pickles in cans (17,99).

Recently a process has been developed to dehydrate the salt cured mango fruit pieces, dry them, mix with spice mixture and pack to produce an instant pickle mix. This mix on addition of water and storing overnight is found to give good quality pickle the next day (85).

Mango Chutney

There are broadly two types of chutneys: (i) sweet chutney, and (ii) hot chutney. Sweet chutney is prepared either from fresh slices or brined slices. The fruit pieces are mixed with sugar, salt and cooked along with the spice bag to the consistency of jam. Then vinegar or glacial acetic acid is added and mixed well. The spice bag is then removed and the product is packed hot into sterilised bottles and sealed airtight. Cardamom, cinnamon, cumin, red chilli powder, garlic and onion are the spices used. Raisins, currants, almonds, dates are also used depending on the recipe.

Hot chutney preparation is similar to that of sweet chutney except that more spices and less sugar are used. Varieties like Tothapuri and Fazli are reported to be ideally suited for this purpose. The chemical composition of sweet chutney is give in Table 5. The subject of chutney has been reviewed exhaustively (8,111). A typical recipe for sweet mango chutney is as follows: mango slices - 100 kg, sugar - 100 kg, salt - 6.25 kg, mixed spices - 3.12 kg, garlic - 0.63 kg, red chilli powder - 1.56 kg, vinegar - 12.5 kg and ginger - 12.5 kg.

Table 5. Chemical Composition of Mango Sweet Chutney

Particulars	Mango sweet chutney
Total soluble solids (%)	64.4-71.1
Total sugars (%)	60.2-67.7
Acidity as citric acid (%)	1.02-1.63
Volatile acidity as acetic acid (%)	0.43-3.31
Total ash (%)	1.63-2.27
Salt content (NaCl) (%)	1.05-2.66
Crude fibre (%)	0.57-0.97
pH	2.60-2.80

Siddappa & Nanjundaswamy (1959).

Dehydrated Green Mango Powder

Raw mango slices of seedling varieties, dried in the sun and powdered, is referred to as 'Amchoor' in the trade and is used in culinary preparations in India. A better quality product is obtained by blanching the prepared slices of unripe fruit followed by sulphitation and drying (108). In Australia machinery has been developed for peeling unripe mangoes (54). Considerable quantity of green fruit drop is recorded due to adverse weather conditions. Utilisation of this type of fruit will go a long way in ensuring better returns to the growers (24).

Systematic studies have recently been conducted to improve the process of making 'Amchoor' by both sun and cabinet drying using totapuri, Pairi and two seedling varieties of mangoes. Optimum stage of maturity was between 9-10 weeks after fruit set. Sulphitation was helpful in better retention of colour and vitamin C. A drying period of 10 hours in a cabinet drier and 15 hours in the sun was necessary to reduce the moisture content to 2-3% when the tray load was 0.6 kg/sq. ft. and drying temperature was 55+5°C. During packing in polythene bags and storage a progressive decrease in ascorbic acid and starch and increase in reducing and total sugars were noticed (24).

Green mango pulp has also been successfully dried on an atmospheric double drum drier (30). Addition of corn starch and tricalcium phosphate was found to improve the flow characteristics of the dried powder. The powder was best stored in OTS cans or aluminium foil laminate pouches. The powder is suggested to be used as a base material for preparation of green mango drinks and thick mango chutney. The process has found commercial application in Calcutta. The chemical composition of green mango pulp and dried flakes is shown in Table 6. The powder is a rich source of carbohydrates, acidic, minerals and ascorbic acid. Loss of ascorbic acid during drying was 30%. The chemical composition of six sun-dried market samples of Amchoor (130) obtained from New Delhi market is shown in Table 7 for comparison. The acidity ranged from 14-18% with no ascorbic acid.

Unripe seedling mango gratings with addition of salt at 2% frozen and stored at -17.8°C is found to keep well and could be used for preparation of chutney (45).

Raw Mango Beverage

This is a popular product prepared and consumed at the household level in North India. A commercial process has now been developed to prepare raw mango beverage base and preserve it by bottling. Gel formation is overcome by enzymatic treatment. The product has been found to keep well for more than one year at ambient conditions (85).

II. TECHNOLOGY FOR PROCESSING RIPE MANGOES

Frozen Products

A great deal of interest is shown by several researchers in freezing preservation of mango. Whole mangoes packed in polythene bags and frozen at -30°C were found good for sucking after thawing (73,119).

Four important table varieties (Alphonso, Pairi, Padri and Mulgoa) were screened for freezing in the form of slices. They are peeled, cut into slices and packed into cans with sugar syrup (40-50°) containing citric and ascorbic acid and frozen at -30°C. During storage at -17.8°C, frozen slices retained their natural colour, flavour and texture even after 12 months (45). Airblast freezing and contact plate freezing at -40°C to -45°C have been suggested for getting a better quality product (54).

Alphonso mango slices in syrup were frozen under thirteen different conditions, stored 3 months at -28°C and the chemical, microbial and organoleptic qualities assessed. The quality was insensitive to the rate of freezing and addition of 0.1% vitamin C to the covering syrup. Pre-soaking of slices in calcium chloride solution (2%) was helpful in forming the slices. Fruit frozen in 40° Brix sugar syrup had better flavour than 20° Brix syrup. During freezing ascorbic acid decreased by 30-50%, reducing sugar by 30-50% and carotenoids by 15-30% (12,23).

Three Egyptian varieties, viz. Pyrie, Taymour, Alb-El-Tore were tested for freezing and none of them were ideal (98). Several varieties of mangoes grown in Hawaii were frozen as slices in various packs and the quality of thawed samples compared after frozen storage for several months. The samples frozen in syrup were superior to those packed in dry sugar or no added sugar or syrup. Ascorbic acid addition produced no improvement in quality (80).

Table 6. Chemical Composition of Green Mango Pulp and Flake Dried by Drum Drying

Particulars	Green mango pulp	Green mango flakes
Moisture (%)	81.5	5.1
Total ash (%)	0.6	3.1
Total sugars (%)	2.3	10.8
Total carbohydrates (%) (other than sugar)	14.1	68.3
Total protein (%)	0.4	2.1
Crude fibre (%)	0.4	2.1
Fat (%)	0.5	2.5
Acidity (%)	1.3	6.2
Ascorbic acid (mg%)	70.0	252.0
		(30% loss during drying).

Gangopadhyaya *et al.* (1976).

Table 7 Chemical Composition of market samples of Amchoor

Particulars	Range
Moisture (%)	5.1-8.0
Acidity (%)	14.4-17.8
Reducing sugars (%)	8.3-10.7
Total sugars (%)	11.1-13.3
Tannins as tannic acid (%)	3.1-4.8
Water insoluble solids (%)	44.4-56.4
Alcohol insoluble solids (%)	28.5-33.5
Ascorbic acid	Traces

Usha & Anand (1981).

Significant differences were found in the texture of thawed frozen slices of different varieties with Haden and Irwin having fair firmness and Buchannare, Kensington and Waterhouse having poor texture. Steam blanching was also found to be not beneficial. The recommended procedure is to place the slices into containers and cover with 25-30°C Brix syrup, seal, freeze in a blast freezer at -23°C and store at -18°C or lower (19). Of the three types of syrup used for freezing of Haden mango slices, sucrose syrup (25-45° Brix) was found to give better flavoured slices than glucose syrup or glucose/sucrose mixed syrup. Calcium pretreatment resulted in better colour retention.

Bombay green, Dashehari, Langra and Chousa of North India and Baneshan of South India were evaluated for freezing of slices. The overall assessment showed that Dashehari was best followed by Baneshan, Langra, Bombay green and Chausa (1).

Frozen Mango Pulp

Mango pulp (Puree) from Alphonso and Pairi varieties with added sugar at 20% level remained in good condition after 12 months of storage at -17.8°C. Addition of citric acid and ascorbic acid helped in the retention of colour and flavour (17).

Bombay green, Dashehari, Langra and Chausa and Baneshan (Indian varieties) were evaluated for comparative methods of preservation of pulps by canning, freezing and chemical preservation. The variety Dashehari scored highest rating followed by Langra, Baneshan, Bombay green and Chousa, irrespective of the method of preservation. Canning was found to give a better quality product (2).

The storage quality of Totapuri mango pulp as such or with addition of ascorbic acid (500 mg%) which was frozen as a slab (7kg) in polythene bags (25 cm x 40 cm x 3 cm) and stored at -18°C for a period of 14 months, was studied along with canned pulp for comparison. It took 4.5 hours at -40°C for the slab to freeze in a plate freezer. During storage ascorbic acid, total carotenoids and the viscosity of the pulp decreased in all the samples. Nectar prepared from the frozen pulp at the end of 6, 10 and 14 months storage, indicated the development of off-flavour. This could be removed either by pasteurising the pulp before freezing or heating the pulp before use. Added ascorbic acid was found to be helpful in retaining colour and flavour (88). Changes in ascorbic acid, total carotenoids and viscosity of the samples at the end of 14 months storage at -18°C are given in Table 8.

Mango pulp (cv. Mallika) sterilised at 95°C filled into a HDPE* container and stored at -5°C for a year was analysed for microbial load and found to be negligible. The sensory quality of the stored pulp has not been reported (44).

Similarly Hawaii mango puree heated to 90°C, cooled to 35°C before filling into 30 lb tins with polythene liner and frozen at -23.5°C was found to keep well and the nectar prepared from it had better flavour than that made from unheated pulp (18).

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* High Density Polyethylene

Table 8. Changes in Frozen Packed and Canned Mango Pulp (Totapuri) after 14 months Storage.

Particulars	Frozen control		Frozen with ascorbic acid		Canned	
	Initial	14 months at -18°C	Initial	14 months at -18°C	Initial	14 months at 4°C
Total soluble solids (%)	16.5	16.0	16.5	16.0	16.0	16.0
Acidity as C.A. (%)	0.45	0.48	0.45	0.47	0.50	0.52
Ascorbic acid (mg%)	17.0	0.9 (5.3)	65.0	12.8 (19.7)	14.0	8.9 (64.6)
Total carotenoids as -carotene (mg%)	4.2	2.15 (51.25)	4.2	3.24 (77.1)	4.10	3.75 (91.5)
Chroma. (%)	49.0	27.0	49.0	36.4	49.5	45.4
Viscosity (cp)	3950	2260 (57.2)	3950	2950 (74.7)	3795	3410 (89.9)

Figures in parenthesis indicate per cent retention.

Rama et al. (1984).

Sweetened mango puree containing 42-43% soluble solids was preserved by both canning and freezing the product diluted with three times its weight of water to form nectar. Sucrose and high fructose corn syrup (HFCS) were used as sweeteners. Canned mango puree sweetened with HFCS was preferred to frozen mango puree (9).

Canned Product

Mango Slices in Syrup

Mangoes are generally canned as slices, cheeks, shoulders or as dices. Of the several commercial varieties grown in India, Alphonso is most suited for canning (110). Other varieties such as Dashehari, Baneshan, Totapuri and Fazli gave canned products of mild flavour and pale colour. Mushiness of slices is a problem. Calcium firming treatment proved effective only in the case of Totapuri slices. In the case of Alphonso and Pairi varieties it proved ineffective and adversely affected the flavour (91).

Peeling and slicing are done by hand using different kinds of knives. Mechanised equipment for peeling of ripe mangoes has yet to be developed and it is a serious bottleneck in the industry. Lye peeling has been tried but not adopted commercially (17).

The prepared slices are filled into plain cans (401 x 411 size) and covered with hot syrup of varying strength (30-50° Brix) depending upon the variety, sealed and processed for 15 min at 100°C. Since the fruit has a pH of 4.0 to 4.5, citric acid is added at 0.25-0.40% to the covering syrup (110). Spin pasteurisation is preferred in place of stationary pasteurisation. The canned product has a shelf life of over 12 months at ambient temperature. Alphonso and Pairi varieties showed no loss of β-carotene after storage for 8 months at 25-30°C (110).

In some countries, slices are scooped with a curved knife from unpeeled cheeks cut from the fruit to give smooth surface. The stones and peels are passed through a pulper. In this process the yield of slices is reduced but the pulp yield is increased. The advantage in this method is the ease of handling unpeeled fruit (17).

The quality of the canned product depends upon the variety. Several researchers have studied the suitability of different varieties (1,50, 68, 82, 104, 126, 127). These include Indian varieties like Alphonso, Baneshan, K08, K016, Mulgova, Badami, Totapuri, Dashehari, Langra, Bombay green, Chousa, Safeda, Pairi and the recently developed hybrid varieties like Mallika, Amrapali and Hyderabad 165. Of the hybrid varieties, Mallika was found best from the point of cheek yield (53% as against 40% in other varieties), texture and flavour (50).

Langra and Sama Bahisht Chausa, two Pakistan varieties have been canned and canning effect on important constitutents studied. β-carotene showed little change during canning and storage for 200 days. Brix acid ratio increased by 40% while vitamin C content decreased by 20% on canning and a further 30% during storage (31). Similar changes have been reported in some Indian varieties (68).

Addition of ascorbic acid to the covering syrup at various levels imparted better flavour. The increase in flavour appraisal scores for Dashehari variety was accompanied by an increase in the estimated values for volatile reducing substances. The retention of flavour was lost in the product with 100 mg% ascorbic acid addition. This is attributed to the reducing and oxygen scavenging action of added ascorbic acid during and after processing (97).

Factors influencing the pectin fraction and their influence on the texture of slices during canning and storage of mango slices have been investigated. Loss of texture during storage of mango slices canned only in sugar syrup is attributed to the conversion of protopectin to water soluble pectin. Addition of calcium salt to the covering syrup inhibited degradation of protopectin to a considerable extent (3).

In order to accommodate more fruit and to improve the texture and flavour of slices of cultivars normally considered unsuitable for canning, partial dehydration (40% weight reduction) before canning was investigated. Texture and flavour of dehydro-canned mango slices were reported to be better (63).

Canning of mango slices (Dashehari) with addition of mango pulp to the covering syrup to improve the quality has shown good possibilities. Addition of 15% mango pulp in the covering syrup was found to be the best. This method not only improved the flavour quality but also increased the drained weight percentage. Further drained syrup (with 15% pulp, 20° Brix and 0.3% acidity) could be utilised as a ready-to-serve beverage (51).

Canned Mango Pulp

The development of a mango beverage industry has increased the demand for canned mango pulp. The flow sheet for production of canned mango pulp is shown in Fig. 1. Fully ripe mangoes are selected and washed. They are peeled or cut into slices and passed through a pulper fitted with a 30 mesh sieve to obtain the pulp. The pulp as such with addition of citric acid if necessary to lower the pH to about 4.0 or sweetened and then heated to 85°C, is filled hot into plain cans (A10 size), sealed and processed at 100°C for 45 min and cooled (17). Addition of ascorbic acid at 100 mg% to the pulp is reported to be helpful in better retention of colour flavour and carotene (122).

Mango pulp used in the preparation of jams and squashes may be preserved in wooden or HDPE barrels by using SO_2 as preservative. For this purpose the required quantity of citric acid is added to the pulp to lower the pH to 3.8-4.0, heated to 85°C and cooled to 35°C. The required quantity of potassium metabisulphite (KMS) is added to pulp so that the pulp may contain 1000-1500 ppm of SO_2. The pulp thus prepared is filled into cleaned and sterilised barrels and sealed air tight and stored for subsequent use (17).

The mango jam prepared from the above sulphited pulp contained a higher than permitted level of SO_2 (40 ppm SO_2) in the prepared jam. A process has now been developed to preserve mango pulp in an HDPE container using mixed preservatives (300 ppm of benzoic acid + 200 ppm of SO_2). Jam made from such pulp contained SO_2 within the limit (71).

Figure 1 Flow sheet for production of canned mango pulp

Ripe Mangoes

↓

Washing

↓

Peeling/Slicing

↓

Pulp Extraction

↓

Pulp

↓

Brix & Acidity Adjustment
(Brix 16-18°, pH 3.8-4.0)

↓

Heating to 85°C

↓

Filling hot into Plain A10 cans

↓

Sealing

↓

Processing
(45 min at 100°C)

↓

Cooling

↓

Labelling

↓

Packing

↓

Storing

A thermal process for bulk packing of mango pulp has been shown to decrease the cost of production without sacrificing chemical and nutritional quality (107). The process involves acidifying the pulp to pH 3.5, heating to 90°C, filling hot into polythene (HDPE) container, heat sealing, cooling and storing. This process is claimed to save 30-40% of the cost on packaging material. The product kept well for about six months.

Since hand peeling is time consuming and expensive, steam peeling and lye peeling have been tried (19). Puree was also extracted by passing unpeeled slices through a cutting mill and paddle pulper fitted with a 0.84 mm screen. Puree extracted thus was found to result in better flavoured nectar (18).

Steam peeling is reported to give higher yield of pulp (84 to 87%) as compared to mechanical peeling (75 to 79%). But both the purees produced were of similar quality (16). Higher yield may be varietal characteristics of Puerto Rican varieties of mangoes.

Mango Beverages

Mango beverages are becoming increasingly popular because of their appealing taste and attractive yellow colour. The flow sheet for production of canned mango juice nectar, ready-to-serve (RTS) beverage, mango squash and syrups are shown in Fig. 2.

Canned Mango Juice

Mango juice is prepared by mixing mango pulp, sugar, citric acid and water. The pulp content, brix and acidity may vary depending upon the buyer's specifications (pulp: 35-45%, Brix: 15-16°, acidity: 0.25-0.30%). The juice prepared according to the specification is heated to 85°C in an heat exchanger, filled hot into plain cans (401 x 411 size), sealed and processed for 20 min at 100°C, cooled and stored (17,57).

Canned Mango Nectar

Mango nectar is prepared and processed in the same way as mango juice. Mango nectar contains only 20% pulp according to Indian specifications. The other specifications are similar to mango juice.

Mango RTS Beverage

The mango ready-to-serve (RTS) beverage is prepared either from fresh pulp or stored pulp according to the following recipe: Pulp: 10%, Brix: 15°, and acidity: 0.3%. The beverage is filled into sterilised glass bottles and pasteurised for about 30 min at 75°C and cooled. Production of this beverage in returnable bottle is increasing year by year and is very popular in all the regions of India.

Figure 2. Flow sheet for production of mango beverages

Ripe Mangoes
↓
Washing
↓
Pulp Extraction
↓
Pulp

Mango Juice & Nectar
↓
Pulp as per recipe
↓
Mixing with clear sugar syrup as per recipe
↓
Heating to 85°C
↓
Filling hot into plain can (A 2½ size)
↓
Sealing
↓
Processing 20 min at 100°C
↓
Cooling
↓
Packing
↓
Storing

Squash & Syrup
↓
Pulp as per recipe
↓
Mixing with clear sugar syrup as per recipe
↓
Production of Preservative (350 ppm SO_2 or 600 ppm benzoic acid)
↓
Bottling
↓
Labelling
↓
Packing
↓
Storing

Mango RTS Beverage
↓
Pulp as per recipe
↓
Mixing with clear sugar syrup as per recipe
↓
Filling into bottles
↓
Processing for 30 min at 75°C
↓
Cooling
↓
Packing
↓
Storing

Mango Squash

Mango squash contains 25% pulp, 45° Brix, 1.2-1.5% acidity and is preserved with either 350 ppm of SO_2 or 600 ppm of benzoic acid in bottles (17). It is to be diluted three times with chilled water by volume, mixed well and then served.

Mango Syrup

This is made similar to squash but contains total soluble solids up to 70-75%. It is bottled with or without the addition of permitted preservative (20).

The choice of the most suitable varieties for preparing the above mango beverages is the subject of investigation of many workers in India, Philippines, Sudan and other countries (10, 25, 49, 64, 95, 96, 126).

Thermal Process Schedule for Canned Mango Product

Thermal process schedules for canned Badami (Alphonso) mango products were evolved using thermal inactivation time (TIT) of the peroxidase enzyme system and an improved graphical method. The TIT was calculated to be

$$F^{18}_{175} = 1.$$

The calculated process time for a 401 x 411 size can at 100°C was 7 min for slices, 8 min for nectar, 7.5 min for juice and 5 min for pulp when the filling temperature was 80°C (69). The validity of these process times was tested at a commercial processing plant. No spoilage of the samples packed was noticed.

Similarly using pectin-esterase (PE) a thermal process schedule for mango (Totapuri) slices in syrup was evolved. The TIT of PE was found to be

$$F^{18.56}_{208.8} = 1.0 \text{ at pH } 3.6.$$

At 207°F for 401 x 411 size cans the process time required was calculated to be 14.4 min. Innoculated pack study using Cl. pasteurianum and B. coagulans confirmed the validity of the calculated process time (75).

Thermal resistance of the peroxidase enzyme and the mould Byssochlamys fulva and process calculations were determined to establish minimum process times for canned mango slices and juice. The enzyme was inactivated at a temperature insufficient to kill the heat-resistant mould. The minimum thermal process for canned mango slices and juice packed in 307 x 409 cans and processed at 100°C were 15 min and 19 min respectively (11).

Internal Corrosion in Canned Mango Products

The limit for tin content in canned products is being reduced in many countries of the world. Russia has specified that the tin content in mango juice to be not more than 100 ppm. Systematic investigations have been carried out to find the effect of various factors and processing practices on internal corrosion and tin pick up in canned mango juice (Table 20).

Mango nectar prepared from the Banganapally (Baneshan) variety caused less corrosion than nectar from Badami or Raspuri varieties. The degree of corrosion was inversely proportional to the viscosity of nectar. Among different fractions of mango pulp, only organic acid fractions were responsible for corrosion. - carotene did not contribute to corrosion. Corrosion was greater in pulp and nectar prepared from unpeeled mangoes. The peel contains gallic acid and ellagic acid of which the former acts as an accelerator of corrosion. Leucopetunidin and leucopelargonidin have been identified in mango peel and they did not affect the process of corrosion (56).

Among the different processing variables tried, de-aeration of mango juice before filling into cans helped in reducing the extent of corrosion. Time lags between sealing and processing and high cooling water temperature accelerated corrosion. The presence of nitrate above 5 ppm level accelerated corrosion. Corrosion was found to be less when the concentration of pulp in the juice was treated (Table 9). Increase in concentration of acid accelerated corrosion (57). Other variables did not have much effect.

Table 9. Process variables and other factors on tin pick-up in canned mango juice (Totapuri) in ppm.

Variable	Initial	R.T. (25-30°C)		37°C	
		6 months	12 months	6 months	12 months
Control	30	52	120	123	520
Low filling temperature	32	53	125	128	507
De-aeration of juice	20	40	80	95	405
Time lag (3 hr)	51	77	152	142	545
Reduced processing time	28	47	115	116	525
High cooling water temp (55°C)	55	100	170	151	565
Nitrate (added) 5 ppm	40	97	158	152	520
10% pulp	53	95	180	207	550
20% pulp	36	86	153	150	525
35% pulp	30	75	120	123	520
45% pulp	26	68	87	106	402

Mahadeviah et al. (1975).

Electrolytic tin plate (E-100) with a tin coating of 22.4 g/M^2 and grain size of tin coating equivalent or larger than ASTM No. 9 were found suitable for canning mango nectar. Corrosion was found to be more in big size cans (401 x 411) as compared to small size (202 x 308) cans with mango nectar (58).

Ascorbic acid and its degradation products like furfural have been shown to act as accelerators of corrosion when added to mango nectar (55).

Polyester lacquered cans were found suitable for canning mango juice with satisfactory quality of the product with respect to taste and flavour as compared to cans coated with epoxy-phenolic lacquer which imparted lacquer taste and flavours (59).

Flexible Packaging Material for Mango Products

Preliminary studies have been conducted to evaluate the suitability of flexible packaging materials for packing mango products as the cost of cans is increasing every year. Polypropylene bags (300 gauge) were used for thermal packing of mango pulp and mango syrup and found to be promising (33). On the contrary, pouches made of polyester/polypropylene have been found to be unsuitable for thermal packing of mango juice. But pouches of low density polypropylene, polycell, paper-foil-poly laminate and aluminium collapsible tubes were found satisfactory for packing mango jam (35).

Aseptic Bulk Packing System for Mango Pulp

Aseptic packing of mango pulp for export purpose has been adopted by three major mango processing units in India using the imported aseptic filling system from Italy and USA. Laminated bags made of poly/aluminium foil/poly/poly liner and poly/metalised polyester/poly/poly liner of 20 kg and 200 kg capacities have been used. Slight discolouration and slight off flavour development are the problems encountered during storage (85).

Mango Jam

Mango pulp extracted from fully ripe mangoes or bulk preserved mango pulp is cooked with a calculated quantity of sugar, pectin and citric acid to 68-70°C Brix. Citric acid is added to improve the sugar acid blend and also to avoid crystallisation of sugar in the jam. The jam is filled into sterilised cans or jam jars, sealed air tight, cooled and stored (20).

Mango Toffee

Mango Toffee can be prepared from mango pulp with other additives according to the following recipe: mango pulp: 53 kg, sugar: 30 kg, glucose: 4 kg, skim milk powder: 8 kg, and hydrogenated fat: 5 kg.

The fruit pulp is first concentrated in a steam jacketed kettle to about one third of its original volume. The other ingredients are then mixed and cooking continued to a final weight equal to about 1.2 times that of fresh pulp taken. The cooked mass is transferred to a level and smooth surfaced tray which has earlier been smeared with little fat and the product spread into thin sheet of 1.0 cm thick. It is then allowed to cool and set. The solid sheet is cut into toffees and wrapped in cellophane paper and packed in air tight tins (20).

A series of investigations have been conducted as regards the nutritive value, storage behaviour of the product, the role of additives like antioxidants and antimould agents, etc. on the quality of the product during long storage (116). The proximate composition of mango toffee is given in Table 10.

Dehydrated Products

Dehydrated Mango Slices

Mango slices dried by sun drying, cross flow air drying and through flow air drying have been compared. Through flow air drying was found to be most efficient. Between Badami and Raspuri varieties the former gave a better product. The dried product with 15% moisture, containing 1500 ppm of SO_2 was found to keep well for about 10 months at ambient storage conditions. Boiling the dried pieces for 10 min in 10% sugar syrup was found necessary for proper reconstitution (4).

Table 10 Proximate composition of various mango products prepared from Badami mangoes

Particulars	Mango toffee	Osmo-air dried mango	Mango cereal flakes	Mango custard powder	Sweetened mango powder
Moisture (%)	8.6	13.6	2.2	1.7	1.2
Ash - Total (%)	1.7	1.9	1.6	3.9	0.4
Ether extractives (%)	8.2	0.1	-	0.1	0.3
Protein (N x 6.25) (%)	6.0	2.2	3.9	11.0	0.3
Acidity as citric acid (%)	0.2	2.9	0.2	1.8	0.5
Reducing sugars (%)	6.8	53.3	32.8	25.9	5.2
Total sugars (%)	67.3	74.0	71.0	58.6	95.7
Crude fibre (%)	0.5	1.2	1.6	2.3	0.2
Starch (%)	-	-	17.9	8.4	-
Minerals:					
Calcium (mg%)	268	25.0	115	233	38.1
Phosphorus (mg%)	154	15.0	50	221	11.9
Iron (mg%)	1.1	1.6	7	13.6	2.6
Vitamins:					
True ascorbic acid (mg%)	4.8	53.4	150	55.5	18.6
- carotene (mg%)	6.5	18.4	7.2	21.1	2.3
Total carotenoids (mg%)	9.6	-	-	30.9	3.9
Thiamine (µg%)	-	-	-	71.5	-

Nanjundaswamy (1984): Siddappa et al. (1962).

Osmotic Dehydration

Mango slices have successfully been dehydrated by the osmotic dehydration using sugar syrup (70° Brix) as osmotic agent. The fruit pieces are cut into suitable sizes and dipped in 67-70° Brix syrup for varying periods, drained, dipped in sulphite solution, drained and the pieces dried in a cross flow air drier or under vacuum in a vacuum drier (12, 36, 42, 65, 72, 87, 128).

Alphonso mango slices were dehydrated by freeze drying and osmo-vac drying. Comparative evaluation of quality attributes such as retention of aroma, taste, colour and structural integrity indicated that osmo-vac dehydrated product was almost identical with those of freeze dried product (87). The economics of the process depend upon the availability of cheap sugar, or the possibility of using spent syrup (36, 72). Effect of osmo-air dehydration on ascorbic acid and - carotene content of mango is shown in Table 22. Retention of ascorbic acid was 55% after osmosis and 52% after osmosis and drying. Retention of - carotene was 82% after osmosis and drying. The proximate composition of osmo-air dried mango is given in Table 11.

Table 11. Effect of osmo-air dehydration on Ascorbic acid and -carotene content of mango (Badami).

Stage	Moisture content (%)	Ascorbic acid		- carotene	
		MFB mg%	Retention %	MFB mg%	Retention %
Initial	81.6	139.1		26.1	
After osmosis	63.2	76.6	55.1	21.5	82.4
After drying	13.6	71.6	51.5	21.3	81.6

MFB = Moisture free basis;

Nanjundaswamy (1984).

Intermediate Moisture Mango (IM Mango)

The IM mango is made by the immersion equilibration procedure wherein the fruit slices are blanched and equilibrated, in a solution composed of the following: glycerol: 42.33, sucrose: 42.33, water: 14.84, potassium sorbate: 0.45, and KMS: 0.1 per cent. The method consists of adding the fruit slices to the soak solution (Fruit : Solution = 1:2.4) previously heated to 95°C, keeping the fruit immersed in the solution at 90°C for 3 min and then quickly cooling the mixture to room temperature and allowing it to equilibrate overnight, draining it and packing the fruit pieces.

Three varieties of mangoes - Badami, Mulgoa and Neelum have been tried for preparing IM mango and the chemical composition of the three final samples are included in Table 12. The water activity achieved in the products (0.76-0.78) was sufficient to prevent bacterial growth while the sorbate present prevented the growth of yeasts and moulds. The IM mango (Badami) packed in cans or paper/foil/poly pouches kept in acceptable condition for more than 9 months at room temperature and 4 months at 37°C.

Table 12 Chemical Composition of IM Mango of different varieties

Particulars	Intermediate Moisture Mango		
	Badami	Mulgoa	Neelum
Moisture (%)	34.8	34.5	32.9
Protein (N x 6.25) (%)	1.0	1.0	1.0
Ether extractives (%)	1.0	1.0	1.0
Reducing sugars (%) (dextrose)	2.4	2.0	2.8
Total sugars, sucrose (%)	28.1	32.9	26.4
Crude fibre (%)	1.8	1.6	1.0
Total ash (%)	0.4	0.7	0.7
Glycerol and other carbohydrates (by difference) (%)	33.9	29.3	38.0
SO_2 (ppm)	246	255	261
Ascorbic acid (mg%)	16.6	13.3	23.3
β- Carotene (mg%)	11.0	2.6	1.13
ERH (%)	78.0	76.0	76.0

Jayaram et al. (1976)

Mango Fruit Bar

This is a fruit confectionery product. The method of preparation is simple and involves mainly mixing the pulp with calculated amounts of sugar and heating the mixed mass to 80°C, cooling and incorporating KMS. The pulp thus prepared is spread in a tray and dried in a cross flow air drier at 70-80°C for about 22 hours. At the end of drying the dried sheet is cut into suitable size and wrapped in cellophane or glossine paper (20,70).

Variety of mango and consistency of the pulp have definite effects on the quality of the fruit bar. The thicker the consistency of the pulp the better is the texture of the final product. However, thinner mango pulp could as well be made use of for preparing mango and banana mixed fruit bar, by mixing mango and banana pulp at 3:1 ratio. The flow sheet for production of mango fruit bar is shown in Fig. 3. Proximate composition of mango fruit bar prepared from different varieties of mangoes is presented in Table 13.

Table 13. Proximate Composition of Fruit Bar from some Important Commercial Varieties.

Particulars	Badami	Banganapally	Totapuri
Moisture (%)	16.0	15.7	16.1
Ash - Total (%)	2.0	1.7	1.1
Acidity (%)	1.2	1.1	0.9
Reducing sugars (%)	28.0	23.5	18.8
Total sugars (%)	65.0	68.2	69.5
Ether extractives (%)	0.1	0.1	0.1
Protein (N x 6.25) (%)	2.0	2.2	1.6
Crude fibre (%)	1.1	1.0	1.1
Carbohydrates other than sugars (%)	12.6	10.0	9.6
Minerals:			
Calcium (mg%)	3.0	3.0	2.4
Phosphorus (mg%)	15.0	14.4	9.4
Iron (mg%)	3.0	3.0	2.4
Ascorbic acid (mg%)	20.0	16.0	8.0
-carotene (mg%)	15.4	11.2	9.2

Nanjundaswamy et al. (1976)

Mango fruit bar is a hygroemissive product and keeps well in the range of 50-60% RH. When wrapped in cellophane or glossine paper and stored in an air tight tin the bars have been found to keep well for about a year at 25-28°C and six months at 37°C (70).

Addition of pectin at about 1.5% level and liquid glucose at 6% level to the prepared pulp is reported to be helpful in getting a product with a smooth texture (62, 103). Mango fruit bar is finding a special place in the design of combat rations, Antarctica food items and space food (85).

Figure 3. Flow sheet for production of mango fruit bar

Ripe Mangoes
(pulpy variety)

↓

Washing

↓

Pulp extraction

↓

Pulp

↓

Heating to 80°C

↓

Partial Cooling

↓

Mixing with sugar
preservative (SO_2)

↓

Spreading on trays

↓

Drying in cross flow air drier

↓

Cutting into bars

↓

Wrapping

↓

Packing

Mango Cereal Flakes

Utilisation of mango pulp for preparation of fruited cereal products is a novel idea. The technique developed consists essentially in blending the fruit pulp with a small amount of wheat flour and sugars, adjusting the acidity and finally drying the blended and homogenised material on an atmospheric double drum drier (39). The following recipe was found quite suitable: Mango pulp: 100 kg. wheat flour (maida): 10.25 kg, sugar: 5.7 kg, glucose: 5.7 kg, calcium carbonate: 100 gm, sodium carbonate: 200 gm, pectin: 60 gm. The wheat flour is mixed with water and heated to gelatinise the starch. This is mixed with the mango pulp, the pH of which was adjusted to 5.0, and the mix heated to 85°C. The other ingredients like sugars, pectin in the form of solution were added, blended and homogenised. The homogenised product is dried in the form of flakes on the drum drier working at a steam pressure of 50-60 psig when the speed of rotation kept at 2-3 rpm and clearance between the drum at 0.35 mm. The product which dries in the form of a crisp, crinkled sheet is broken into smaller flakes and filled into 4 gallon friction top tins. It is designed to be used as breakfast food or as snack food (39). The critical relative humidity of the product is found to be 45%. Hygroscopicity of the flakes has been found to increase with increasing fructose content in the pulp. For preparing the flakes, Badami and Dushehari varieties have been found most suitable (47, 52). Flakes packed in pouches of aluminium foil laminate were found to have one year shelf life (81).

The flow sheet for production of mango cereal flakes is shown in Fig. 4, and the proximate composition is given in Table 10. With high carbohydrate, -carotene, ascorbic acid, and mineral content, mango cereal flakes are a highly nutritious product.

Strained Baby Foods

The manufacture of canned fruit and vegetable pulps free from excessive fibre has attained considerable importance in developed countries for feeding to infants. Systematic investigations have been done in India to produce strained mango pulp, strained mango custard and dehydrated mango custard (113). Incorporation of small quantities of skim milk powder and starch proved useful to facilitate drying (114).

Mango custard is prepared based on the following recipe: Mango pulp: 100 kg, sugar: 5 kg, skim milk powder: 5 kg, corn starch : 2.5 kg, and sodium bicarbonate to raise the pH of pulp to 5.6-5.8. The starch is first cooked into a paste with water and then mixed with sugar, milk powder and mango pulp. The mixture is then passed through a 60 mesh sieve and cooked for 5-6 min in a kettle. The pH is raised to 5.6, homogenised and dried on an atmospheric double drum drier into a thin continuous band. The dried product is powdered and packed in hermatically sealed cans.

Effect of canning and drum drying on proteins, ascorbic acid and -carotene have been studied. Drum drying preserved more ascorbic acid than canning. -carotene was quite stable in both cases (113). The dried product packed in cans under N_2 kept well for about a year at 5°C and about six months at 37°C (114).

Feeding trials with children have given good results and shown their usefulness in milk diets (46). The proximate composition of drum dried Badami mango custard powder is given in Table 10. The flow sheet for manufacture of mango custard powder is shown in Fig. 5.

Figure 4 Flow sheet of production of mango cereal flakes

Ripe Mangoes

↓

Washing

↓

Pulp Extraction

↓

Pulp heating
pH adjustment

↓

Mixing with other ingredients
like sugar pectin solution and
gelatinised starch

↓

Homogenisation

↓

Drying in double
drum drier

↓

Flakes

↓

Secondary drying
in a cabinet drier

↓

Packing

↓

Storing

Figure 5. Flow sheet for production of mango custard powder

Ripe Mangoes

↓

Washing

↓

Pulp Extraction

↓

Sieving

↓

Sieved pulp

↓

Neutralisation of excess acidity

↓

Mixing with sugar, gelatinised corn starch, skim milk powder

↓

Homogenisation

↓

Drying in double drum drier

↓

Powdering

↓

Packing in tins under N_2

↓

Storing

Mango Powder

Several methods have been studied to dry mango pulp with or without the additives to produce free flowing powder which could be used as a beverage base flavouring agent (115).

Freeze drying produces dried product with very little loss of flavour or aroma, but cost of production is high. Freeze drying mango pulp (82% moisture) required 11.5 hr to reduce moisture content to approximately 1% (5). The dried product packed in cans under N_2 kept well for about a year and in ambient conditions. Addition of sucrose to the pulp increased the shelf life of the fruit powder (123).

In foam mat drying the pulp is whipped to form heat stable low density foam. The foam is spread on wiremesh trays or a continuous belt in a thin layer and dried with hot air. Glyceride monosterate was found to be a good foaming agent for mango pulp. Drying was accomplished in a cabinet drier at 70-80°C in an hour (42). The powder is reconstituted with cold water. Alphonso mango powder produced by this technique was converted into nectar and the nectar rated poor by sensory evaluation and hence the process is not satisfactory for production of mango powder (22).

Spray drying is accomplished by atomising the diluted or enzyme treated puree into a stream of hot air. The atomised particles are dried to powder as they fall. Alphonso mango is treated with 0.1% (w/v) ultrazyme for 2 hr at 30°C and diluted with water (2:1 v/v). In the drier the inlet and outlet temperatures were maintained at 154°C and 84°C respectively. Taste panel evaluation of nectar made from the spray dried powder rated the colour as bright and attractive but slightly lacking in flavour (12). Addition of skim milk to the pulp at 1:1 and addition of whole milk or curd at 1:2 facilitated spray or drum drying (42). Good quality spray dried powder with a shelf life of one year was reported to have been produced based on the following recipe: Mango pulp (Chausa); 36 kg. sugar: 10.8 kg. concentrated buffalo milk (30% solids): 32.6 kg. cream (40% fat): 14 kg, and 200 gm each of glyceryl monosterate and sodium alginate. The dried product contained 25% moisture (106).

Vacuum puff drying technique has been made use of for preparing sweetened mango powder. It consists of mixing the mango pulp with equal quantity of sugar and the mixed material spread evenly in trays, keeping the tray load at the optimum level of 8 kg/sq. metre. The trays are then transferred to a vacuum shelf drier and dried at 65°C and 27 inch vacuum for about 8 hr. The dried material in the form of spongy mass was detrayed, powdered and packed in hermatically sealed cans (20, 72). Addition of sulphur dioxide at the rate of 200 ppm helped in the retention of colour, ascorbic acid and β-carotene and the retention of these in the dried product was 90%, 80% and 9% respectively. Badami variety was best suited for preparing the powder as compared to Totapuri and Neelum varieties. The powder remained good for about 8 months at ambient condition and less than 4 months at accelerated conditions (72). The proximate composition of mango powder thus prepared is given in Table 10. The flow sheet is shown in Fig. 6.

Figure 6. Flow sheet for production of sweetened mango powder

Ripe Mangoes
↓
Washing
↓
Pulp extraction
↓
Pasteurisation of pulp
↓
Mixing with sugar and preservative
↓
Spreading on trays
↓
Vacuum puffing and drying in a vacuum shelf drier
↓
Detraying
↓
Powdering
↓
Packing
↓
Storing

Mango Concentrate

Concentration by reducing bulk results in the economy of handling, packing, storage, transporation and distribution cost. The demand for mango concentrate in the export market is increasing. Studies conducted in the laboratory has shown the possibility of preparing the concentrate by two methods. In the first method, the pulp is concentrated in a forced circulation evaporator under vacuum up to 30–35° Brix which facilitates easy removal of the concentrate from the evaporator (73,90).

Attempts have also been made to treat the pulp with pectic enzymes, separate the serum from fibrous pulp residue, concentrate the serum and remix it with the fibrous pulp residue and homogenise to obtain 40° Brix mango concentrate (21).

The effect of concentration of Totapuri mango pulp in a forced circulation evaporator on the important constituents is shown in Table 14. During concentration, retention of ascorbic acid, –carotene and total carotenes were found to be 82, 87 and 85% respectively. The concentrated pulp is found to retain a fairly good amount of volatile flavour as indicated by chemical oxygen demand, and the nectar prepared from it was found to be quite acceptable as evaluated by the panelists. This may be due to retention of less volatile components which contribute much to the mango flavour.

Table 14. Effect of concentration in forced circulation evaporator on the important constituents of Totapuri Mango Pulp.

Constituents	Fresh feed pulp	Mango concentrate
Total soluble solids (%)	17.00	35.00
pH	3.8	3.7
Acidity as citric acid (%)	0.53	1.10
Ascorbic acid (mg%)	10.90	18.60 (82.1)
β-Carotene (mg%)	1.17	2.10 (87.2)
Total carotenoids (mg%) as β-carotene	1.90	3.31 (84.6)
Chemical oxygen demand	1200	300

Figures in parenthesis indicate per cent retention.

Nanjundaswamy (1986) - unpublished data.
Ramteke (1987).

Aroma Recovery and Mango Concentrate

Recent investigations have shown the possibility of stripping the aroma from mango pulp, concentrating it and adding it back to the concentrate prepared from the stripped mango pulp to obtain full flavoured concentrate (90). A total of 16 components were identified in the fresh Alphonso mango pulp. Of these 12 were carbonyls, 3 alcohols, one hydrocarbon myrcene. The aroma concentrate recovered from the same pulp showed the absence of myrcene (90).

Among the various additives studied, addition of sodium sulphite was found to enhance the storage stability of mango aroma concentrate. The shelf life of aroma concentrate was found to be a week without the additive and 2 months with additive when packed in glass bottles and stored at 25°C. At 2°C it was six months without additive and 10 months with additive. At -18°C the shelf life was more than one year even without the addition of any additive. The recovered aroma concentrate was added at various levels to the mango concentrate (30-35° Brix) and the nectar prepared subjected to sensory evaluation using a fresh sample for comparison. Addition of flavour concentrate at 50% level was found to be quite satisfactory (90). Some authors have reviewed literature on tropical fruit flavours (89).

Alcoholic Beverages

Dry wines and fortified wines prepared from some mango varieties were poor in colour and body. Strong aroma in a few varieties often masked the bouquet. After fortification with sugar and alcohol and madeirization at 50°C for three weeks, the colour, body and bouquet of most varieties were improved (76, 77). Similarly addition of ascorbic acid (0.1% w/v) helped in rapid madeirization. These processes reduced titratable and volatile acidities and increased the pH, volatile esters, aldehydes, colour, brightness and organoleptic scores of dessert wines. Madeirized wines were more acceptable than corresponding dry and dessert wines. Madeira prepared from Totapuri variety was more acceptable than those from Raspuri, Mulgoa, Dushehari and Langra varieties (79).

Production of aromatized wine from mango, designated as Mango Vermouth has been worked out. Herb and spice mixture formulae to produce dry and sweet vermouths with mild aroma and flavour have been developed (78). The composition of mango vermouth is shown in Table 15.

Table 15. Chemical Composition of Mango Vermouths made from Banganapally variety.

Particulars	Mango Vermouth	
	Dry	Sweet
Colour at 420 nm	0.42	0.68
pH	3.4	3.42
Total acidity (gm tartaric acid/100 ml)	0.59	0.59
Volatile acidity (gm acetic acid/100 ml)	0.09	0.07
Alcohol - v/v/100 ml	17.00	17.20
Total aldehydes (ppm)	15.8	26.4
Total phenols (%)	0.06	0.07
Organoleptic score	13.0	15.5

Onkarayya (1985)

UTILISATION OF MANGO WASTE

Seeds (stones) and peels are the important wastes which constitute 35-55% of ripe as well as unripe mangoes (17). Studies have shown the possibility of utilising mango waste for recovering useful products, and simultaneously avoid the serious disposal problem. Peel of Totapuri mango has been found to yield 15.7% pectin. The pectin produced by the alcohol precipitation method, contained 4.9% moisture, 0.94% ash, 8.9% methoxyl, and with jelly grade of 200-220, found to be of good quality (14, 118).

During production of mango pulp, besides peel with adhering puree, pulper waste pulp is also obtained. The chemical composition of these materials are shown in Table 16. Studies have shown the possibility of treating these with pectic enzyme, expressing the juice and utilising this juice in the preparation of nectar and vinegar (15).

Table 16. Chemical Composition of Mango (Totapuri) Peel and Waste pulp from Pulper

Particulars	Peel	Waste pulp from pulper
FRESH MATERIAL		
Total soluble solids (%)	21.0	12.5
Moisture (%)	68.5	83.2
pH	3.1	3.2
DRIED MATERIAL (Moisture 3-4%)		
Sugars - Total (%)	48.1	51.3
Acidity (%)	2.6	2.3
Pectin (%)	12.9	10.6
Starch (%)	2.9	5.2
Nitrogen (%)	0.26	0.53
Crude fibre (%)	8.4	6.00
Tannins (%)	2.3	Trace
Total ash (%)	2.9	2.4

Beerh *et al.* (1976b)

The stone content is found to range from 9-23% with an average of 15% for 29 varieties (82). Mango seed kernel contains protein, fat, carbohydrates including starch, fibre and ash as major constituents (83) as shown in Table 17. Due to its blandness, plasticity and absence of toxic substances it enjoys a potential use as edible fat in sweet meats (74). It can also be used as a substitute for tallow in the preparation of quality soaps and cocoa butter (13). No difference was noticed in the texture, taste and flavour of toffee prepared from mango seed oil and cocoa butter (66).

Table 17. Important Chemical Constituents of Mango Seed Kernels

Constituents	Range
Moisture (%)	8.2-8.7
Protein (N x 6.25) (%)	5.6-9.6
Fat (%)	9.3-16.1
Total carbohydrates (%)	69.2-79.8
Fibre (%)	0.14-2.95
Total ash (%)	0.35-3.11
Total tannins (%)	10.0-11.0

Parmar et al. (1984); Bhatnagar & Subramanian (1973)

Mango seed kernel also contained 47-63% starch of which 19-22% was Amylose (94). Gelatinisation characteristics, temperature, paste clarity, retrogradation and swelling power and solubility of mango seed starch have been studied (84) and the starch is recommended for food use (17). But the major problem is in the collection of peel and stones so as to enable its economic commercial use (17).

PROBLEMS IN PROCESSING OF MANGOES

Processing of mangoes presents several problems to the industry and to the market expansion. Irregular and alternate bearing, non-uniform ripening and short storage life of ripe fruits affect the regular production schedule. Large number of varieties with their variable attributes affect the quality and uniformity of the processed products. The lack of simple, reliable methods for determining the stage of maturity of various varieties for processing also affects the quality of the finished products. Presence of weevil within the fruit of some varieties of mangoes affects the quality and so far no successful method has been developed to prevent this insect problem. Quite often, mangoes are required to be peeled and sliced for production of certain products and lack of mechanised equipment is the bottleneck in increasing their utilisation (17,121). Variation in flavour in many varieties and non-availability of information on blending as a means of adjusting flavour (129) is a disadvantage. The cost of processed mango products is also prohibitive to the common man in the areas where most mangoes are grown. There is considerable export potential to richer countries, but in these countries the processed mango products must compete with other established processed fruits of uniform quality and relatively low price (121). As a result of these problems there is very low input into the processing industry (0.2% of world production). Hence, concerted research and development efforts are needed to find a solution to these problems and thus give fillip to the processing industry especially in the countries where mangoes are the major fruit crop.

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