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REVIEW ARTICLE

Mango and it's by product utilization–a review

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Abstract

Mango is one of the most important tropical fruits in the world and currently ranked 5th in total world production among the major fruit crops. As mango is a seasonal fruit, about 20% of fruits are processed for products such as puree, nectar, leather, pickles, canned slices, and chutney. These products experience worldwide popularity and have also gained importance in national and international market. During processing of mango, by-products such as peel and kernel are generated. Mango peels and seeds are rich in valuable bioactive compounds such as polyphenols, carotenoids, dietary fibres, enzymes phytosterols and tocopherol; whereas and the peel extract exhibits potential antioxidant properties. Processing of mango by-products reduces waste disposal problem, adds value to the product for food and other industrial use, and the isolated active component can be used in food fortification.

Keywords: Mango, nectar, peel, kernel, polyphenols, carotenoids.

Introduction

Mango (*Mangifera indica L.*) is the king among tropical fruits and is greatly relished for its succulence, exotic flavour and delicious taste in most countries of the world (Bhatnagar and Subramanyam, 1973). Apart from its delicacy, it is a nutritionally important fruit being a good source of vitamin A, B and C and minerals. Nutritive value of mango fruits is shown in Table 1. Mango is considered to be a fruit with tremendous potential for future. Worldwide production of mango is 38.95 million tonnes (FAO, 2011). Mango has its origin in India and approximately a thousand different types of mango fruits are produced in the country. Annual production of mango in India is 15.19 million tonnes (FAO, 2011).

Large number of mango cultivars has been screened (Sadhu and Bose, 1976; Gangopadhyay *et al*., 1976; Dhar *et al*., 1976; Rameshwar *et al*., 1979; Kalra *et al*., 1981) for their physico-chemical characteristics, from which inference can be drawn for their suitability for different product preparation. Succulent juicy varieties are popular for dessert purposes and non-fibrous fleshy varieties are largely used for processing.

It is reported that about 75 % of the fruits are knocked off, right from the flowering stage till ripening. The losses however, can be minimized to a great extent by utilizing the dropped fruits. Fortunately, mango is one of the few fruits which can be utilized in all stages of maturity. The fruit is used as a dessert, as a table fruit between meals and is also processed for preparing a host of products. Established processed products include pulp, juice, squash, nectar, pickles, chutney, preserve, jam, canned slices, dried powder, - and many other products. This conventional type of mango products have been developed to a considerable level and a significant demand has been built up by the processing industry, both for domestic and export market (Sadhu and Bose, 1976; Rameshwar *et al*., 1979; Kalra *et al*., 1981; 1982). The international market is becoming more competitive and other mango producing countries are also entering the market. The industry has therefore, to look forward to the development of newer categories of products, so as to retain the monopoly for processed mango products in the international market.

The processing technologies for different categories of mango products are briefly described in this paper.

Ripe mango products

Mango pulp: Mango pulp is stored during the peak season of mango crop for subsequent use for various products. With the development of ready-to-serve beverage industry, there is an increasing demand for mango pulp in A-10 packs (Subbiah, 1961; Mathur and Purnanandam, 1976; Kalra and Tandon, 1986; Khurdiya and Roy, 1986; Chakraborthy *et al*., 1991). The pulp is generally standardized to 14-18°B and 5-6.5% acidity as citric acid by adding sugar syrup and citric acid, respectively. No preservative is used in the caned mango pulp. However, when the pulp is filled in polyethylene jars or far own use as a base material for beverage and jam preparation, potassium metabisulphite is used as preservative at a level of

about 0.02% (Kumbhar, 1992). Pulp is heated to 85°C, filled hot into cans and sealed and processed at 100°C for 20 min (for A2½ cans) and cooled. Addition of ascorbic acid at 100 mg % in the caning of mango pulp helps in the retention of colour, flavour and carotene (Subbiah, 1961; Roy *et al*., 1997).

Azizi and Ranganna, (1993) have studied spoilage organisms of canned acidified mango pulp and their relevance to thermal processing of acid foods. Swelling due to gas forming in commercial canned Alphanso mango pulp (pH 4.3) was caused by *Bacillus licheniformis* (having thermal resistance i.e. D_{100} = 1.25 min at pH 4.2 and D_{100} = 3.12 min at pH 7.0) and clostridium sporogenes (D_{100} = 6.8 min at pH 4.5 and $D_{121.1}$ = 0.51 min at pH 7.0). The metabiosis of the former increased the pH, thereby creating conditions favourable for the growth of the latter. These findings indicated that products having a pH higher than 4.0, but lower than 4.6, should be given thermal treatment, adequate to destroy *B. licheniformis*, except when *B. coagulans* spoilage is likely to occur.

Mango beverages: Mango juice, nectar and squash are the three important beverages prepared on a commercial scale. As the mango pulp is very viscous, juice is prepared by adding almost equal quantity of water and adjusting the total soluble solids and acids to taste (12 to 15% TSS and 0.4 to 0.5% acidity). Mango nectar contains 20% pulp with sugar and acidity properly adjusted to give 15°B and 0.3% acidity as citric acid. These beverages are packed in cans. They are heated to about 85°C in heat exchanger, filled hot into cans, sealed, processed and cooled (Mahadeviah *et al*., 1969). Mango squash contains 25% juice, 45% TSS and 1.2 to 1.5% acidity and is preserved with Sulphur dioxide (350 ppm) or sodium benzoate (1000 ppm) and is preserved in glass bottles (Mathur and Purnanandam, 1976; Kumbhar, 1992). Similar work has also been reported by Roy *et al*. (1972) with north Indian varieties. Mango nectar was prepared with pulp from dehydrated ripe mango slices and sugar in the ratio of 4:3 (20% pulp, 15°B and 0.23%) keeping into consideration of flavour, colour and texture.

Flow characteristics of pulp, juice and nectar of 'Baneshan' and 'Neelum' mangoes were studied by Gunjan and Waghmare (1987). The consistency coefficient values were found to be considerably lower for pulp, juice, and nectar of 'Baneshan' than those of 'Neelum'. Consistence coefficient decreased with increase in temperature, while there was no appreciable effect on the values of flow behavior index.

Chakraborthy *et al*. (1991) studied the suitability of various varieties (Dasheri, Chausa, Safeda, Tamburia Dasheri, Mala Fazli, Lucknow Fazli, Mallika, Bhagwankera and Golbhadiya) for production of various mango products. The pulp was extracted from fully ripe fruits, canned and used for preparing nectars and juice. Canned nectar and juice samples prepared from seven commercial varieties of mangoes were ranked for colour, aroma, taste and overall acceptability with reference to Badami mangoes. Based on the overall acceptability Dasheri, Tamburia Dasheri were found to be good and comparable to Badami (Alphanso) for preparing canned mango nectar and juice (significantly superior at $p<0.01$). Mala Fazli, Chausa and Golbhadiya were next preferable (significant at $p<0.05$). Nectar and juice made from Safeda and Lucknow Fazli were found significantly inferior.

Carbonated mango beverage: The mango based beverages were prepared containing: mango pulp 5, 7 and 10%; sugar 9.07, 11.7, and 13.15%; TSS 10, 13 and 15% and acidity 0.1, 0.15 and 0.2%. All the three drinks contained carbon dioxide (3% gas vol.).

Table 1: Nutritive value of mango per 100g

Nutrients	Ripe mango	Unripe mango
Protein (g)	0.6	0.7
Fat (g)	0.4	0.1
Minerals (g)	0.4	0.4
Fiber (g)	0.7	1.2
Carbohydrates (g)	16.9	10.1
Energy (kcal)	74	44
Vitamin C (mg)	16	3
Total carotene (mcg)	2,210	90
Beta carotene (mcg)	1,990	-
Potassium (mg)	205	83
Sodium (mg)	26	43
Calcium (mg)	14	10
Iron (mg)	1.3	0.33
Phosphorous (mg)	16	19

(Source: Nigam *et al*., 2007)

Chemical composition, shelf life and acceptability of drink were examined at 7 days interval for 28 days and then at 30 days interval for 210 days. Apart from vitamin C content, no significant changes in colour, % TSS, acidity, pH, preservative, gas volume, fat, protein and mineral content of the drinks were observed during storage. Taste panel assessment showed differences in consumer acceptability of the beverages. The beverage containing 7% mango pulp, 11.7% sugar, 13% TSS and 0.15% acidity was preferred by panelist (Islam *et al*., 1990).

Milk based beverage from mango pulp was also studied by Al-haq and Mahyuddin (1992). A total of 15 milk based beverages were prepared from SMP (3%) with added mango pulp var. Chausa pulp at 1-3% and the Maxpectin RS 450 stabilizer. It was pasteurized by HTST and aseptically packed in brick pack on a combiblock machine and had a shelf life of 49 days under refrigerated storage condition.

Mango wine: Onkararayya (1985) standardized the technology for mango vermouths preparation, which is diluted wine. The ripe fruits were washed, peeled and pulped. Pulp was diluted 1:1 (v/v) with water. The initial TSS was raised to 22°Brix by adding cane sugar. 100ppm KMS was added to suppress activity of natural microflora. Pectinase was added at 0.5% (v/v) level. Ameliorated must was inoculated with a 24 h old culture of *Saccharomyces cerevisiae* var. ellipsoideus, Montrachet strain No.522 at 2% (v/v) grown in yeast extract-peptone-dextrose broth. Fermentation was carried out at 20$\pm$2°C for 5 days in BOD incubator. The fermented fluid was filtered and stored in glass bottles at 20-24°C. The clear supernatant was racked and fined with bentonite at 0.1% (w/v). Crystal clear supernatant was racked after one month; 100 ppm sulphur dioxide was added and it was then bottled. The dry wine used as base wine to prepare mango vermouth had alcohol 11% v/v, total acidity 0.65% as g tartaric acid, volatile acidity 0.05% as g acetic acid, total aldehydes 20 ppm, pH 3.65, reducing sugars 0.52 as g glucose and total phenols 0.06%.

Pruthi (1992) reported that wines made from varieties like Fazli, Langra and Chausa were good. The alcohol content of the wines ranged from 5 to 13%, while the tannins in those wines were low.

Dry mango products: Production of fruit juice powder assumed great dimensions in recent years because of several advantages. Dried mango powder is good adjunct in ice cream, bakery and confectionery industry. Mango pulp or juice after concentration is mixed with powdered sugar and dried (Bhatnagar and Subramanyam, 1973; Baldry *et al*., 1976; Nanjundaswamy *et al*., 1976). Mango pulp was successfully dehydrated in a double drum drier in 6-8 seconds at 141°C yielding a product of golden yellow colour with original flavour, but highly hygroscopic in nature. In a patented process, cabinet drier at 60-63°C has been used for dehydrating mango pulp (Siddappa *et al*., 1953).

Nanjundaswamy *et al*. (1976) observed that glyceromonostearate (GMS) was the most suitable as foaming agent compared to dried egg albumin and fresh egg white for foam mat drying of mango pulp. Data on the effect of concentration of foaming agent and whipping time on foam density were presented and concluded that 0.75 % of foaming agent and 20 minutes whipping time were optimum. Mango pulp and GMS whipped with Hobart mixer upto optimum foam density of 0.3-0.35 g/ml. The foam was spread on stainless steel wire mesh tray with 0.5kg per sq ft load and dried in a hot air drier at 70°C with cross flow drying technique. The product was dried in 6 h to a moisture level below 2% (wb). The product was yellow in colour, crisp with mild mango flavour. Baldry *et al*. (1976) have reported that mango pulp also can be dried by spray drying techniques.

Studies have been conducted to prepare good quality dehydrated mango slices adopting osmotic dehydration technique. The dehydrated product on reconstitution was found to be nearer to canned slices in terms of colour, flavour and texture point of view (Nanjundaswamy *et al*., 1976). Weight loss of slices was more rapid with smaller fruit pieces, in more concentrated syrups, at higher temperatures and with agitation of syrup. However, during osmotic dehydration, acids and carotenoids were leached out and sugar entered at the same time. Prolonged treatments reduced the moisture content to levels appropriate to a microbiologically stable intermediate moisture food, but by this stage aroma was lost and off-flavours had developed. The dehydrated ripe mango slices contained 18.70% reducing sugars, 60.23% total sugars and 42.03% sucrose (Baldry *et al*., 1976; Chaudhari *et al*., 1993; Sagar and Khurdiya, 1996; Giraldo *et al*., 2003).

Mango leather: The pulp of the sour and seedling varieties is traditionally dried in the sun on an extensive scale for use as flavouring ingredients in Indian food preparations. The Central Food Technological Research Institute has worked on improving conditions for the hygienic drying of the ripe mango pulp in the form of bars for direct consumption. Fruit bars consisting of mango and other fruit pulps have also been developed (Bhatnagar and Subramanyam, 1973). The methods employed by the

various workers to improve the quality of mango sheet, include addition of sugar, citric acid, potassium metabisulphite and pectin etc. Attempts were made to replace the use of costly pectin by addition of guava pulp, which is not only a good source of natural pectin but also of vitamin 'C' (Hemakar *et al*., 2000; Nigam *et al*., 2007).

Mango leather can also be prepared from pulp dried in cross flow cabinet drier at a temperature of 60±5°C. The ideal sugar/acid composition for the preparation of mango sheet/leather of mango cultivars Baneshan, Green and Dushehari were found to be 25°B and 0.5% (Rao and Roy, 1980a). During the storage of mango sheets, acidity and reducing sugars increased with the increase in storage temperature. The cultivars having good retention of carotenoids and less browning were orgenoleptically acceptable even after storage at higher temperature (Rao and Roy, 1980b).

Mango fruit bar was prepared from Alphanso fruits, which were otherwise discarded due to small size and irregular shape, by the addition of sugar (20%), citric acid (0.2%) and potassium metabisulphite (700ppm) in different combinations. Drying in shade or tray drier gave good quality product in terms of colour, texture and flavour (Gowda *et al*., 1995).

Changes in chemical, textural and sensory characteristics of three types of mango bars (plain mango, mango desiccated coconut powder and mango soya protein concentrate bars) during 90 days storage at -18°C, 27±3°C (65% RH) and 38±1°C (92% RH) were studied (Mir and Nath, 1993). Moisture, acidity and reducing sugars of mango bars increased significantly during storage in all the cases. Storage decreased the overall acceptability and textural characteristics. The deteriorative changes were minimum in mango stored at -18°C. Sorption isotherm of plain mango bar (86.9% total sugar, 2.7% protein and 0.54% fat on dry weight basis), mango coconut bar (81.8% total sugar, 3.0% protein and 5.0% fat on dry weight basis) and mango soy protein concentrate bar (75.2% total sugar, 13.1% protein and 0.4% fat on dry weight basis) were also determined and found that the bars retained their quality best at RH 64.8% (Mir and Nath, 1995).

Mango jam: To prepare mango jam, pulp from dehydrated mango slices was heated with an equal quantity of sugar to 65-68°B and citric acid was added at the end to get 0.6-0.7% acidity in the final product score for colour and flavour (Mallik, 1976; Mathur and Purnanandam, 1976; Sagar and Khurdiya, 1998). Kanekar (1992) had studied sugar and acid tolerant microorganisms causing spoilage in mango jam. It was observed that incidence of *Micrococcus luteus* was the highest (100%) followed by *Bacillus coagulans* (50%) and *Aspergillus niger Penicillum sp.* (35%).

Mango toffee: Mango toffee can be prepared from mango pulp, with other additives according to the following recipe, mango pulp: 53kg, sugar: 30kg, glucose: 4kg, skim milk powder: 8kg and hydrogenated fat: 5kg with essence and colour of suitable choice in required quantities (Gupta, 1993; Sagar and Khurdiya, 1998). 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 cooked to a final weight equal to about 1.2 times that of fresh pulp taken. Flavouring material is added at this stage. The cooked mass is then transferred to leveled and smooth surfaced tray which has earlier been smeared with a little fat and the product spread into thin sheet of 1.6cm thick. It is then allowed to cool and set. The solid sheet is cut into toffees at 50-55°C having moisture content of 5-6% and wrapped in a cellophane or tissue paper and packed in air-tight tin jars (Pruthi, 1992).

Mango yoghurt: Mango yoghurt could be an excellent substitute for the high calorie dessert pudding which contain sufficient amount of curd with cream. Sagar and Khurdiya (1996) reported that mango yoghurt can be prepared with mango poser and boiled-cooled milk in the presence of starter culture (curd). Jayaraman *et al*. (1976) had reported that a drum dried mango pulp and curd (1:2) was better in its colour and flavour. The mango yoghurt prepared with mango poser and milk in the ratio of 3:10 obtained the highest statistically significant score in respect of colour, flavour and texture.

Balasubhramanyam and Kulkarni (1992) standardized the process for high fat dessert type yoghurt with added mango pulp. Yoghurt made from milk having 10% fat and 8% sugar and homogenized at 200 bars with addition of mango pulp upto 4% of the milk content resulted in a good flavored and smoother consistency yoghurt.

Other products from mango

Mango custard powder: which is a rich source of nutrition for the children, can be prepared by mixing of mango powder, sugar, skim milk powder, corn starch, lime juice, cream, salt and water (APEDA).

Mango ice-cream: a non-conventional product was prepared by mixing mango powder and milk in the ratio of 3:10. The ice-cream made from structured mango pieces modified with natural ingredients has also been discussed by Britnell (1991).

Mango shake: is a delicious and popular drink during summer months, when fresh mangoes are not available

in the market. Mango shake can be prepared by addition of mango powder in sweetened, boiled and cooled milk. Grewal and Jain (1982) have reported that mango shake from spray dried product comprised of mango, milk and sugar solids and sterilized in glass bottles had good consumer acceptability. The mango shake prepared with addition of powder mixed with equal amount of water to the sweetened milk was superior in respect of colour, flavour and texture followed by the products made in the ratio of 1:10 and 3:1 of mango powder and milk.

Mango lassi: is also a delicious and popular drink during summer months, which can be prepared with mango powder with curd and other ingredients. The mango lassi made with mango powder and curd in the ratio of 3:10 obtained the highest score in respect of colour, flavour and texture followed by mango lassi prepared from mango powder and curd in the ratio of 2:5 and 1:5 (Sagar and Khurdiya, 1996).

Mango cereal flakes, vermicelli and powder: A process for the preparation of the mango cereal flakes (fruited cereal) has been developed at CFTRI, Mysore. It was made by adjusting the pH of the pulp to around 5.4 by neutralizing part of the acidity with sodium bicarbonate; mixing with precooked wheat flour and sugar; and drying in a double drum drier at 2-3 rpm and steam pressure of 2872.8-3112.2 N/m^2. The dried product was highly hygroscopic and needed moisture proof packing. The finished product was golden yellow in colour and had the characteristic taste and aroma of the fruit.

Mango cereal vermicelli and powder have also been prepared by adding into cooked wheat flour to obtain dough of suitable consistency for extrusion through vermicelli press or drying as such by spreading on trays. Drying is done in a hot air cabinet drier. (Siddappa and Lal, 1953)

Strained baby food: Strained pulps and custards using mango have been prepared and examined for their suitability and acceptance. The pulp is passed through a 60 mesh sieve to remove the fiber. Sugar is added to this pulp to get the desired blend, the mixture is then homogenized and then canned. In the preparation of fruit custard, acidity of the pulp is partially neutralized to adjust the pH to 5.3-5.6, added with sugar, skimmed milk powder and pre-cooked starch. The mixture was then homogenized and drum dried as in the case of mango cereal flakes. The dried product is powdered and packed under nitrogen and stored at 5^oC. The products are highly nutritious (Siddappa and Ranganna, 1961).

Ong *et al*. (2014) has prepared mango tablet from ripe and unripe mango. Mango powder was prepared by freeze-drying mango pulps. Green mango powder exhibited medium flow and was poorly compressible compared with ripe and mixed mango powders. Tabletting of powders was performed using a uniaxial die compaction machine and dissolution tester with a moving paddle for the dissolution study. Among five formulations, the tensile strength of the mixed tablets was higher than the individual and mixed-fruit tablets. The dissolution kinetics revealed that the dissolution rate of the mixed-fruit tablets was highly influenced by the disintegrant content. In conclusion, mixed mango tablets can be used as an effective vitamin C supplement if the formulation is optimised with balanced sweetness and acidity and can easily be consumed by chewing or by dissolving in water.

Unripe mango products

Mango is one of the few fruits which is utilized in all stages of its maturity i.e. from very young immature unripe stage to the fully mature and ripe stage. During fruiting, mango crop is very much exposed to the adverse weather conditions. It is reported by Roy and Singh (1952) that about 75% of the fruits are knocked off, right from the flowering stage till ripening. The losses however, can be minimized to a great extent by utilizing the dropped green fruits in the processing industry for making pickles, chutneys, candy, preserve, juice, dried powder (amchur), beverages, jam and other products (Bhatnagar and Subramanyam, 1973; Teotia *et al*., 1987; Pruthi, 1992).

Raw mango fruits are valued for their tangy taste, nutritional content and as a therapeutic agent. Various products being made from unripe mango fruit are discussed in following sub-sections.

Mango pickle: Green mangoes in India are mostly used as pickles and chutneys. Pickles are prepared in almost every Indian home and also commercially. Mango pickles are classified as salt pickle or oil pickle or sweet pickle based on the type of preservation used. They are made from peeled or unpeeled fruit with or without stones and with different kinds of proportions of spices (Bhatnagar and Subramanyam, 1973; Mathur and Purnanandam, 1976; Kumbhar, 1992; Gupta, 1993; Maneepun and Yunchalad, 2004).

Sastry and Krishnamurthy (1974) worked on Indian pickles prepared from high acid (5-6%), moderate acid (about 3.6%), low acid (about 1%) and very low (<1%) acid mango varieties. Physico-chemical changes in the composition of green mangoes during growth with respect to the preparation of pickles were also studied (Sastry *et al*., 1974). The storage

studies of pickles prepared from those mangoes was also studied separately by Sastry *et al*. (1975) and Sastry and Krishnamurthy (1975).

Some of the technological aspects for production of green mango pickles have been described by Narayana (1976). Instant mango pickle processing was also studied at CFTRI (Anon, 1988). Fully mature, fresh mangoes are washed and cut into uniform size, brine cured at optimal conditions and dried suitably either in sun or in mechanical driers. Cleaned and dried spices like red chillies, turmeric and mustard are ground separately and mixed with the cured and dried mango pieces, packed in polyethylene bags in required quantities and sealed. The ready mix is reconstituted in water overnight to get ready-to-eat pickle.

Kanekar *et al*. (1989) have studied the role of salt, oil and native acidity in the preservation of mango pickle against microbial spoilage. Mango pickle inoculated with salt tolerant strain of *Aspergillus niger* got spoiled at 10% salt, 40% oil and 4.2% native acidity. Salt concentration of 15% protected the pickles against spoilage by the inoculated organism as well as the native flora of the pickles. It was observed that groundnut oil did not have any preservative effects against microbial spoilage. Preservation of raw mango slices for use in pickle and chutney was also studied by Sethi (1991). Preservation in a chemical solution containing 5% salt, 1.2% acetic acid and 0.01% KMS was found to be better than dry salting. Addition of 0.5% calcium chloride helped to retain texture of slices during subsequent storage.

Chemical changes and microbial growth during green mango fermentation for pickling was studied by Yunchalad *et al*. (2003). The mangoes were fermented in brine with 10 and 12% (by weight) salt, with and without acetic acid (0.1%) and/or sodium benzoate (0.1%), and stored for one month. The level of lactic acid produced was 0.4 to 0.7%. Most of the acid present was produced by yeast fermentation. When pickling mangoes in brine with 8 and 10% salt, with upto 5% (by weight) sucrose, the growth of lactic acid bacteria was found to be similar to that in pickled mangoes without added sucrose. For all the treatments, the final acidity was ~0.5% as lactic acid with pH of 2.9.

Mango chutney: Mango chutney is prepared from peeled, sliced or grated unripe or semi ripe mangoes by cooking them with spices, salt, onion, garlic, sugar/jaggery, vinegar or acetic acid to a thick consistency. Both brined and fresh slices are used for the preparation of this product. Chutney prepared from mature but unripe mango has good colour and full flavour. Some Indian varieties like Totapuri and Fazli are ideally suited for this purpose. Mango chutney usually contains 55-60% total soluble solids and 1.0-1.5% acidity as acetic acid (Mathur and Purnanandam, 1976; Teotia *et al*., 1987). Mango chutney prepared from mango pulp and sugar in the ratio of 1:1 received the highest scores for colour, flavour and texture (Sagar and Khurdiya, 1998).

Green mango powder: From time immemorial, green mango slices have been in use after sun drying. It takes about 16 h exposure to sun at 35-40°C for complete drying of the slices. The drying rate was increased when forced air circulation was used (Teotia *et al*., 1987). Dabhade and Khedkar (1980c) compared sun drying with cabinet drying of green mango slices and observed that the rate of drying was much faster in cabinet drying than sun drying. In cabinet drier, it took 10 h to dry the pieces with 6.45 kg/sq m tray load while 15 h were required with same tray load in case of sun drying. The blanched pieces could be dried earlier than un-blanched ones both in cabinet as well as in sun drying.

Dehydration of green mango for making powder in double drum drier was studied by Gangopadhyay *et al*. (1976). Green mango powder prepared in an atmospheric double drum drier can form the base material for preparation of green mango drink, thick mango chutney and other products of acceptable quality. They boiled the green mango fruits in water for 15 min, peeled and extracted pulp using a pulper. The pulp was then dried in 152.4 × 163.2 mm wide chrome coated steel drum drier. The drums were rotated at 4 rpm. Dried samples packed in poly-aluminium foil laminates and sanitary cans were found to have higher storability as compared to the material packed in high density polyethylene bags under ambient conditions. Loss of ascorbic acid was upto the extent of 20% in all cases after 6 months of storage.

Higher reconstitution ratio was found in cabinet dried raw mango slices as compared to the sun dried slices, may be due to less rupture of cells during drying in cabinet drier than sun drying (Khedkar and Roy, 1980).

Dabhade and Khedkar (1980a) carried out investigation on physico-chemical composition of raw mangoes of four cultivars with respect to the preparation of dried raw mango pulp powder (amchur). The optimum stage of fruit harvesting for use in the preparation of mango powder could be the 7th week onwards. Dabhade and Khedkar (1980b) also separately studied leaching losses in raw mango pieces during blanching and sulphitation for dehydration of raw mangoes. Heavy leaching losses of acids, sugars and ascorbic acid were observed during blanching in boiling water as well as during sulphitation of raw mango pieces.

Changes in chemical constituents of raw mango powder during storage were also studied by Dabhade and Khedkar (1980d). During storage, cabinet dried, sulphured and sulphited product had better retention of ascorbic acid and less browning as compared to the sun-dried product. A progressive decrease in ascorbic acid, acidity and starch and increase in both reducing and total sugars was noticed. The powder prepared from mangoes with blanching and sulphuring had a better overall organoleptic score. The curry prepared from the mango powder had better overall organoleptic score compared to that from tamarind and cocum (Dabhade and Khedkar, 1980e).

Six market samples of amchur (dry mango powder) were analyzed for chemical composition. The product did not contain sodium chloride, ascorbic acid or sulphur dioxide. Wide variations were observed in water and alcohol insoluble material, non-enzymatic browning and tannin content. Two types of insects and three strains of Aspergillus were also observed (Usha and Anand, 1981).

Considerable variations were also observed in the quality of amchur sold in the market by Teotia and Pruthi (1987). The factors having a direct bearing on the cost of prepared amchur, like flesh recovery (60%), peeling and slicing capacity (15 kg green mangoes/person/day), drying characteristics (drying ratio 7.5:1) were also recorded. Sun drying at the temperature of about 35°C took 16-18 h. As per typical material balance and project costing data for the 100 kg raw mangoes batch size, manufacturing cost of amchur ranged from Rs. 35/- to Rs 50/- per kg depending upon raw material cost, turnover, drying or dehydration technique used.

Absorption and retention of sulphur dioxide in raw mango slices during drying and dehydration was studied by Khedkar and Roy (1983). Raw mango slices after blanching were sulphited by steeping the slices in 1, 2, 3 and 4 % KMS solution for 15 to 30 min. Absorption and retention of sulphur dioxide increased with increasing concentration of KMS solution and duration of steeping. Longer steeping time (30 min) helped in better retention of sulphur dioxie.

Green mango beverage: Mallik (1976) used the following method for preparation of green mango beverage. The fruits were washed, sliced and boiled in water for 20 to 30 minutes, for making the pulp tender. The pulp was then separated from the skin and strained through a coarse muslin cloth. Measured quantity of sugar and salt was dissolved in water in another container. The strained sugar-salt solution and mint extract were mixed with the strained green mango pulp. Citric acid, powdered cumin and black pepper were also added as per recipe. The contents were stirred thoroughly for proper mixing and then boiled. It was observed that recipe having 25% pulp, 40% sugar, 2% salt and 1.5% citric acid gave satisfactory quality.

A new process of extraction of green mango pulp was developed by Chau *et al*. (1989). The whole green mangoes were baked in a muffle furnace. Baked green mangoes were then peeled by hand and the pulp was scraped out of the stone and passed through a stainless steel sieve (20 mesh). The baked green mango pulp was then made into squash and nectar which had 25 and 15% pulp, 45 and 20°Brix TSS, 1.0 and 0.3% acidity, respectively. Squash was preserved with sulphur doxide (300ppm), while the nectar was heat processed for the preservation purpose. The squash and nectar were more acceptable when they were prepared from the pulp obtained on baking green mangoes at 200°C for 25 min or at 300°C for 20 min as compared to other temperature-time combinations.

Kaushik and Nath (1992) used a pressure cooking method for preparation of green mango beverage. Pressure cooking the whole unripe fruits at 7.34×10^{4} N/m^{2} steam pressure for 20 min followed by removing peels and stones manually, and pulping in a blender gave highest pulp yield (67.8%) without adversely affecting TSS and acidity of pulp, or sensory attributes of the beverage. Prepared beverage contained 16.7% pulp, 1.5% NaCl, 0.2% citric acid, 5% sugar and 1% of commercial spice mix. Dashehari cultivar was rated significantly superior among the four different mango varieties used (i.e. Dashehari, Deshi, Safeda and Chousa).

Pandey *et al*. (1995) cooked raw mangoes in pressure cooker for 10-15 min using 10% water. The cooked mangoes were cooled, peeled, destoned and the pulp was recovered. They observed that the beverage prepared using recipe having raw mango pulp (19.09%), water (66.82%), common salt (1.19%), black salt (0.24%), roasted cumin powder (0.48%), black pepper powder (0.1%), red chilli powder (0.14%), asafoetida powder (0.01%), mint leaves extract (4.77% of 2°Brix TSS), coriander leaves extract (4.77% of 3°Brix TSS), edible green colour (0.07%), lemon juice (2.39%) and without sugar was adjudged the best as far as colour, flavour, consistency and taste were concerned. Mango beverage was processed at 100°C for 10 min in glass bottles for preservation purpose.

Singh *et al*. (1999) have also tried to standardize the process for preparation of raw mango pana concentrate, which can be diluted to serve as beverage. The fully unripe, mature mangoes of Deshi variety were washed well in running water and then in warm water of about 50°C. The mangoes were then pressure cooked for one whistle (cooker of 5 kg capacity) using 10% water. The cooked mangoes were immediately cooled in running tap water, peeled, destoned and the

pulp was recovered. Organoleptic evaluation showed that raw mango pana concentrate prepared using recipe which included raw mango pulp (69.56%), cumin powder (1.39%), funnel powder (0.70%), black pepper powder (1.04%), black salt (3.13%), asafoetida (0.14%), salt (4.87%), mint leaves extract (10.43% of 4°Brix TSS), coriander leaves extract (3.48% of 4°B TSS), green chilli extract (3.48% of 6°B TSS), edible green colour (0.01%), sodium benzoate (500 ppm) and lemon juice (1.74%) on dilution with cold water in 1:6 ratio was adjudged the best as far as colour, flavour, consistency and taste were concerned. The pana concentrate kept well upto twelve months of storage at room temperature (22 to 35°C).

Kaur *et al*. (2006) also prepared pana concentrate using the process consisted of steaming, destonning, pulping the green mango and preservation with KMS at the rate of 150 ppm. The pana base was utilized for preparing ready-to-drink beverage with 25% juice, 15°B TSS, 0.25% total acidity (as citric acid) and 3.8 pH. Sugar, basil leaves, cardamom, cumin seeds, pepper and mixed spices were also used.

Ravani and Joshi (2011) standardized the processing parameters for the production of ready-to-serve unripe mango beverage (*pana*). The unripe mango RTS beverage prepared from Langra fruits pressure cooked at 68.96×10^3 N/m^2 for 10 min, peeled, pulped, diluted with 8 times water, and spiced with 0.56% salt and 8.00% sugar was found to be highly acceptable. The diluted product when thermally processed at 75±2°C for 15 min and added with sodium benzoate @ 100 ppm could be safely stored for at least one month under refrigerated condition.

By product utilization

Several million tons of mango wastes are produced annually from factories. Because mango is a seasonal fruit, about 20% of fruits are processed for products such as puree, nectar, leather, pickles and canned slices, among others, which have worldwide popularity (Loelillet, 1994). During the processing peel and mango kernel, which are good source of nutrients, are discarded. The byproducts are valuable source of nutrients and value addition can generate revenues and can address the disposal issues as well.

Mango peel: During processing of mango, peel a major by- product, contributes about 15-20% of the fruit (Beerh and Raghuramaiah, 1976). As peel is not currently utilized for any commercial purpose, it is discarded as a waste and becoming a source of pollution. Peel has been found to be a good source of phyto-chemicals, such as polyphenols, carotenoids, vitamin E, dietary fibre and vitamin C and it also exhibited good antioxidant properties (Ajila *et al*., 2007; Kim *et al*., 2010). The proximate composition of mango peels is given in Table 2.

Ajila *et al.* (2011) incorporated mango peel into macaroni at three different levels (2.5, 5.0, 7.5%) and studied its effect on the cooking properties, firmness, nutraceutical and sensory characteristics of macaroni. The total dietary fiber content in macaroni increased from 8.6 to 17.8%. The content of polyphenols increased from 0.46 to 1.80 mg/g and carotenoid content increased from 5 to 84 µg/g of macaroni with 7.5% incorporation of mango peel powder. The macaroni products incorporated with mango peel exhibited improved antioxidant properties.

Larrauri *et al*. (1996) developed technology for jam manufactured from mango peel. Inactivation of polyphenol oxidase was done by immersion of peel in boiling water and followed by extraction of peel soluble compounds at 80°C, and addition of sugar, citric acid and pectin as required. The mixture was then concentrated, cooled and packed. The jam was rated good in sensory test.

Effect of some technological parameters on preparation of mango peel dietary fiber was studied (Larrauri *et al*., 1996). Fresh mango peel was wet milled, washed with water and dried. Results showed that mango peel is a good source of tropical fruit fiber.

Mango kernel: Mango kernel is a good source of starch and fat. A preliminary study showed that the seed represents from 20% to 60% of the whole fruit weight, depending on the mango variety and the kernel inside the seed, which represents from 45% to 75% of the whole seed (Maisuthisakul and Gordon, 2009). Following tables (table 3 and 4) show the value of fatty acid composition (12.3 g lipid per 100 g dry seed kernel powder) and phenolic compounds (mango seed kernel contains total polyphenols, 112 mg per 100 g dry seed kernel powder) present in mango seed kernel.

Soong *et al*. (2004) indicated that mango seed kernel has potent antioxidant activity with relatively high phenolic contents. They observed that that mango seed kernel was also a good source of phytosterols, such as campesterol, bsitosterol, stigmasterol and also contains tocopherols. Schiber *et al*. (2003) and Nunez-Selles (2005) referred that the antioxidant effect of the mango seed kernel was due to its high content of polyphenols, sesquiterpenoids, phytosterols and microelements like selenium, copper and zinc. Mango seed kernels have a low content of protein but they contain the most of the essential amino acids, with highest values of leucine, valine and lysine (Kittiphoom, 2012).

Ashoush and Gadallah (2011) evaluated the effect of mango by products i.e. mango peel and seed kernel powder incorporated in biscuit to check its total

phenolic content and antioxidant activity effect in prepared biscuit.

Mango kernel fat alone or when blended with other nut fats like almond, palm stearin, can act as cocoa butter replacer (Moharram and Moustafa, 1982; Solís-Fuentes and Durán-de-Bazúa, 2004; Jahurul *et al*. 2013; 2014). The cocoa butter replacer has good triglyceride content and thermal properties.

Moharram and Moustafa (1982) extracted fat from mango seed kernel (Mangifera indica) and observed that triglycerides, fatty acids and phospholipids were comparable with those of cotton seed oil, cocoa butter. They also incorporated mango seed kernel oil in butterscotch toffee and found that mango kernel oil and cocoa butter were almost identical in several of their triglycerides, fatty acids and effects on taste, odour and texture of the toffee. Arogba (2001) prepared biscuit from equal amount of wheat and mango seed kernel powder.

Pectin from solid (mango peel and kernel) waste: A study was carried out to establish optimum extraction conditions for the extraction of pectin from mango solid waste. Highest pectin yield was obtained at pH-3, bleaching with alcohol and extraction time of 60 minutes (Pedroza *et al*., 1994)

Tandon and Kalra (1991) extracted pectin from dry peel and kernel of immature and ripe Dashehari Mangoes using 0.05N NaOH, 0.05NHCl and 0.3% sodium hexameta-phosphate (SHMP). Maximum yield of 12.79% pectin was obtained in ripe mango peel from SHMP extraction. The kernel contained very little amount of pectin. The water soluble pectin was more in peel of ripe fruit while alkali soluble fraction was more in peel of immature fruit.

Production of vinegar from mango waste: The potential of using mango (var. Totapuri) peels and stones for the production of vinegar was investigated (Ethiraj and Suresh, 1992). Alcoholic fermentation of these waste products was carried out by two methods. Peels or stone were mixed with (cold or hot water) (50%w/w) and saccharin. The extracts of peels or stones were treated with 50ppm SO_2 inoculated with *Saccharomyces cerevisiae* var. ellipsoideus and fermented (24$\pm$4°C, 72hrs). The base wine from peel and stone washings contained 2.5 and 3% alcohol, respectively. The alcohol content was increased to the desired level for acitification (5%) by alcohol fortification or secondary fermentation (addition of 4% cane sugar and 0.15 yeast extract). Acetification by batch type fermentation using Acetobacter rancans required 3½ days for completion and produced good quality vinegar (4.5-5% acetic acid) characterized by mild mango flavour.

Table 2: Proximate composition (g/100 g dry sample, except for moisture)

Component	Content
Moisture (%)	10.5±0.5
Fat (%)	2.2±0.06
Ash (%)	3.0±0.18
Total protein (%)	3.6±0.6
Total carbohydrate (%)	80.7±1.2
Total dietary fiber (%)	51.2±1.08
Soluble dietary fiber (%)	19.0±0.26
Insoluble dietary fiber (%)	32.1±1.34
Total polyphenols (mg GAE/g MPP)	96.2±1.4
Total carotenoids (µg/g MPP)	3092±98
Free radical scavenging activity, IC50 (µg MPP)	79.6±2.2

Table 3: Fatty acid composition of mango seed kernel lipid classes

Fatty acid	Lipid fractions (% of total fatty acids) (mean±SD)
Myristic $C_{14:0}$	0.5 ± 0.1
Palmitic $C_{16:0}$	5.8 ± 0.3
Stearic $C_{18:0}$	38.3 ± 1.2
Oleic $C_{18:1}$	46.1 ± 2.3
Linoleic $C_{18:2}$	8.2 ± 0.6
Linolenic $C_{18:3}$	1.2 ± 0.2
Saturated fatty acids	44.6 ± 1.3
Unsaturated fatty acids	55.0 ± 0.5

(Source: Abdalla *et al*., 2007)

Table 4: Phenolic compounds in mango seed kernel extract (Mean ± SD)

Phenolic compounds	Values (% of total compounds)
Tannin	20.7 ± 1.3
Gallic acid	6.0 ± 0.5
Coumarin	12.6 ± 0.9
Caffic acid	7.7 ± 0.8
Vanillin	20.2 ± 2.1
Mangiferin	4.2 ± 0.4
Ferulic acid	10.4 ± 1.1
Cinammic acid	11.2 ± 1.0
Unknown compounds	7.1 ± 0.9

(Source: Abdalla *et al*., 2007)

Conclusion

Mango has an established export market and poses bright opportunities for export in the international market whether in fresh or processed forms. Similarly, the mango industry has provided livelihood opportunities to its growers and those involved in its marketing channel. Creation of essential infra-structure for preservation, cold storage, refrigerated transportation, rapid transit, grading, processing, packaging and quality control are the important aspects which needs more attention.

The international market is becoming more competitive and other mango producing countries are also entering the market. The industry has therefore, to look forward to the development of newer categories of products, so as to retain the monopoly for processed mango products in the international market. A wide variety of products from ripe and unripe mangoes, their peels and kernels are prepared. The list of mango products ranges from mango pulp, juice, nectar, jam, custard powder, bars, wine, fortified yoghurt to other nutraceutical compounds.

Considerable amount of by-products e.g, mango stones, peels remain unutilized which is a rich source of many utilizable components. These by products can be converted to value added products to generate more revenue and to reduce environmental pollution.

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