Agro-Products from mango

This review discusses the utilisation of fresh and dried mango as well as waste products such as peel, kernel, leaves, wood and latex.

Background
Mango, described as the king of fruits, originates from East India, Burma and the Andamar Islands (De La Cruz Medina & Garcia, 2003). The fruit was introduced by Buddhist monks to Central and East Asia. Persian traders established the mango in Middle East Africa around the tenth century A.D. Mango travelled to the west after the sea-routes was discovered. Portuguese brought it to Brazil, South Africa and the West Indies in the sixteenth century\(^1\). Hundreds of mango cultivars are grown throughout the world. In India, where the mango tree is revered as a symbol of love and fertility, more than 500 varieties are propagated (De La Cruz Medina & Garcia, 2003).

About half of the South African production is processed as atchar, which is very popular with local consumers, and 15% is used for juice. An additional 15% is exported and roughly 30% is consumed by the local market as fresh or dried fruit (Saúco, 2004). The nutrients present in mango are numerous and include protein, fat, carbohydrates, carotene, vitamins A, B1, B2, B3, B5, B6, B9, C, folic acid, calcium, magnesium, iron, zinc, phosphorous and potassium. Some of the medicinal properties attributed to the fruit include antiviral, antiparasitic, antiseptic, antiasthmatic, contraceptive, laxative, aphrodisiac and other properties (Morton, 1987).

The ripe fruit has a fresh, delicious taste and are very flavoursome. The pulp of inferior fruit can be used for various sweet fruity processed products, such as juice, milk beverages, yoghurts, squash, syrups, jams, marmalades, fruit bars, and...
fruit rolls, jellies and mango sweets. The volatiles from mango can be extracted from the pulp and used as a flavouring agent. In the west, ripe mangoes are used for the production of sweet chutney, but in India chutney is prepared from unripe mangoes combined with hot chilies or lime. Other more spicy ways to process the fruit include: pickles, achar and amchur, a spice made from dried, sour mangoes (Maneenpun & Yunchalad, 2004). The fruit can be dried and is a delicious and nutritional snack. Dried mango is sweet and chewy and can be added to muesli and granola, or used in desserts, pies and milkshakes. Wine can be produced by fermentation of the fruit pulp.

Mango Pulp
Processing of numerous mango products requires extraction of the pulp. The fruit is peeled and stoned after which the pulp is homogenised with a small amount of water, heated to 85 °C and 0.1% potassium metabisulphite added. The pulp is vacuum stored and can be used for the preparation of various processed products. Mango juice, nectar and squash can be prepared by adding varying quantities of sugar, citric acid and sugar syrup to 1 L of pulp. Mango juice concentrate can be produced by removing water either through freezing or heating of the pulp.

The mango concentrate can be dried into a powder, either by freeze drying, vacuum drying or spray drying. The mango powder has a long shelf life, is water soluble and can be added to various products as a flavourant. Juice can also be prepared from mango powder which has been reported to be more stable than fresh mango juice (Djantou et al., 2011). Processing mango pulp into powder will reduce post-harvest losses. The biggest problem with the production of the powder is caking. Alternating drying and grinding of ripe mango results in grinding without caking, as well as producing smaller particles.

Mango Wine

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In the production of wine from mango, sugar and citric acid are added to the pulp. Preservative, 50 ppm potassium metabisulphite are added to prevent discolouration of the juice through oxidation as well as to supress wild yeast present in the pulp. After 6-8 hours the juice was inoculated with yeasts starter culture. Fermentation was allowed to take place for 10-12 days, after which the liquid are filtered and stored in glass bottles. After a month the clear wine has separated from the suspended matter. In the preparation of sweet wine 5g/L cane sugar is added to the pulp.

**Mango milk shakes**

Mango milk shakes are made by combining mango pulp with skim milk powder. This product is an exceptional nutritional beverage. The milk provides protein and the mango, carbohydrates, vitamin C, polyphenols, antioxidants and inorganic potassium. The beverage can be stored in a refrigerator for 32 days.

**Other mango products from ripe mango**

Jam is prepared using equal amounts of fruit pieces and sugar with a small amount of citric acid or lime or lemon juice.

Chutney can be prepared from green or semi-ripe fruit. The fruit is cut in slices and cooked with salt for five min and then sugar, spices and vinegar added, and cooked until a thick puree is formed. Spices such as cumin, cloves, cinnamon, chilli ginger and nutmeg may be added. Various other fruit, as well as onions, garlic and nuts could also be added.

Pickled mango pieces can be produced by adding mustard, chili, turmeric, fenugreek seeds, and oil to the fruit.

Mango slices can be preserved by placing the fruit in hot sugar syrup and sealing the mixture in glass bottles.

Fresh-cut mangoes turn brown and soften as a result of oxidation. By irradiating the fruit with pulsed light the fruit maintains its physical and nutritional quality much longer, thereby increasing the shelf life of the fruit. Pulsed Light is a nonthermal emerging technology that works with Xenon lamps that can produce intense and short time pulses of broad spectrum "white light". The ultra violet part
of the spectrum (200 to 280 nm) is the most important for microbial inactivation. The only problem using this technology is that it has not yet been approved by the European Union (Charles et al., 2013).

The fruit can be coated with food grade sodium alginate as carbohydrate biopolymer as carrier for antibrowning agents such as ascorbic and citric acid. This application of antbrowning agents to mango slices produced mango slices with higher antioxidant activity due the ascorbic acid addition. The combination of alginate and antibrowning agent preserved the colour and also improved the antioxidant potential of fresh-cut mangoes. Fresh cut Kent mango can be stored 12 days at 4 °C, without deteriorating nutritional and physicochemical quality (Robles-Sánchez et al., 2013).

**Dried products**

Pulp is poured into buttered tray and dried. The pulp would be spread out in thicker layers for the bars than for strips. The pulp is dried to 5-8% moisture for fruit strips but 15% for fruit bars, and cut into small pieces and packaged. Drying can be achieved by sun-drying, vacuum drying, tunnel dehydration and osmotic dehydration. Immature fruit can be peel, sliced, dried and powdered to produce amchur.

**Waste product utilisation**

The processing of ripe and green mango products as fruit slices, pulp, fruit bars and chutney produce a lot of peels as a waste product. Valuable bioactive compounds can be isolated from the peels. Mango peel can be processed and used in the production of nutraceutical products. This would solve the problem of waste treatment and increase the revenue made from the whole fruit (Ajila, Bhat & Prasada Rao, 2007).

**Phenolic compounds**
Phenolic compounds are secondary metabolites that are derivatives of metabolic pathways in plants (Randhir, Lin & Shetty, 2004). These compounds are of considerable physiological and morphological importance in plants. Besides contributing towards the colour and sensory characteristics of fruits and vegetables these compounds play an important role in protection against pathogens.

Phenolic compounds exhibit a wide range of physiological properties, such as anti-inflammatory, anti-microbial and antioxidant activity, chelation of metal ions, inactivation of lipid free radical chains and the prevention of the conversion of hydroperoxide into reactive oxyradicals.

A major concern regarding the consumption of phenolic compounds has been in relation to the perceived role as "antinutrients". Tannins, for example form complexes with dietary proteins and carbohydrates, as well as with enzymes (Naczk et al., 1996; Naurato et al., 1999). Besides, tannins have also been shown to reduce the absorption of minerals such as iron and copper (Reddy & Cook, 1991; Samman et al., 2001). However, chelation of these metals could sometimes be beneficial as this is one of the mechanisms by which phenolic compounds exert their antioxidant activity (Bravo, 1998).

Concerns of potential adverse effects due to excessive consumption of phenolic compounds have been expressed and it is clear that extensive research should be done before a new product is used.

Though phenolic compounds are present in almost all foods of plant origin, fruits, vegetables, and beverages are the major sources of these compounds in the human diet. Soong and Barlow (2004) have reported that the total phenolics content of seeds of several fruits, i.e., mango, longan, avocado, and jackfruit were higher than that of the edible flesh, as such these seeds could be a valuable source of antioxidant phenolics (Soong & Barlow, 2004).
The phenolic content of mango pulp is quite high at 546 mg/100g mango pulp, expressed as gallic acid equivalent. Pineapple for example contains only 129 mg/100g pulp. The mango waste product would normally be discarded and can be obtained at low cost and applied as nutraceutical resources such as dietary supplements. It could also be used as nutritional supplement by the pharmaceutical industry due to the bioactive compounds in the fruit waste products. The cultivars Jose’, Tommy Atkins, Ngowe, Haden, and Heidi have the highest levels of polyphenols however other factors such as ripening also affect polyphenol content (Berardini et al., 2005).

Some bioprocesses such as heat treatment or addition of alkali can enhance recovery of phenolic compounds from agri-industrial wastes.

The preceding introduction should clearly indicate that research should be done before any of the possible applications, as reported in literature, is adopted.

**Mango peel and seeds**

The peels and seeds of mango comprise 35-60% of the total fruit weight (Berardini et al., 2005). Waste products from mango processing can be added as a dietary fibre for the enrichment of food. Peel, pulp and seeds of fruit can be used in the food industry because of the high dietary fibre content. The fibre obtained from mango has a balanced ratio of soluble to insoluble dietary fibre content, which is important for the nutritional effects of fibre (Martínez et al., 2012).

Soft dough biscuits can be prepared using different levels of mango peel powder with wheat flour. By incorporating 20% mango peel powder the total dietary fiber content increased from 6.5 to 20.7%. Polyphenols content increased from 0.54 to 4.50 mg/g and carotenoid content increased from 17 to 247 mg/g of biscuit. The biscuits incorporated with mango peel exhibited improved antioxidant properties. The biscuits has an acceptable mango flavour (Ajila, Leelavathi & Prasada Rao,
Enriched macaroni can be produced by mixing mango peel powder with semolina at a level of 5% of the macaroni formulation with acceptable results. The enriched macaroni had high levels of polyphenols, carotenoids and dietary fibre (Ajila et al., 2010).

One way to maximise economic value from fruit produced is by fruit processing. Mango fruit, as well as waste products and other parts from the tree such as bark and leaves are rich in bioactive compounds that can be used as nutraceuticals and pharmaceuticals (Ribeiro & Schieber, 2010). The macronutrient content of flour obtained from mango kernels contained 66.1 g protein, 94.0 g fat, 28.0 g fiber and 500.0 g of starch per kilogram kernel. The protein content of mango kernel, though low, contained essential amino acids making it a good quality protein. The tannin content of the kernel can reduce the biological value of the protein. Mango seed kernels contain many micronutrients such as calcium, magnesium, iron and zinc. Mangoes contain several bioactive compounds with a great potential to modulate risk factors of diseases.

Bioactive compounds such as Vitamin C, carotenoids, phenolic compounds such as mangiferin, quercitin and kaempferol, terpenoids and fibre. Bioactive compounds protect against diseases because of antioxidant activity. Mango contains three classes of compounds, ascorbic acid, carotenoids, and phenolic components that can support the antioxidant protection in humans. Mangiferin, produced by mango leaves and bark is a very potent antioxidant, even more potent than Vitamin C (Ribeiro & Schieber, 2010). Many studies have determined that mangiferin is the major active compound in bark and leaf extracts with a wide range of pharmacological effects: antioxidant, anticancer, antimicrobial, antiatherosclerotic, antiallergenic, anti-inflammatory, analgesic, and immunomodulatory. The mangiferin content ranged from 4.4 mg/kg pulp to 1690 mg/kg in dried mango peel. Mangiferin, as a pure compound is less active then whole leaf extracts proving that other mango bioactive compounds play a sunergistic role in the activity. The fact that all parts of the plant, pulp, peel, seed,
bark, leaves, and flowers are sources of polyphenols with the potential to reduce
diseases such as cancer, diabetes and obesity (Masibo & He, 2008).

Lactic acid is used as a preservative and to acidify foods but the production of
this substance is very costly. The use of agro-industrial wastes would provide an
alternative way to produce lactic acid from less costly raw materials. Currently the
production of lactic acid takes place through a two-step procedure;
saccharification followed by microbial fermentation. Direct conversion of mango
peel to lactic acid by fermenting bacteria is a more economical procedure.
Temperature, pH and incubation time plays a significant role in production.
Maximum production occurred at 35 °C and a pH of 10 during fermentation
(Jawad et al., 2013).

Mango peel extracts can be used to synthesize silver nanoparticles. Silver has
antibacterial properties and the nanoparticles can be applied to non-woven
fabrics and used for medicinal applications. Existing synthesis procedures involve
toxic chemicals that could still be present when applied to the fabric which would
be prevented using agricultural waste products (Yang & Li, 2013).

Phenolic compounds extracted from mango seed kernel powder was found to
extend the shelf life of buffalo ghee (Puravankara, Boghra & Sharma, 2000).

Mango leaf
The antioxidant and pharmaceutical properties of aqueous and ethanolic extracts
of mango have been studied extensively. Mango leaves as well as the bark
contain very high levels of phenolic compounds, mainly mangiferin, that is
responsible for the various pharmaceutical activities (Mohan et al., 2013).
Mango leave extracts can be used in food applications as natural antioxidant
additive replacing toxic synthetic antioxidants such as butylhydroxytoluene (BHT)
(Morsi et al., 2010). In cosmetic products the use of mango leaf extracts had anti-
aging activity, the capacity to protect the skin against ultraviolet radiation and
prevent or reduce the effects of heat stress on the skin, lips and hair (Charrier et al., 2006).

**Mango wood**
Radical scavengers were isolated and identified in olive tree (*Olea europaea*) wood. Hydroxytyrosol was isolated from the wood and displayed higher activity than the natural antioxidant rosmarinic acid in radical scavenging. Cycloolivil and oleuropein showed stronger activities than the synthetic antioxidant BHT against the same radical (Perez-Bonilla et al., 2006). This study was done on olive tree wood but it is very possible that the mango wood will also contain valuable phenolic compounds. No literature reference towards such a study could be found.

**Mango seed kernel**
The city of Araguari, Brazil produces more than 1300 tons/year of mango seeds. This waste product can be used for the production of carbon nanoparticles. Mango seeds are currently primarily used the production of animal feed, glucose from starch and activated carbon for use in water treatment. The kernel comprise of two parts, the tegument and the almond. The tegument is the hard fibrous outermost layer of the seed, and the almond, and is the main part containing the embryo and albumen. The kernel represents 11.69% of the total weight of the fruit.

Arogba (1997) determined the amino acid composition of the mango kernel and found that six of the essential amino acids were present at levels 70 % higher than that in standard protein references. Arginine was nearly double that in the standard protein while valine was only 10% (Arogba, 1997).

However, the very high tannin levels in mango kernel could be a problem in its use. The tannin level in mango kernel was found to be very high, 45 g/ kg. Repeated soaking and thermal treatment could extract 48% of the tannin. Consequently, the calculated LD$_{50}$ per 70 kg body weight was 0.78 kg raw kernel
and 1.5 kg processed flour, respectively. This author concluded that the processed flour has potential application in the preparation of steamed solid meals for adults in a traditional Nigerian household and could also be suitable for infant formulations.

Carbon nanoparticles can be manufactured from mango seed and be used as reinforcement agents for the production of ecofriendly nanofillers for diverse application (Henrique et al., 2013)

Lipids, and particularly fats and oils, are important compounds in the structure and functioning of cells. Mango kernel fat can be used as an alternative to processed semi-solid fats high in trans fatty acids content.

Kaphueakngam et al. (2009) reported that Cocoa butter (CB), the fat extracted from the *Theobroma cacao* seeds, is commonly used as an ingredient in several confectionery products, especially in chocolate. CB is one of the most expensive vegetable fats. Cocoa Butter Equivalents, vegetable fats with chemical and physical properties similar to cocoa butter, have been used in chocolate products for many years. According to the 2003 EU regulations, only six vegetable oils/fats can be used in EU chocolate and mango seed oil is one of them (Kaphueakngam, Flood & Sonwai, 2009).

Momeny et al. (2013) extracted 11.6 % (m/m) oil from dried Alphonso mango kernel using hexane as solvent (Momeny et al., 2013). Mango seed kernel must be reconsidered, not only for its qualities as a natural food and its biological properties, but also because the fat has significant functional and physicochemical characteristics that could lead to it replacing fats like cocoa butter in the food industry and in food processing. Trans-fatty acids have been implicated in the development of many major diseases, such as heart problems and diabetes. Mango kernel fat has the physical and chemical characteristics that
make it a feasible alternative to currently used trans-fatty acid dietary fats (Solís-Fuentes & María del Carmen, 2011).

**Latex from mango fruit.**
The pulp and latex of a particular mango variety share similar terpenoid compounds. The raw mango flavour is essentially due to terpenoids in the latex while the aroma of the ripe fruit is due to the other aroma components such as esters and alcohols.

John *et al.* (1999) reported that the sap contains an aqueous and a non-aqueous phase that can be separated by simple centrifugation. The aroma components of the non-aqueous phase can be used directly in various confectionery items, bakery products and beverages, to impart the raw mango aroma (John *et al.*, 1999).

Certain terpenoids such as β-myrcene, ocimene, limonene, α- and β-pinene are being used in low concentrations as aroma components in various processed foods. Besides this, the individual components of sap can be used as raw materials for nature-identical aroma chemicals rendering the sap a potential valuable agricultural by-product.

**References**


