International Food Research Journal 19(4): 1325-1335 (2012)
Journal homepage: *http://www.ifrj.upm.edu.my*

Mini Review

Utilization of Mango seed

Kittiphoom, S.

Faculty of Agro Industry, Rajamangala University of Technology Srivijaya, Nakhon Si Thammarat, 80240, Thailand

Article history

Received: 18 November 2011
Received in revised form: 17 January 2012
Accepted:17 January 2012

Keywords
Mango seed
utilization
oil
starch
antioxidants

Abstract

Mango (*Mangifera indica* Linn.) is one of the most important tropical fruits in the world. During processing of mango, by-products such as peel and kernel are generated. Kernels take up about 17-22% of the fruit. The major components of mango seed are starch, fat and protein. The oil of mango seed kernel consist of about 44–48% saturated fatty acids (majority stearic) and 52–56% unsaturated. 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. Mango seed kernels were shown to be a good source of polyphenols, phytosterols as campesterol, sitosterol and tocopherols. In addition, mango seed kernel could be used as a potential source for functional food ingredients, antimicrobial compounds and cosmetic due to its high quality of fat and protein as well as high levels of natural antioxidants. The mango stone obtained after decortication of mango seed can be utilized as adsorbent.

Introduction

The mango is a very common tropical fruit usually found in Southern Asia, especially in Eastern India, China, Burma, Andaman Islands and Central America. Mangoes belong to the genus *Angifera*, consisting of numerous species of tropical fruiting trees in the flowering plant family Anacardiaceae. It is cultivated and grown vastly in many tropical regions and widely distributed in the world. The mango is indigenous to the Indian subcontinent and Southeast Asia (Fowomola, 2010). Cultivated in many tropical regions and distributed widely in the world. It is one of the most extensively exploited fruits for food, juice, flavor, fragrance and color and a common ingredient in new functional foods often called superfruits. Its leaves are ritually used as floral decorations at weddings and religious ceremonies.

Mango trees (*Mangifera indica*) reach 35 - 40 m in height, with a crown radius of 10 m. The leaves are evergreen, alternate, simple, 15 - 35 cm long and 6 - 16 cm broad; when the leaves are young they are orange-pink, rapidly changing to a dark glossy red, then dark green as they mature. The fruit takes from 3 - 6 months to ripen. The ripe fruit is variable in size and color, and may be yellow, orange, red or green when ripe, depending on the cultivar. When ripe, the unpeeled fruit gives off a distinctive resinous sweet smell. In its center is a single flat oblong seed that can be fibrous or hairy on the surface, depending on the cultivar.

In 2008 Thailand is the third biggest mango producer, with a 2.5 millions of tons after India (13.6 millions of tons) and China (4.2 millions of tons) (*http://faostst.fao.org*). In Thailand, mangos are the most popular fruits. There are several varieties grown in Thailand, “Nam Dawk Mai” and “Ok Long” are the favorites choices as dessert fruit. Keow Savoey is sweet and has a powdery texture, while Ma-muang Rat is predominantly sour with a hint of sweet.

Ripe mangoes are processed into frozen mango products, canned products, dehydrated products, and ready-to-serve beverages (Ramteke and Eipeson, 1997). After consumption or industrial processing of the fruits, considerable amounts of mango seeds are discarded as waste (Table 1.) (Puravankara *et al*., 2000); they account for 35%–55% of the fruit (Bhalerao *et al*., 1989), depending on the variety. Actual figures on the quantity of mango waste generated commercially are not readily available. Therefore, the utilization of mango by-products especially mango seed may be an economical way

*Corresponding author.
Email: *kit_src@yahoo.com*

Table 1. Different components obtained during mango pulp extraction

Component	Percentage
Mango pulp	45–65
Peels	15–20
Pulpier waste	10–15
Stones	10–20

(Source: Central Food Technological Research Institute, 1985)

Table 2. Proximate analysis of mango seed kernel

Characteristic	Reported values (Mean)			
	Nzikou *et al.*, 2010	Dhingra and Kapoor, 1985[1]	Dhingra and Kapoor, 1985[2]	Changso, 2008
Moisture content (%)	45.2	38.55	50.98	40.5
Crude protein (%)	6.36	5.34	5.25	1.43
Fats /oils (%)	13.0	7.82	6.98	4.92
Crude fiber (%)	2.02	1.75	1.65	3.96
Ash content (%)	3.2	2.75	2.47	0.83
Total carbohydrate (%)	32.24	nr	nr	48.19

Note: nr, not reported
Dhingra and Kapoor, 19851 variety Chausa
Dhingra and Kapoor, 19852 variety Dusheri

Table 3. Mineral elemental composition of mango seed kernel (mg/100g)

	Nzikou *et al.*, 2010	Fowomola, 2010
Calcium, Ca	10.21	111.3
Magnesium, Mg	22.34	94.8
Potassium, K	158.0	22.3
Sodium, Na	2.70	21.0
Phosphorus, P	20.0	nr
Iron, Fe	nr	11.9
Zinc, Zn	nr	1.10
Manganese, Mn	nr	0.04

Note: nr, not reported

Table 4. The amino acids contained in mango seed kernel based on dry weight compared to the FAO/WHO reference

Amino acid	Quantity (mg/100g)			
	Fowomola, 2010	Om El-Saad El-Gammal, 2011	Arogba, 1999	World Health Organization, 1985
Essential amino acids				
Isoleucine	3.23	2.68	4.4	4.20
Lysine	3.13	3.94	6.9	4.20
Methionine	1.04	0.38	1.2	2.20
Phenylalanine	4.46	2.75	3.4	2.80
Threonine	2.04	3.46	3.4	4.00
Tyrosine	3.17	2.74	2.7	2.80
Valine	3.80	6.07	5.8	4.20
Non essential amino acids				
Arginine	5.17	14.27	7.3	
Alanine	6.40	4.86	4.2	
Aspartate	6.33	8.66	6.5	
Cysteine	2.30	-	-	
Glutamate	13.00	15.66	18.2	
Glycine	3.50	2.81	4.0	
Histidine	2.31	2.19	5.5	
Leucine	8.40	-	-	
Proline	3.00	4.50	3.5	
Serine	2.93	3.94	3.3	

Table 5. Vitamins contents of mango seed kernel

Vitamins	Amount (mg\100 g)
A	15.27
E	1.30
K	0.59
B1	0.08
B2	0.03
B6	0.19
B12	0.12
C	0.56

(Source: Fowomola, 2010)

to reduce the problem of waste disposal from mango production.

Mango seed

Mango seed is a single flat oblong seed that can be fibrous or hairy on the surface, depending on the cultivar. Inside the seed coat 1 - 2 mm thick is a thin lining covering a single embryo, 4 - 7 cm long, 3 - 4 cm wide, and 1 cm thick. Mango seed consists of a tenacious coat enclosing the kernel. The seed content of different varieties of mangoes ranges from 9% to 23% of the fruit weight (Palaniswamy *et al*., 1974) and the kernel content of the seed ranges from 45.7% to 72.8% (Hemavathy *et al*., 1988). Table 2 shows the results of proximate analysis of mango seed kernel. The results showed that mango seed kernel contain crude protein, oil, ash, crude fiber, and carbohydrate. Variation in characteristic yield may be due to the differences in variety of plant, cultivation climate, ripening stage, the harvesting time of the seeds kernels and the extraction method used.

Mango seed kernel was high in potassium, magnesium, phosphorus, calcium and sodium (Table 3). Potassium is an essential nutrient and has an important role is the synthesis of amino acids and proteins (Malik and Srivastava, 1982). Calcium and magnesium plays a significant role in photosynthesis, carbohydrate metabolism, nucleic acids and binding agents of cell walls (Scalbert, 1991). Calcium assists in teeth development (Brody, 1994). Magnesium is essential mineral for enzyme activity, like calcium and chloride; magnesium also plays a role in regulating the acid-alkaline balance in the body. Phosphorus is needed for bone growth, kidney function and cell growth. It also plays a role in maintaining the body's acid-alkaline balance (Fallon and Enig, 2001).

The amino acids content of mango seed kernel are demonstrated in Table 4. Data in this table showed that valine and phenylalanine achieved higher values compared to the FAO/WHO reference (World Health Organization, 1985) followed by therionine, lysine and tyrosine which were somewhat equaled to the reference. On the other hand, arginine and glutamic acids revealed the highest values of all non essential amino acids in mango seed kernel content. Table 5 showed that mango seed contained 15.27 (IU) vitamin A; (1.30 mg/100 g) vitamin E; (0.59 mg/100 g) vitamin K; (0.08 mg/100 g) vitamin B1; (0.03 mg/100 g) vitamin B2; (0.19 mg/100 g) vitamin B6; (0.12 mg/100 g) vitamin B12 and (0.56 mg/100 g) vitamin C. These results also showed that mango seed is richer in vitamins.

The results of proximate analysis show that mango seed kernel is a nutritional promising seed because of its high levels of carbohydrate and oil. The results of mineral assayed showed that mango seed is very rich in calcium, potassium and magnesium. The presence of antioxidant vitamins such as vitamin C, E and A suggests that mango seed could be used as an alternative source of these vitamins. Antioxidant vitamins have been reported to reduce oxidative processes which are known to be vital in the initiation

Table 6. Chemical properties of Mango seed kernel oil extracted using solvent process

Chemical properties	Dhingra and Kapoor, 1985	Nzikou *et al.*, 2010	Abdalla *et al.*, 2007
Peroxide Value PV	0.20	nr	0.96
Free Fatty Acid FFA (as % oleic acid)	3.93	5.35	1.22
Iodine Value IV (wijs)	43.0	39.5	53.15
Saponification value	206.0	207 .5	192.16
Unsaponifiable matter Content (%)	4.35	nr	2.78

Note: nr, not reported

Table 7. Relative percent composition of fatty acid in mango seed kernel oil

Fatty acid		Nzikou *et al.*, 2010	Dhingra and Kapoor, 1985[1]	Dhingra and Kapoor, 1985[2]	Arogba, 1997	Cavaletto, 1980
Myristic acid	C14:0	-	-	-	-	0.7
Palmitic acid	C16:0	6.48	7.18	7.5	10.5	9.1
Palmitoleic acid	C16:1	-	-	-	21.9	-
Steric acid	C18:0	37.94	38.9	38.7	27.0	2.2
Oleic acid	C18:1	45.76	42.6	43.2	48.3	59.9
Linoleic acid	C18:2	7.45	5.7	6.2	14.0	1.9
Linolenic acid	C18:3	2.37	5.3	2.9	-	-
Saturated		44.42	46.08	46.2	37.5	-
Unsaturated		55.58	53.6	52.3	62.3	-

Note: Dhingra and Kapoor, 19851 variety Chausa.
Dhingra and Kapoor, 19852 variety Dusheri.

Table 8. Profile of fatty acids in the mango seed kernel oil, palm oil, a commercial sample of cocoa butter and 80/20 (%wt of mango seed kernel oil/palm oil)

Fatty acid	mango seed kernel oil[1]	palm oil[2]	cocoa butter[1]	80/20 (%wt of mango seed kernel oil/palm oil)[2]
Palmitic	9.29	51.65	24.27	16.26
Stearic	39.07	4.21	35.10	37.25
Oleic	40.81	35.63	36.47	39.6
Linoleic	6.06	-	2.85	-
Linolenic	0.64	-	0.30	-
Arachidic	2.48	-	1.01	-
Behenic	0.64	-	-	-
Lignoceric	0.49	-	-	-

Note: [1]Solis-Fuentes and Duran-de-Bazua, 2004
[2]Kaphueakngam *et al.*, 2009

of arthrosclerosis (Steinberg *et al.*, 1989).

Applying mango seed kernel

The properties of mango seed kernel oil

Mango seed kernel oil is pale yellow in color. The chemical properties of mango seed oil are amongst the most important properties of the oil (Table 6). Free fatty acid and peroxide values are always used as an index of oil quality. The low free fatty acid of mango seed oil indicated that the mango seed was almost free from hydrolytic rancidity brought almost by lipases and enables the direct use of such as oil in industries without further neutralization as described by Arogba (1997). On the other hand, mango seed oil had a high quality due to the low level of peroxide value. Iodine value represents the amount of unsaturation contained in oil. The iodine number ranged from 39 to 53. Saponification value represents the average molecular weight (or chain length) of all the fatty acids. Unsaponifiable matter is component of an oily mixture which fails to form soap when blended with NaOH. The composition of unsaponifiable matter of vegetable oils including tocopherols, sterols and squalene is of great importance for oil characteristics and stability (Sim *et al.*, 1972).

The major saturated fatty acids in mango seed kernels oil were stearic and palmitic acids and the main unsaturated fatty acids are oleic and linoleic acids (Table 7). The comparison of the composition in fatty acids of mango seed kernel oil with that of vegetable oils indicates that this plant is rich in acids stearic and oleic. Accordingly, mango seed kernel oil is more stable than many other vegetable oils rich in unsaturated fatty acids. Such oils seem to be suitable for blending with vegetable oils, stearin manufacturing, confectionery industry or/and in the soap industry.

Cocoa butter

Cocoa butter is the fat extracted from the Theobroma cacao seeds (Becktt, 2000) that is commonly used as an ingredient in several confectionery products, especially in chocolate due to its specific properties. Cocoa butter is one of the most expensive vegetable oils consisting mainly of palmitic acid, stearic acid and oleic acid and a trace amount of lauric acid and myristic acid (Kheiri, 1982; Pease, 1985). So industries have tried to look for alternative vegetable oils that have chemical and physical properties similar to cocoa butter but they are cheaper. The research from Kaphueakngam et al. (2009) found that oil obtained from the mango seed kernels could be an alternative source of edible oil. With the right proportion, an oil blend between mango seed kernel oil and palm oil could be used as Cocoa butter. Fatty acid compositions of mango seed kernel oil, mixture of mango seed kernel oil/palm oil and cocoa butter are given in Table 8. The results show that, like cocoa butter, the mixture of mango seed kernel oil/palm oil was composed mainly of palmitic acid, stearic acid and oleic acid. Hence, mango seed kernel oil is a good source of stearic acid and oleic acid whereas palm oil is a source of palmitic acid and oleic acid. The 80/20 (%wt of mango seed kernel oil/ palm oil) blend mainly consisted of three fatty acids that were also the main fatty acid components of cocoa butter, the melting behavior and slip melting point were closest to that of cocoa butter.

Natural antioxidants

Vegetables and fruits have been used as natural materials to maintain human health as they may help to reduce the risk of many age-related degenerative diseases (Amin and Tan, 2002; John and James,

Table 9. The total antioxidant activity and phenolic contents of seed of mango, tamarind, longan, avocado and jackfruit

Item	Antioxidant activity (μmol/g)	Phenolic content (mg/g)
Mango kernel	762± 72.9	117±13.5
Tamarind seed	698±30.3	94.5±4.9
Longan seed	488±82.5	62.6±3.2
Avocado seed	236.1±45.1	88.2±2.2
Jackfruit seed	7.4±2.0	27.7±3.4

(Source: Soong and Barlow, 2006)

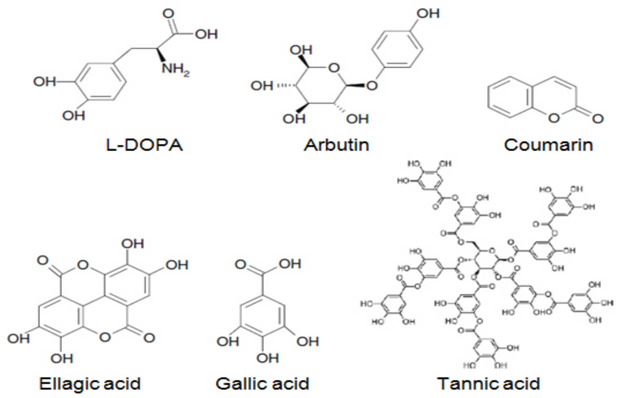

Figure 1. Chemical structures of some phenolic compounds

2005; Lee *et al*., 2007). In fact, fruits contain many antioxidant compounds such as phenolics, betalains and carotenoids. Antioxidants can be defined as substances able to inhibit or delay the oxidative damage of protein, nucleic acid and lipid caused by dramatic increase of reactive oxygen species (ROS) during environmental stress (Lim *et al*., 2006). Antioxidants act by one or more of the following mechanisms: reducing free radical activity, scavenging free radicals, potential complexing of pro-oxidant metals and quenching of singlet oxygen (Tachakittirungrod *et al*., 2006). Antioxidants can be classified into primary and secondary antioxidants due to their protective properties at different stages of the oxidation process. Primary antioxidants stop or delay oxidation by donating hydrogen atoms or electrons to free radicals to convert themselves to more stable products. As for secondary antioxidants, they function by many mechanisms, including binding of metal ions, scavenging oxygen, converting hydroperoxides to nonradical species, absorbing UV radiation or deactivating singlet oxygen (Maisuthisakul *et al*., 2005).

Food antioxidants are compounds or substances that are present naturally in some ingredients or are intentionally added as food additive with the aim of inhibiting product oxidation (Halliwell, 1996). Thus, their use in the food industry is important to maintain quality, mainly in foods that contain high levels of lipids, such as meat products. In industrial processing, synthetic antioxidants, such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA), are frequently used in order to inhibit the formation of free radicals and to prevent lipid auto oxidation and food spoilage. Synthetic antioxidants show good stability during processing and storage of high lipid foods. In recent years, however, many countries (Japan and some European countries) have suppressed the use of synthetic antioxidants because of their potential toxicity and carcinogenicity (Wanasundara and Shahidi, 1998; Tang *et al*., 2001). Thus, the demand for antioxidant substances naturally found in fruits and vegetables has increased since the use of those substances in products has been considered due to healthy benefits to consumers such as the reduction in the incidence of cardiovascular diseases and cancer. Moreover, natural antioxidants can be more effective in retarding food oxidation (Zandi and Gondon, 1999; Kang *et al*., 2001; Bub *et al*., 2003).

The importance of natural antioxidants for cosmetic and food applications has been underlined by numerous works. The limitations of using a plant extract as a natural antioxidant are availability and cost. Several studies have shown that mango seed kernels contain various phenolic compounds and can be a good source of natural antioxidants (Puravankara *et al*., 2000; Abdalla *et al*., 2007). In addition, polyphenols from mango seed kernels were found to contain tannins, gallic acid, coumarin, ellagic acid, vanillin, mangiferin, ferulic acid, cinammic acid (Figure 1) (Arogba, 1997). The total antioxidant capacity and phenolic content vary considerably from one kind of fruit to another. Antioxidant activity and phenolic content of seeds of avocado, jackfruit, longan, mango and tamarind were shown in Table 9. Mango seed kernel had the highest antioxidant activity and phenolic content, followed by the seeds of tamarind, avocado, longan and jackfruit. This suggests that the fruit seeds should be further utilized rather than just discarded as waste.

The main components of unsaponifiables in vegetable oils are tocopherols and sterols, present in different amounts. Tocopherols are recognized as very efficient natural antioxidants and their amount in the plant is probably governed by the content of unsaturated fatty acids. Isomers of tocopherols have different antioxidative activity in vitro and in vivo. In the food system, the antioxidant activity of the tocopherol isomers decreases in the following order: $\gamma > \delta > \beta > \alpha$ (Kamal-Eldin and Appelqvist, 1996). Tocopherols are about 250 times more effective than butylated hydroxytoluene (BHT) (Burton and Ingold, 1989). Lipid peroxy radicals react with tocopherols several magnitudes faster than with other lipids. A

Table 10. Content of tocopherols (mg/kg) in selected vegetable oils

Oil	α-tocopherol	γ-tocopherol	δ-tocopherol
Canola	272	-	423
Coconut	3	1	1
Corn	191	-	942
Linseed	8	-	500
Linola	20	-	471
Mango	140	63	62
Palm	189	-	-
Palm kernel	2	21	9
Rice bran	347	-	89
Sesame	-	-	335
Soybean	144	16	870
Sunflower	608	17	11
Walnut	563	-	595
Wheatgerm	1330	71	260

(Source: Anwar and Rashid, 2007; Gunstone, 2002)

Table 11. Content of sterols and sterol esters (mg/100 g) in selected vegetable oils

Oil	Total sterols	Campesterol	Stigmasterol	Sitosterol	Δ5- Avenasterol
Coconut	67	8	13	49	-
Corn	908	200	68	646	10
Cotton	489	33	5	402	19
Mango	99	16	19	46	11
Olive	182	2	-	130	44
Palm	65	14	10	43	3
Palm olein	79	19	10	51	-
Peanut 206	38	22	169	-	
Rapeseed	811	293	-	420	111
Soybean	318	57	58	173	13
Sunflower	399	41	34	265	43
Walnut	139	8	-	136	-

(Source: Verleyen *et al*., 2002; Anwar and Rashid, 2007)

single molecule of tocopherol can protect about 103 to 106 molecules of polyunsaturated fatty acids in the plant and animal cells. This explains why the ratio of tocopherols to polyunsaturated fatty acids in the cells is usually 1:500 to provide sufficient protection against oxidation (Patterson *et al*., 1981). These components are also effective as singlet oxygen quenchers, but they are less potent than carotenoids. A single molecule of tocopherol can react with up to 120 molecules of singlet oxygen (Bowry and Stocker, 1993). The high potency of tocopherols as antioxidants and quenchers of singlet oxygen is based on their ability to be transformed back from the oxidized form into the active structure by other molecules such as ascorbic acid and glutathione (Tapel, 1998).

Table 10 contains results of detailed tocopherols analyses of most of the some vegetable oils. Among readily available oils, palm, mango seed kernel and sunflower (as well as walnut and wheat germ oils) are good sources of vitamin E because of the high level of the α-compound, whereas soybean tocopherols are effective antioxidants by virtue of the high levels of γ and δ-compounds.

Natural tocopherol mixtures are used as antioxidants at levels up to 500 ppm along with ascorbyl palmitate which extends the antioxidant activity. At higher levels (>1000 ppm) α-tocopherol is considered to act as a pro-oxidant. Since vegetable oils contain tocols at 200±800 ppm further additions show only a limited effect. The tocols themselves are very sensitive to oxidation and are more stable in esterified form where the all-important hydroxyl group is not free.

Most vegetable oils contain 1000±5000 mg/kg of sterols. Higher levels are present in rapeseed oil (5±11 g/kg, mean ~7.5) and in corn oil (8±22 g/kg, mean 14). Sitosterol is generally the major phytosterol (50±80 percent of total sterols) with campesterol, stigmasterol and Δ5-avenasterol frequently attaining significant levels. Table 11 contains results of detailed sterol analyses of most of the major oils in their crude state. Total sterols range from 60±910 mg/kg, with palm oil and the two lauric oils being lowest (60±80 mg/kg) and corn, rape and cottonseed oil having the highest levels at 500±900 mg/kg.

The sterols, lipid-soluble components extracted with the triacylglycerols, are not effective as traditional antioxidants; however, some specific sterols have remarkable antipolymerization activity in heated oils. The unsaponifiable fraction that contains sterols was isolated from olive, corn and wheat and found effective at protecting safflower oil from oxidative polymerization during heating at frying temperature (Sims *et al*., 1972). Δ5-Avenasterol and fucosterol reduced polymerization at 180°C in a triacylglycerol mixture similar in composition to olive oil (Gordon and Magos, 1983). The addition of oat-sterol fractions containing G5-avenasterol reduced the deterioration of soybean oil at 180°C. The antipolymerization activity of the effective sterols was shown to reside in the side chain, which contains an ethylidene group (Yan and White, 1990). Thus, retaining some of these effective sterols in processed oil would be desirable for oil quality.

Mango seed kernel extracts enhanced oxidative stability of fresh-type cheese and ghee and extended their shelf life (Parmar and Sharma, 1990; Puravankara *et al*., 2000; Dinesh *et al*., 2000). This could be attributed to the phospholipids and phenolic compounds in mango seed extract that transferred to significant quantities to ghee, suggesting a synergistic action of the two types of compounds. Besides these two major classes of compounds, other factors such as tocopherols and carotenoids may also be involved in the effectiveness of mango seed kernel powder in extending the shelf life of buffalo ghee. Youssef (1999) indicated that adding 1% of crude oil extracted from mango seed kernel exhibited antioxidant potency similar to that of 200 ppm of butylated hydroxytoluene (BHT) against

Table 12. Anti-allergic activity of some Thai crops on antigen-induced degranulation in RBL-2H3 cells

Plant name	Part-used	Yield of extract (w/w)	Anti-allergy activity (% Inhibition at 100 μg/ml)
Banana	peel	0.97	30.45±3.88
Durian	skin	3.19	60.86±1.12
Jackfruit	seed	3.87	93.89±3.90
Jampadah	seed	4.95	82.55±0.83
Mango	seed	9.20	97.10±0.96
Rambutan	seed	3.94	61.79±6.72
Tamarind	seed	2.67	27.28±5.37

(Source: Tewtrakul *et al*., 2008)

oxidation of sunflower oil. The research from Pereira *et al*., (2011) who studied the effects of mango seed extract and butylated hydroxytoluene on physical and chemical properties of Bologna-type mortadella during refrigerated storage for 21 days found that mango seed extract can be used in 0.1 or 0.2% levels in Bologna-type mortadella with similar or better antioxidant effects than those of BHT 0.01%.

It can be concluded that mango seed kernel oil can be use as natural antioxidant in different kind of foods, due to high content of different phenolic compounds, tocopherols, and different sterols. Although the antioxidant properties of natural products have been widely recognized, natural antioxidants are still not widely used due to high costs, color and flavor problems. However, high amounts of antioxidants in the mango kernels has shown that it may be commercially feasible and justified in the near future to perform large-scale extraction of antioxidants from mango kernels. Industries can then both cut costs on transporting waste as well as profiting from unwanted materials.

Cosmetic

The potential use of phenolic compounds for the development of new skin care cosmetics has been emphasized. Phenolic compounds can be used as whitening, sunscreen and anti-wrinkle agents (González, 2008). Melanin is the root cause for darkening of the skin. Its formation beneath the skin proceeds through a free-radical mechanism. UV-radiations facilitate this chain reaction and it could be disrupted by selective use of compounds, potent enough to inhibit this reaction (Choi, 2007). It is well documented that tyrosinase is an essential enzyme, which contributes towards pigment formation in a mammal's body as well as in plants, microorganisms and fungi (Choi, 2007). The use of tyrosinase inhibitors is becoming increasingly important in the cosmetic industry due to their skin-whitening effects.

The mango seed kernel was shown to be a good source of phenolic compounds (Soong and Barlow, 2004) including microelements like selenium, copper and zinc (Schiber *et al*., 2003). In addition, the extract of mango seed kernel exhibited the highest degree of free-radicalscavenging and tyrosinase-inhibition activities compared with methyl gallate and phenolic compounds from the mango seed kernel and methyl gallate in emulsion affected the stability of the cosmetic emulsion systems. It can be concluded that mango seed kernel oil can be use as adding chemicals and ingredients cosmetics and pharmaceuticals.

Antimicrobial compounds

In recent years, there has been a dramatic increase in number of reported poisoning outbreaks caused by food-borne pathogenic bacteria. In 1996, one of the serious outbreaks caused by *Escherichia coli* O157:H7 occurred in Sakai, Japan (National Institute of Infections Diseases and Infectious Diseases Control Division, 1997). Consequently, there has been considerable interest in preventing food contamination by food-borne pathogens. Traditionally, various methods, such as heating, reducing water activity, smoking, fermentation, and adding antimicrobial agents, have been used to prevent spoilage of foods. The addition of antimicrobial agents has been a particularly effective method for controlling microbial contamination. Unlike chemically synthesized antimicrobial agents, those from natural sources are acceptable to consumers. Phenolic compounds, tannins and flavonoids in mango seed are found to be responsible for antimicrobial property. They prevent microorganisms by inhibiting extracellular microbial; growth and by avoiding oxidative phosphorylation (Schiber *et al*., 2003).So mango seed kernel oil is used to kill abdominal worm and also given as a cure for vomiting, diarrhea and hyperacidity (Vatsayan, 2002).

The research from Tewtrakul *et al*. (2008) who used the extractions from Thai crops tested for test anti-allergic effect using RBL-2H3 cells and anti-microbial activity found that some Thai crops may have potential as functional foods and neutraceuticals for the treatment of allergy, allergy-related diseases and some bacterial infections, especially Gram-positive bacteria (Table 12).

Starch

Starch, the principle carbohydrate constituent of most plant materials, merits a detailed investigation to better understand its biochemical and functional characteristics as well as its variations. Extensive research has been conducted on the structure and functional properties of the main starches of commerce, such as wheat, corn, potato, and rice, due to their ready availability and their extensive utilization in food and non-food applications (Singh *et al*., 2003). Starches from different sources vary,

Table 13. Low cost adsorbents and their sorption capacities for the removal of methylene blue from its aqueous solutions

Adsorbent	Sorption capacity	Reference
Pear millet husk carbon	66 mg/g	Inbaraj *et al.*, 2002
Aspergillus niger	15.5 mg/g	Fu and Viraraghavan, 2003
Rice husk	312.25 mg/g	McKay *et al.*, 1999
Coal	323.68 mg/g	McKay *et al.*, 1999
Hair	158.23 mg/g	McKay *et al.*, 1999
Cotton waste	277.77 mg/g	McKay *et al.*, 1999
Bark	914.58 mg/g	McKay *et al.*, 1999
Carbonized press mud	50 mg/g	Kumara and Kumaran, 2005
Bagasse bottom ash	142 mg/g	Kumara and Kumaran, 2005
Mango seed shell	142.85 mg/g	Kumara and Kumaran, 2005
Raw kaolin	27.49 mg/g	Gosh and Bhattacharya, 2002
Pure kaolin	91.87 mg/g	Gosh and Bhattacharya, 2002
Calcined raw kaolin	13.44 mg/g	Gosh and Bhattacharya, 2002
Calcined pure kaolin	56.31 mg/g	Gosh and Bhattacharya, 2002
NaOH treated raw kaolin	204.00 mg/g	Gosh and Bhattacharya, 2002
NaOH treated pure kaolin	122.01 mg/g	Gosh and Bhattacharya, 2002
Guava seeds activated carbon	0.67 mg/g	Rahman and Saad, 2003
Iron humate	0.09 mmol/g	Janos, 2003
Neem saw dust	2.12 mg/g	Khattri and Singh, 2000
Clay	6.3 mg/g	Gurses *et al.*, 2004

particularly in their qualitative and quantitative make up, as well as in some of their physicochemical and functional properties. Identification of native starch sources is required for desired functionality and unique properties (Duxbury, 1989). The physical properties of starch granules have been determined by the fine structure of the polysaccharide and the percentage distributions of amylase and amylopectin (Boyer and Shannon, 1987). Starch granules from different sources have been characterized by size, shape, amount of minor components (such as lipids), and the amylose–amylopectin ratio. The literature contains very little information on isolation and properties of starches from non-conventional sources, such as seeds of fruits.

Mango kernel is rich in carbohydrates, fats, proteins and minerals (Anand and Maini, 1997). The kernel obtained after decortication of mango stone can be utilized as a supplement to wheat flour or for extraction of edible oils (Tandon and Kalra, 1989). Besides its use in animal feed, mango kernel flour can be utilized for edible purposes (Jain, 1961; Patel *et al*., 1971). The research from Maninder Kaura et al. (2004) found that amylose content of mango kernel starches was observed to be lower than those of corn and potato starches. Mango kernel starches showed oval-to elliptical-shaped granules, similar to those of legume starch granules. Transition temperatures of the mango kernel starches were higher than those of corn, rice, wheat and potato. Various properties of mango kernel starches are comparable with the starches from corn, wheat, rice and potato and could be effectively utilized as a starch source.

Activated carbon

The removal of color from dye bearing effluents is one of the major problems due to the difficulty in treating such wastewaters by conventional treatment methods. The most commonly used method for color removal is biological oxidation and chemical precipitation. However, these processes are effective and economic only in the case where the solute concentrations are relatively high. Currently sorption process is proved to be one of the effective and attractive processes for the treatment of these dye-bearing wastewaters. Great number of low cost adsorbents have been tried for dye removal. These include cola nut and Groundnut shells (Itodo and Aminu, 2010; Itodo *et al*., 2010a), palm kennel and sheanut shell (Itodo *et al*., 2009a), bird droppings (Itodo et al., 2009b), bird waste (Itodo *et al*., 2009c) etc. Thermally cracked or active carbons are high porosity, high surface area material manufactured by carbonization and activation of carbonaceous materials which find extensive use in the adsorption of pollutants from gaseous and liquid streams (Itodo and Itodo, 2010). Activated carbon is a carbonaceous material which is amorphous in nature and in which a high degree of porosity is developed by the process of manufacturing and treatment (Itodo, 2011). Its high degree of porosity and surface area makes it the most versatile absorbent to be used for effective removal of organic solid that has extraordinarily large internal surface and pore volumes. These unique pore structures play an important role in many different liquid and gas phase applications (Itodo, 2011). Major properties of activated carbon are dependent on the raw material source (Itodo *et al*., 2010b). Charcoal with high specific surface area and pore volumes can be prepared from a variety of carbonaceous material such as coal, coconut shell, wood, agricultural wastes and industrial wastes. In industrial practices, coal and coconut shell are the two main sources for the production of activated carbon (Itodo *et al*., 2010c). Other materials like lignite, petroleum, coke, saw dust, peat, fruit pits and nut shell may be to manufacture activated carbon but the properties of the finished material are governed not only by the raw material used but also the method of activation used. The source of this raw material was based on the need for developing low cost absorbent for pollution control as well as reducing the effect of environmental degradation poised by agricultural waste.

In the present study mango seed shell, a waste material obtained from mango juice manufacturing industry have been used as adsorbent for the removal of methylene blue from its aqueous solution. Several researchers had proved several low cost materials. The research from Itodo *et al*., (2011) shows that mango seed shell is potentially low cost substrates for generation of activated biosorbent, giving up to 60%

dye removal. Table 13 shows the sorption capacity of mango seed shell to uptake methylene blue). From the Table 13, it was observed that, the sorption capacity of mango seed shell determined from the present study is comparable enough to some of the low cost adsorbents previously reported for the uptake of methylene blue from its aqueous solutions.

Conclusion

Based on the above reviews, it could be concluded that the mango seed could be used as a potential source for functional food ingredients natural antioxidants antimicrobial compounds, cosmetic, activated carbon and, in addition, it could be further processed into therapeutic functional food products. This suggests that the mango seeds should be further utilized rather than just discarded as waste.

Acknowledgements

This work supported from Faculty of Agro Industry, Rajamangala University of Technology Srivijaya,Nakhon Si Thammarat (Thailand).

References

Abdalla, E. M., Darwish, S. M., Ayad, E. H. E. and El-Hamahmy, R. M. 2007. Egyptian mango by-product 1. Compositional quality of mango seed kernel. Food Chemistry 103: 1134–1140.

Amin, I. and Tan, S. H. 2002. Antioxidant activity of selected commercial seaweeds. Malaysian Journal of Nutrition 8(2): 167-177.

Anand, J. C. and Maini, S. B. 1997. Utilisation of fruit and vegetable wastes. Indian Food Packer 51(2): 45-63.

Anwar, F. and Rashid, U. 2007. Physico-chemical characteristics of *moringaoleifera* seeds and seed oil from a wild provenance of Pakistan. Pakistan Journal of Botany 39(5): 1443-1453.

Arogba, S. S. 1999. The performance of processed mango (*Mangifera indica*) kernel flour in a model food system. Bioresource Technology 70: 277-81.

Arogba, S. S. 1997. Physical, chemical and functional properties of Nigerian mango (*Mangifera indica*) kernel and its processed flour. Journal of the Science of Food and Agriculture 73: 321–328.

Beckett, S. T. 2000. The science of chocolate, p. 175. Cambridge: The Royal Society of Chemistry.

Bhalerao, S. D., Mulmuley, G. V. Anathakrishna, S. M. and Potty, V. H. 1989. Wash and waste water management in food industry. Fruit and vegetable processing. Indian Food Packer 43(2): 5-11.

Bowry, V. W. and Stocker, R. 1993. Tocopherol-mediated peroxidation. The prooxidant effect of vitamin E on the radical-initiated oxidation of human low-density lipoprotein. Journal of the American Oil Chemists' Society 115: 6029-6044.

Boyer, C. D. and Shannon, J. C. 1987. Carbohydrates of the kernel. In Watson, S.A. and Ramstad, P.E. (Eds.) Corn: chemistry and technology, p. 253-272. St Paul, Minn., USA: Amer Assn of Cereal Chemists.

Brody, T. 1994. Nutritional Biochemistry, p. 450-459. New York: Academic Press.

Bub, A., Walzl, B., Blockhaus, M., Briviba, K., Lieqibel, U., Muller, H., Pool-Zobel, B. L. and Rechkemmer, G. 2003. Fruit juice consumption modulates antioxidative status, immune status and DNA damage. The Journal of Nutritional Biochemistry 14: 90-98.

Burton, G. W. and Ingold, K. U. 1989. Vitamin E as an in vitro and in vivo antioxidant. Annals of the New York. Acadamic of Sciences 570: 7-22.

Cavaletto, C. G. 1980. Macadamia nuts. In Nagy, S. and Shaw, P. E. Tropical and subtropical fruits, composition, properties and uses, p. 542-559. Westport, Conn.: Avi.

Central Food Technological Research Institute (CFTRI). 1985. Mango pulp concentration, p. 25-39. Mysore, India.

Changso, C. 2008. Study of extraction process, chemical and physic properties of mango seed almond fat CV. Kaew. Bangkok, Thailand: Silpakorn university, MSc thesis (In Thai).

Choi, S. W., Lee, S., Kim, E. O., Oh, J. H., Yoon, K. S. Parris, N. and Moreau, R. A. 2007. Antioxidant and antimelanogenic activities of polyamineconjugates from corn bran and related hydroxycinnamic acids. Journal of Agricultural and Food Chemistry 55: 3920-3925.

Dhingra, S. and Kapoor, A. C. 1985. Nutritive value of mango seed kernel. Journal of the Science of Food and Agriculture 6: 752-756.

Dinesh, P., Boghra, V. R. and Sharma, R. S. 2000. Effect of antioxidant principles isolated from mango (*Mangifera indica* L.) seed kernels on oxidative stability of ghee (butter fat). Journal of Food Science and Technology 37(1): 6-10.

Duxbury, D. D.1989. Modified starch functionalities - no chemicals or enzymes. Food Processing 50: 35-37.

Fallon, S. and Enig, M. G. 2001. Nourishing Traditions. The cookbook that challenges politically correct nutrition and the diet dictocrats, p. 40-45. Washington, DC: NewTrends.

Fowomola, M. A. 2010. Some nutrients and antinutrients contents of mango (*Magnifera indica*) seed. African Journal of Food Science 4(8): 472 – 476.

Fu, Y. and Viraraghavan, T. 2003. Column studies for biosorption of dyes from aqueous solutions on immobilised *Aspergillus niger* fungal biomass. Water SA 29(4): 465–472.

González, S., Fernández-Lorente, M. and Gilaberte-Calzada, Y. 2008. The latest on skin photoprotection. Clinics in Dermatology 26(6): 614–626.

Gordon, M. H. and Magos, P. 1983. The Effect of sterols on the oxidation of edible oils. Food Chemistry 10: 141-147.

Gosh, D. and Bhattacharya, G. 2002. Adsorption of methylene blue on kaolinite. Applied Clay Science 20: 295–300.

Gunstone, F. D. (ed.) 2002. Vegetable Oils in Food Technology, p. 220-237. Oxford: Blackwell Publishing.

Gurses, A., Karaca, S., Dogar, C., Bayrak, R., Cikyildiz, A. and Yalcin, M. 2004. Determination of adsorptive properties of clay/water system: methylene blue sorption. Journal of Colloid and Interface Science 269: 310–314.

Halliwell, B. 1996. Antioxidants in human health and diseases. Annual Review of Nutrition 16: 33-50.

Hemavathy, J., Prabhakar, J. V. and Sen, D. P. 1988. Drying and storage behavior of mango (*Mangifera indica*) seeds and composition of kernel fat. Asean Food Journal 4(2): 59-65.

http://faostst.fao.org on 10/10/2011.

Inbaraj, B. S., Selvarani, K. and Sulochana, N. 2002. Evaluation of a carbonaceous sorbent prepared from Pearl Millet Husk for its removal of basic dyes. Journal of Scientific and Industrial Research 61: 971–978.

Itodo, A. U. 2011. Submitted to the Department of Pure and Applied Chemistry, Usmanu Danfodiyo, Sokoto, PhD thesis.

Itodo, A. U., Abdulrahman, F. W., Hassan, L. G., Abubakar, M. N., Dogonyaro, A. I. and Sirajo, M. 2009c. Activation chemistry and kinetic studies of shea nut shells biosorbent for textile wastewater treatment. Journal of Research in Science Education Information and Communication Technology 1(2): 1-7.

Itodo, A. U., Abdulrahman, F. W., Hassan, L. G., Maigandi, S. A. and Itodo, H. U. 2009b. Gas chromatographic prediction of equilibrium phase atrazine after sorption onto derived activated carbon. International Journal of Poultry Science 8(12):1174-1182.

Itodo, A. U., Abdulrahman, F. W., Hassan, L. G., Maigandi, S. A. and Itodo, H. U. 2010a. Application of GC/MS quantitation in the adsorption of herbicide by sorbents from two abundant nut shells. Researcher 2: 64-73.

Itodo, A. U., Abdulrahman, F. W., Hassan, L. G., Maigandi, S. A. and Itodo, H. U. 2010b. Physicochemical parameters of adsorbents from locally sorted H_3PO_4 and ZnCl2 modified agricultural wastes. New York Science Journal 3: 17-24.

Itodo, A. U. and Aminu, A. S. 2010. GCMS Estimation of the removal of organochlorine andorganophosphorus pesticide from solution: A comparative study. International Journal of Chemical Sciences 2(2): 166-173.

Itodo, A. U., Happiness, U. O., Obaroh, I. O., Usman, A. U., Audu, S. S. and Temkin, R. D. 2009a. Langmuir and Freundlich adsorption isotherms of industrial dye uptake unto H_3PO_4 catalyzed poultry waste bioadsorbent. Journal of Science and Technology Research 8(1): 52-56.

Itodo, A. U. and Itodo, H. U. 2010. Sorbents capacities and intensities of thermochemically cracked shea nut shells for the removal of waste water dyestuff. Academia Arena 2: 41-50.

Itodo, A. U., Itodo, H. U., Atiku, F. A., Koko, R. A. and Kwaido, A. A. 2011. Dyes uptake onto processed and raw mango seed back. Asian Journal of Plant Science and Research 1(1): 57-66.

Itodo, A. U., Itodo, H. U., Gafar, M. K. 2010c. Evaluation of dyestuff removal by shea nut. Journal of Applied Sciences and Environmental Management 14(4): 163-168.

Jain, N. J. 1961. Chemistry and technology of mango. Food Technology 3: 131–133.

Janos, P. 2003. Sorption of basic dyes onto iron humate. Environmental Science and Technology 37: 5792–5798.

John, S. and James, H. M. 2005. Functional foods from fruit and fruit products. In John, S., Chi-Tang, H. and Shahidi, F. Asian Functional Foods, p. 303-340. Florida: CRC Press.

Kamal-Eldin, A. and Appelqvist, L. A. 1996. The chemistry and antioxidant properties of tocopherols and tocotrienols. Lipids 31: 671-701.

Kang, K. R., Cherian, G. and Sim, J. S. 2001. Dietary palm oil alters the lipid stability of polyunsaturated fatty acid-modified poultry products. Poultry Science 80: 228-234.

Kaphueakngam, P., Flood, A. and Sonwai, S. 2009. Production of cocoa butter equivalent from mango seed almond fat and palm oil - mid fraction. Asian Journal of Food and Agro - Industry 2(4): 441-447.

Kaura, M., Singha, N., Singh, K., Harmeet, S. and Gurayab, S. 2004. Physicochemical, morphological, thermal and rheological properties of starches separated from kernels of some Indian mango cultivars (*Mangifera indica* L.). Food Chemistry 85: 131–140.

Khattri, S. D. and Singh, M. K. 2000. Color removal from synthetic dye wastewater using a biosorbent. Water Air and Soil Pollution 120: 283–294.

Kheiri, M. S. A. 1982. Formulation, evaluation and marketing of cocoa butter replacers fat. Palm Oil Research Institute of Malaysia (PORIM). Kuala Lumpur.

Kumara, V. and Kumaran, A. 2005. Removal of methylene blue by mango seed kernel powder. Biochemical Engineering Journal 27: 83–93.

Lee, W. Y., Emmy Hainida, K. I., Abbe Maleyki, M. J. and Amin, I. 2007. Antioxidant capacity and phenolic content of selected commercially available cruciferous vegetables. Malaysian Journal of Nutrition 13(1): 71-80.

Lim, Y. Y., Lim, T. T. and Tee, J. J. 2006. Antioxidant properties of guava fruit: comparison with some local fruits. Sunway Academic Journal 3: 9-20.

Maisuthisakul, P., Suttajit, M. and Pongsawatmanit, R. 2005. Assessment of phenolic content and free radical-scavenging capacity of some Thai indigenous plants. Food Chemistry 100: 1409-1418.

Malik, C. P. and Srivastava, A. K. 1982. Textbook of Plant Physiology, p. 1-20. New Delhi: Ludhiana.

McKay, G., Porter, J. F. and Prasad, G. R. 1999. The removal of basic dyes aqueous solution by adsorption on low-cost materials. Water Air and Soil Pollution

114: 423–438.
National Institute of Infections Diseases and Infectious Diseases Control Division, Ministry of Health and Welfare of Japan. 1997. Verocytotoxin-producing *Escherichia coli* (enterohemorrhagic *E. coli*) infection, Japan, 1996-1997. Infection Agents Surveillance Report. 18: 153-154.
Nzikou, J. M., Kimbonguila, A., Matos, L., Loumouamou, B., Pambou-Tobi, N. P. G., Ndangui, C. B., Abena, A. A., Silou, Th., Scher, J. and Desobry, S. 2010. Extraction and characteristics of seed kernel oil from mango (*Mangifera indica*). Research Journal of Environmental and Earth Sciences 2(1): 31-35.
Om El-Saad El-Gammal. 2011. Chemical and technological studies on mango seed kernels for enhancing the organoliptic and keeping quality of one bakery products. 15: 489-504. Downloaded from *http://app6.mans.edu.eg/mus/Future/libraries/LibCataloging/UploadDownloadFile.py?item_id=1039758.&filename=14.pdf&tablename=issuesarticals* on 30/10/2011.
Palaniswamy, K. P., Muthukrishna, C. R. and Shanmugavelu, K. G. 1974. Physicochemical characteristics of some varieties of mango. Indian Food Packer 28(5): 12-18.
Parmar, S. S. and Sharma, R. S. 1990. Effect of mango (*Mangifera indica* L.) seed kernel pre-extract on the oxidative stability of ghee. Food Chemistry 35(2): 99-107.
Patel, B. M., Shukla, P. C. and Patel, C. A. 1971. Nutritive value of mango seed kernels. Food Farm Agriculture 3: 19-20.
Patterson, L. K., Rodgers, M. A. J. and Powers, E. L. 1981. Oxygen and oxy-radicals in chemistry and biology, p. 89-109. New York: Academic Press.
Pease, J. J. 1985. Confectionery fats from palm oil and lauric oil. Journal of the American Oil Chemists' Society 62(2): 426-430.
Pereira, A. L. F., Vidal, T. F., Teixeira, M. C., Oliveira, P. F., Pompeu, R. F., Vieira, M. M. and Zapata J. F. 2011. Antioxidant effect of mango seed extract and butylated hydroxytoluene in bologna-type mortadella during storage. Cienc. Tecno. Aliment., Campinas 31(1): 135-140.
Puravankara, D., Bohgra, V. and Sharma, R. S. 2000. Effect of antioxidant principles isolated from mango (*Mangifera indica* L.) seed kernels on oxidative stability of buffalo ghee (butter-fat). Journal of the Science of Food and Agriculture 80(4): 522-526.
Rahman, I. A. and Saad, B. 2003. Utilization of guava seeds as a source of activated carbon for removal of methylene blue from aqueous solution. Malaysian Journal of Chemistry 5: 8-14.
Ramteke, R. S. and Eipeson, W. E. 1997. Effect of additives on the stability of mango aroma concerntrate during storage. Journal of Food Science and Technology 34(3): 195-199.
Scalbert, A. 1991. Antimicrobial propertied of tannins. Phytochemistry 30: 3875-3883.
Schiber, A., Berardini, N. and Carle, R. 2003. Identification of flavonol and xanthol glycosides from mango peels by HPLC. Journal of Agricultural and Food Chemistry 51: 5006-5011.
Sims, R. J., Fioriti, J. A. and M. J. Kanuk. 1972. Sterol additives as polymerization inhibitors for frying oils. Journal of the American Oil Chemists' Society 49: 298-301.
Singh, N., Singh, J., Kaur, L., Sodhi, N. S. and Gill, B. S. 2003. Review: Morphological, thermal and rheological properties of starches from different botanical sources. Food Chemistry 81: 219-231.
Soong, Y. and Barlow, P. J. 2004. Antioxidant activity and phenolic content of selected fruit seeds. Food Chemistry 88(3): 411-417.
Solis-Fuentes, J. A. and Duran-de-Bazua, M. C. 2004. Mango seed used: thermal behavior of mango seed almond fat and its mixtures with cocoa butter. Bioresource Technology 92(1): 71-78.
Soong, Y. Y. and Barlow, P. J. 2006. Quantification of gallic acid and ellagic acid from longan (*Dimocarpus longan* Lour.) seed and mango (*Mangifera indica* L.) kernel and their effects on antioxidant activity. Food Chemistry 97(3): 524-530.
Steinberg, D., Parthasarathy, S., Carew, T. E., Khoo, J. C. and Witztum, J. L. 1989. Beyond cholestrol: modification of low density lipoprotein that increase its atherogenicity. The New England Journal of Medicine 320: 915-924.
Tachakittirungrod, S., Okonogi, S. and Chowwanapoonpohn, S. 2006. Study on antioxidant activity of certain plants in Thailand: mechanism of antioxidant action of guava leaf extracts. Food Chemistry 103: 381-388.
Tandon, D. K. and Kalra, S. K. 1989. Utilisation of mango waste. Beverage and Food World 16(1): 21-22.
Tang, S., Kerry, J. P., Sheehan, D., Buckley, D. J. and Morrissey, P. A. 2001. Antioxidative effect of added tea catechins on susceptibility of cooked red meat, poultry and fish patties to lipid oxidation. Food Research International 34: 651-657.
Tapel, A. L. 1968. Vitamin E and free redical peroxidation of lipids, Annals of the New York. Acadamic of Sciences 203: 12-28.
Tewtrakul, S., Itharat, A., Thammaratwasik, P. and Ooraikul, B. 2008. Anti-allergic and anti-microbial activities of some Thai crops. Short communication. Songklanakarin Journal of Science and Technology 30(4): 467-473.
Vatsayan, R. 2002. Medicinal Plants. In Hari, J. Mango, the fruit medicine, p.52-59. Chandigarh, India: The Tribune House.
Verleyen, T., Forcades, M., Vehre, R., Dewetlinck, K., Huyghebaert, A. and De Greyt, W. 2002. Analysis of free and esterified sterols and vegetable oils. Journal of American Oil Chemical' Society 79: 112-122.
Wanasundara, U. N. and Shahidi, F. 1998. Antioxidant and pro-oxidant activity of green tea extracts in marine oils. Food Chemistry 63: 335-342.
White, P. J. and Armstrong, L .S. 1986. Effect of selected oat sterols on the deterioration of heated soybean oil. Journal of the American Oil Chemists' Society 63: 525-529.

World Health Organization. Energy and Protein Requirment. 1985. Report of a Joint FAO/WHO/UNU Expert Consultation. Geneva: World Health Organization.

Yan, P. S. and White, P. J. 1990. Linalyl acetate and other compounds with an ethylidene group as antioxidants in heated soybean oil. Journal of Agricultural and Food Chemistry 38: 1904-1908.

Youssef, A. M. M. 1999. Utilization of the seed of mango processing wastes as a secondary source of oil and protein. Alexandria Journal of Agricultural Research 44(3): 149–166.

Zandi, P. and Gondon, M. H. 1999. Antioxidant activity of extracts from old tea leaves. Food Chemistry 64: 285-288.