The multiple nutrition properties of some exotic fruits: Biological activity and active metabolites

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1. Introduction

The major source of biologically active substances, such as vitamins and secondary metabolites (polyphenols, carotenoids, sterols, glucosinolates, and saponins) is present in herbs, fruits and vegetables (Alothman, Bhat, & Karim, 2009; Cassileth, 2008; Xu et al., 2004; Yang, Paulino, Janke-Stedronska, & Abawi, 2007; Yuka, Yumiko, Miyo, & Takashi, 2003). The consumption of fruits and vegetables is globally insufficient and should be encouraged, and it may be useful to enhance fruit concentrations of vitamins and secondary metabolites by genetic and/or environmental approaches (Poiroux-Gonord et al., 2010). It has been shown that individuals who eat daily five servings or more of fruits and vegetables have approximately half the risk of developing a wide variety of cancer types, particularly those of the gastrointestinal tract (Gescher, Pastorino, Plummer, & Manson, 1998). The collected data (Burton-Freeman, 2010) suggest that consuming phenolic-rich fruits increase the antioxidant capacity of the blood. When the fruits are consumed with high fat and carbohydrate prooxidant and pro-inflammatory meals, they may counterbalance their negative effects. It was reported that one of the important predisposing mechanisms in the development of atherosclerosis is oxidation of the cholesterol-rich LDL-C particles (Aviram, 1993; Steinberg, Parthasarathy, Carew, Khoo, & Witztum, 1989; Witztum & Steinberg, 1991). The oxidation of LDL-C particles facilitates penetration of lipids into the arterial wall, causing the occlusion of arteries in general and coronary arteries in particular. It is now known that nutritional antioxidants in general, especially phenolic substances, can prevent lipid peroxidation. It was shown that a low level of plasma antioxidants leads to a high mortality from coronary atherosclerosis (Rankin et al., 1993). Therefore, some authors propose diets rich in vegetables and fruits, which are the natural source of antioxidants (Lorgier et al., 1994). There is evidence that fruits and vegetables are playing a beneficial role in prevention and even treatment of different diseases (Kris-Etherton et al., 2002; Lim, Lim, & Tee, 2007; Luximon-Ramma, Bahourun, & Crozier, 2003; Paganga, Miller, & Rice-Evans, 1999; Proteggente et al., 2002). Some studies have shown that dietary fiber and polyphenols of fruits improve lipid metabolism and prevent the oxidation of low density lipoprotein cholesterol (LDL-C), which hinder the development of atherosclerosis (Gorinstein, Bartnikowska, Kulasek, Zemser, & Trantkenberg, 1998; Gorinstein, Kulasek, et al., 1998; Gorinstein, Zemser, Haruenkit, et al., 1999; Gorinstein, Zemser, Vargas-Albores, et al., 1999). Indeed, recent experiments on rats fed diets supplemented with persimmon show that this fruit exercises a marked antioxidant effect that is most likely due to a relatively high content of polyphenols (Gorinstein et al., 2010). Some studies have shown the effect of various phenols such as gallic acid, myricetin, flavan-3-ols (1)-catechin and (2)-epicatechin, and others as antioxidants. Gallic acid occurs naturally in plants and has been found to be pharmacologically active as an antioxidant, antimutagenic, and anticarcinogenic agent. It is an established fact that supplementation of diet with fruits and vegetables prevents atherosclerosis and other diseases (Duttaroy & Jorgensen, 2004). It was shown that consumption of kiwifruit lowered blood triglyceride levels by 15% compared with control. The authors reported that consuming two or three kiwifruit per day for 28 days reduced platelet aggregation response to collagen (Duttaroy & Jorgensen, 2004). It was demonstrated that consumption of certain berries and fruits such as blueberries, mixed grape and kiwifruit, was associated with increased plasma hydrophilic (H-) or lipophilic (L-) antioxidant capacity (AOC) measured as Oxygen Radical Absorbance Capacity (ORAC). AOC in the postprandial state and consumption of an energy source of macronutrients containing no antioxidants was associated with a decline in plasma AOC. Previous studies (Chidambaram, Kotamballi, Jayaprakash, & Patil, 2010) have demonstrated that δ-limonene inhibits cancer cells (pulmonary, colon and breast) based on cell culture and animal studies. δ-Limonene, a major monoterpene found in citrus, represents for 40–90% of volatile components (Chidambaram et al., 2010). Fruit flavor is important for human health and well-being. Many fruits, including citrus, berries, mangosteen, pomegranate, have attracted much attention of their health benefits due to the wide range of bioactivities (Chen & Wang, 2008). The antioxidant, anti-inflammatory, anticancer and antimalarial activities are connected with phytochemicals, such as anthocyanins, flavonoids, polyphenolics, and vitamins. Similar biological activities of the essential oils in fruit seeds, flesh and peels have not been paid enough attention compared with those of non-volatile chemicals. The chemical compounds and metabolites of fruit flavors, as well as their bioactivities and bioavailabilities in relation to their potential impact on human health and diseases have to be studied. In recent years some pharmacological activities such as anti-tyrosinase, anti-glycated and anticancer activities, and memory-enhancing effects of longan aril, pericarp or seed extract have been found, implicating a significant contribution to human health (Yang, Jiang, Shi, Chen, & Ashraf, 2011-this issue). The synergetic effect, which could exist between individual bioactive compounds, means that the antioxidant capacity may be higher than their sum (Poeggeler et al., 1995), and not only individual bioactive compounds, but also the overall antioxidant capacity have to be determined in fruits. Some antioxidant assays give different antioxidant activity trends (Ou, Huang, Hampsch-Woodill, Flanagan, & Deemer, 2002). Total phenolics, flavonoids and flavanols
of natural products and related to these compounds antioxidant activity have a health protective effect (Andreasen, Christensen, Meyer, & Hansen, 2000; Leontowicz, Leontowicz, Drzewiecki, Jastrzebski, et al., 2007; Lim et al., 2007; Shui & Leong, 2005; Yang et al., 2007; Zadernowski, Czaplicki, & Nacz, 2009). Exotic fruits play exactly the same role in the prevention of atherosclerosis, therefore a detailed description has to be paid to this kind of fruits. Tropical fruit crops are common in the geographical zone stretching from 30 south latitude with up to 30 north latitude. Temperature conditions in this area differ (the average in year 25 °C, while the oscillations are observed from 16 to 36 °C). In the tropics, the maximum number of cultivated plant families: here are grown not only plants that are in the culture of temperate and subtropical zones, but also endemic to many families. In tropical countries, fruits play a major role in human life. Bananas, breadfruit and papaya trees, nuts, coconut and fruit of date palms are among the basic food of the population in the tropics. A large number of exotic fruits can be seen in Malaysia throughout the year (Althoman et al., 2009; Ikram et al., 2009). Among the variety of fruits that can be distinguished are papaya, rambutan, guava, chiku, coconut, durian, pineapple, mango, watermelon, duku, mangosteen, bananas, pomelo, jumbo sweet flag and cannon. Lorenzi, Bacher, Lacerda, and Sartori (2006) described 827 tropical fruits, including 389 species and 438 fruits and showed high DPPH radical-scavenging activity (Ishiwata, Talcott, Percival, Pittet-Moore, & Celoria, 2003; Wu et al., 2005; Yuka Martinez-Tome, 2001; Nilsson et al., 2005; Proteggente et al., 2002; Kanlayanarat, 2005; Luximon-Ramma et al., 2003). The homeland of açaí (Euterpe oleracea, acaízeiro) is northern Brazil and the most abundant palm açaí grows in the Brazilian state of Pará. Açaí fruit has an unusual taste, which is reminiscent of the taste of raspberries and blackberries with a touch of walnut, and especially rich in iron, vitamins B1 and E. The outside skin is of a similar texture like blueberry, smooth on the exterior to the touch, showing the same size, shape, and color. The inside of the açaí berry is soft and is easily formed into a pulp, which is one of the preferred forms of this fruit. It

### Table 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>Brassicasterol</th>
<th>Campesterol</th>
<th>Stigmasterol</th>
<th>δ-Sitosterol + siostanol</th>
<th>Δ5-Avenasterol + Δ7-stigmasterol</th>
<th>Δ7-Avenasterol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil nut</td>
<td>1.5</td>
<td>4.0</td>
<td>11.3</td>
<td>79.4</td>
<td>6.8</td>
<td>ND</td>
</tr>
<tr>
<td>Cota nut</td>
<td>ND</td>
<td>5.0</td>
<td>25.0</td>
<td>50.0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Mucaja nut</td>
<td>10.0</td>
<td>25.0</td>
<td>5.3</td>
<td>130.0</td>
<td>42.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Mucaja pulp</td>
<td>3.0</td>
<td>21.0</td>
<td>12.0</td>
<td>64.3</td>
<td>20.3</td>
<td>ND</td>
</tr>
<tr>
<td>Red açaí pulp</td>
<td>ND</td>
<td>5.0</td>
<td>12.0</td>
<td>94.0</td>
<td>18.0</td>
<td>ND</td>
</tr>
<tr>
<td>Inajá pulp</td>
<td>3.5</td>
<td>23.5</td>
<td>7.5</td>
<td>79.5</td>
<td>27.5</td>
<td>ND</td>
</tr>
<tr>
<td>Jenipapo pulp</td>
<td>ND</td>
<td>1.0</td>
<td>8.0</td>
<td>150.0</td>
<td>21.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Jenipapo pulp</td>
<td>ND</td>
<td>ND</td>
<td>74.0</td>
<td>123.0</td>
<td>33.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Buriti pulp</td>
<td>2.5</td>
<td>16.0</td>
<td>38.5</td>
<td>154.3</td>
<td>35.4</td>
<td>ND</td>
</tr>
<tr>
<td>Buriti pulp</td>
<td>ND</td>
<td>8.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.0</td>
<td>ND</td>
</tr>
<tr>
<td>UXI pulp</td>
<td>19.0</td>
<td>8.0</td>
<td>12.0</td>
<td>88.0</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

*a The values are expressed as mean ± standard deviation (n = 9).

*b ND = not detected.

### Table 2

<table>
<thead>
<tr>
<th>Sample</th>
<th>α-Tocopherol</th>
<th>γ-Tocopherol</th>
<th>δ-Tocopherol</th>
<th>Total tocopherol</th>
<th>α-TE*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil nut</td>
<td>72.5</td>
<td>74.3</td>
<td>5.9</td>
<td>152.8</td>
<td>80.2</td>
</tr>
<tr>
<td>Red açaí pulp</td>
<td>147.7</td>
<td>ND</td>
<td>ND</td>
<td>147.7</td>
<td>147.7</td>
</tr>
<tr>
<td>Inajá pulp</td>
<td>114.8</td>
<td>50.9</td>
<td>ND</td>
<td>165.8</td>
<td>117.4</td>
</tr>
<tr>
<td>Buriti pulp</td>
<td>252.2</td>
<td>878.4</td>
<td>224.2</td>
<td>1129.8</td>
<td>346.7</td>
</tr>
<tr>
<td>Buriti pulp</td>
<td>ND</td>
<td>616.9</td>
<td>378.8</td>
<td>995.7</td>
<td>73.3</td>
</tr>
<tr>
<td>UXI pulp</td>
<td>167.2</td>
<td>337.5</td>
<td>ND</td>
<td>504.7</td>
<td>200.9</td>
</tr>
</tbody>
</table>

*a Values expressed as mean ± standard deviation (n = 9).

*b α-TE = α-tocopherol equivalents.

*c ND = not detected.
is also considered quite useful as a freeze-dried powder. Processing of fruit and wood of acai is fundamental to the industry in the region (Lorenzi et al., 2006). Palm red varieties are more common than white. The availability of acai berries in Brazil is between July and December. In the studied species, which were from the North and Northeast regions of Brazil (Red acai (E. oleracea M.), Cotia nut (Aptandrospruceana M.), Brazil nut (Bertholletia excelsa H.B.K.), Mucaja (Coumarigida M.), Inaja (Maximiliana maria D.), Jenipapo (Genipa americana L.), Buriti (Mauritia flexuosa L.) and Uxi (Endopleurauchi C.),) phytosterol and tocopherol contents were reported. The pulps of Mucaja (26–236), Inaja (119–285) and Jenipapo (216) showed the highest total phytosterol contents (mg/100 g). Considering α-tocopherol equivalent, the pulps of Buriti (346.72 μg/g) and Uxi (200.92 μg/g) contained the highest vitamin E activity. The results indicated that these fruits and nuts have high potential to be cultivated and marketed as alternative dietary sources for these bioactive compounds (Costa, Ballus, Teixeira-Filho, & Godoy, 2010). All the samples contain β-sitosterol + sitostanol as the major phytosterols (Table 1), mostly in the case of Mucaja, Jenipapo and Buriti pulps. The phytosterol, which was detected in the lowest concentrations, was Δ7-avenasterol. Among the fruits and nuts assayed, Buriti pulp showed (Table 2) the highest content of α-tocopherol (252.15 μg/g), followed by Uxi pulp (167.17 μg/g). These results suggested that Buriti and Uxi can be considered for vitamin E sources. Obtained study confirms the presence of cyanidin 3-glucoside and cyanidin 3,5-torisides as major anthocyanic compounds. Four main compounds were also identified for the first time, i.e. homoorientin, orientin, taxifolin deoxyhexose, and isovitexin. Traces of methyl-derivatives of homo-orientin were also detected (Gallori, Bilia, Bergonzi, Barbosa, & Vincieri, 2004). Anthocyanin and polyphenolic compounds present in acai (E. oleracea Mart.) were determined and their respective contribution to the overall antioxidant capacity established. Cyanidin 3-glucoside (1040 μmol/L) was the predominant anthocyanin in acai and correlated to antioxidant content, while 16 other polyphenolics were detected from 12 to 636 mg/kg. Acai was recognized for its functional properties for use in food and nutraceutical products (Del Pozo-Infran, Brenes, & Talcott, 2004). Acai fruit (E. oleracea Mart.) has been demonstrated to exhibit extremely high antioxidant capacity. Seven major flavonoids were isolated from freeze-dried acai pulp. Their structures (Fig. 1) were elucidated as orientin, homo-orientin, vitexin, luteolin, chrysoeriol, quercetin, and dihydrokaempferol. Compounds vitexin and quercetin were reported from acai pulp for the first time (Kang et al., 2010). Antioxidant capacities of these flavonoids were evaluated by Oxygen Radical Absorbance Capacity (ORAC) assay, cell-based antioxidant protection (CAP-e) assay and reactive oxygen species (ROS) formation in polymorphonuclear (PMN) cells (ROS PMN assay). ORAC values varied distinctly (1420–14,800 μmol TE/g) among the seven compounds based on numbers and positions of hydroxyl groups and/or other substitute groups. The ORAC values of aglycones are generally higher than that of glycosides. CAP-e results indicated (Fig. 1) that only three compounds (luteolin, quercetin, and dihydrokaempferol) could enter the cytosol and contribute to the reduction of oxidative damage within the cell. The ROS PMN assay showed that five compounds (homo-orientin, vitexin, chrysoeriol, quercetin, and dihydrokaempferol) demonstrated exceptional effects by reducing ROS formation in PMN cells, which produced high amounts of ROS under oxidative stress. In evaluating the antioxidant capacity of natural products, combining both chemical and cell-based assays will provide more comprehensive understanding of antioxidant effects and potential biological relevance (Kang et al., 2010). Absorption experiments (Pacheco-Palencia, Talcott, Safe, & Mertens-Talcott, 2008), using a Caco-2 intestinal cell monolayer demonstrated that phenolic acids such as p-hydroxybenzoic, vanillic, syringic, and ferulic acids, in the presence of DMSO, were readily transported from the apical to the basolateral side along with monomeric flavanols such as (+)-catechin and (−)-epicatechin. Results from this study provide further evidence for the bioactive properties of acai polyphenolics and offer new insight on their composition and cellular absorption. Acai improves (Sun, Jiang, et al., 2010; Sun, Seeberger, et al., 2010) survival of flies fed a high fat diet through activation of stress response pathways and suppression of Penk expression. Acai has the potential to antagonize the detrimental effect of fat in the diet and alleviate oxidative stress in aging.

2.2. Acerola

Acerola (Malpighia puncticfolia Linn.) or Barbados Cherry, West Indian Cherry, Cereza, Cerisier, Semeruco, aceroleira, cereja-das-antilhas, cereja-de-bárbaros, is originated from the Yucatan and is distributed from South Texas, through Mexico (especially on the West Coast from Sonora to Guerrero) and Central America to northern South America (Venezuela, Surinam, and Colombia) and throughout the Caribbean (Bahamas to Trinidad). Currently, the most extensive plantations of acerola are in South America, India and Brazil (De Assis et al., 2009; Lorenzi et al., 2006). The fruit is round to oblong in shape, with a diameter between 1 to 2 cm and 20 g of weight. The thick texture of the acerola is juicy and soft, it has thin bright red edible skin, a very sweet taste and a pleasant tart apple like flavor, when fully ripe. It has a clear pale yellow color. The availability of the fruit is in the period of May–November. Acerola is one of the fruits which contains mainly natural vitamin C sources. Acerola contains a large number of pro-vitamin A, vitamins B1 and B2, niacin, albumin, iron, phosphorus and calcium, rich in vitamin C. The vitamin C in acerola exceeds 30–100 times the vitamin.
C in oranges (one cherry contains double the allowance intake of vitamin C). The fruit is used in jellies, jams, and can be frozen without losing its vitamin C content. 100 g of acerola with a low percentage of water (9.4%) has high calorie contents (332 kcal) due to 3.2 g lipids, 16.94 g protein and 57.24 g carbohydrates in 100 g FW. Acerola contains a high content of crude fiber (26.5%), ash (0.4%), ascorbic acid (66 mg/g FW) and minerals (mg/100 g FW) such as iron (37), calcium (41), potassium (41), magnesium (22), zinc (0.09), manganese (0.7), phosphorus (0.08) and copper (0.15 μg/100 g FW). Such nutritional macro- and micro-component values make acerola one of the most important fruits for human consumption (Rufino et al., 2010). The reported results (Rufino et al., 2010; Sampaio et al., 2009) show the considerable antioxidant capacity by the DPPH, ABTS and FRAP methods found for acerola, vitamin C, anthocyanins, yellow flavonoids, total carotenoids, and total extractable polyphenols. Its lipid fraction has the following fatty acids: oleic (31.9%), linoleic (29.2%), palmitic (21.8%), stearic (13.9%) and linolenic (1.3%) (Medeiros De Aguiar, Rodrigues, Ribeiro Dos Santos, & Sabaa-Srur, 2010). Two acerola genotypes which were harvested from a Brazilian plantation during the 2003 and 2004 summer harvests presented the major carotenoids (μg/100 g FW): β-carotene (265–1669), lutein (37–100), β-cryptoxanthin (16–56) and α-carotene (7.8–59). In both harvests, the β-carotene, β-cryptoxanthin and α-carotene levels were higher in the Olivier genotype, whereas the lutein content was higher in the Waldy Cati 30 genotype (De Rosso & Mercadante, 2005). Anthocyanin aglycons and other phenolic compounds were identified in acerola (M. punicea, L.). Anthocyanins, flavonoids, and flavonoids were fractionated and characterized. The total content of anthocyanin pigments was 37 mg/100 g of ripe acerola skin. The identified phenolic pigments were pelargonidin, malvidin-3,5-diglycoside and cyanidin 3-glycoside (Fig. 2). Quercetin, kaempferol and the phenolic acids (p-coumaric, ferulic, caffeic and chlorogenic) were also identified (Vendramini & Trugo, 2000; Vendramini & Trugo, 2004). Five different polyphenolic compounds were identified in the samples by HPLC and diode-array detection: chlorogenic acid, (1)–epigallocatechin gallate, (1)–epicatechin, procyanidin B1 and rutin, being the two last predominant. Three soluble polyphenolic fractions (phenolic acids, anthocyanins and flavonoids) were separated from the different sample extracts, and their respective antioxidant activities calculated. Among them, phenolic acids are the main contributors to the antioxidant activity (Mezadri, Villaño, Fernandez-Pachán, García-Parrilla, & Troncoso, 2008). The 31 compounds in the mature (red) fruits, such as as acetyl Me carbinol, 2-methylpropyl acetate, limonene, E or Z-octenal, Et hexanoate, isoprenyl butyrate and acetoephone; 25 — in the intermediate (yellow), such as, Me hexanoate, 3-octen-1-ol and hexyl butyrate, and 14 — in the immature green fruit, such as Me Pr ketone, E or Z-hexenyl acetate and 1-octadecanol were identified in acerola fruit. Volatiles of acerola were characterized by GC/MS. 3-Methyl-3-buten-1-ol was identified as the major constituent. Organoleptic properties of its esters are also documented (Schippa, George, & Fellous, 1993).

2.3. Avocado

Avocado, or Perseus American (P. americana Mill.) is a kind of evergreen fruit plants of the genus Perseus family, the type species of this genus, and an important fruit crops. The pear-shaped, egg-shaped or spherical fruit is 7–20 cm long, with a weight from 100 to 1000 g and has a large central seed (5–6.4 cm long). The non-processed avocado does not have a specific taste. In the world there are about 500 varieties of avocados, which differ in the fruit shape and color. Flavor selection is hardly affected, and, of course, avocados retain their useful properties. The availability of the fruit is May–February according to variety. In Mexico one of the most common and easy-care varieties of avocado Hass cultivar is harvested all year. The pulp contains about 30% of fat, protein, calcium, iron, a large number of easily digestible fats, mineral salts, vitamins E, B1, B2, and D. Avocado has a positive influence on short-term memory and reduces the risk of cardiovascular disease. Avocado is rich in serotonin 5-hydroxytryptamine (5-HT) which is a monoamine neurotransmitter (Fig. 3). Other fruits and nuts have also a high concentration of serotonin (μg/g wt) such as pineapple 17.0; banana 15.0; kiwifruit 5.8; plums 4.7; and tomatoes 3.2. Urinary excretion of 5-hydroxyindoleacetic acid was measured in 129 healthy subjects, 69 were on a free diet and 60 on a diet lacking the above foods. The average excretion of serotonin was 3.49 mg/24 h for control group, with a range of 1.10–7.92 mg/24 h, and the serotonin-poor group was 1.67 mg/24 h, with a range of 0.72–3.12 mg/24 h. Ingestion of these fruits resulted in an increase in urinary 5-hydroxyindoleacetic acid excretion with no change in platelet serotonin concentration (Feldman & Lee, 1985). Tryptophan is an essential amino acid and metabolic precursor of serotonin. Serotonin is both a classical neurotransmitter and a signaling molecule that plays crucial roles in the development of neural circuits and plasticity (Serfaty, Oliveira-Silva, Faria Melibeú, & Campello-Costa, 2008). Twenty-four minerals were quantified by inductively coupled plasma optical emission spectrometric analysis for avocado honey samples. The elements Al, Ba, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, P, Pb, Se, Si, Zn were detected in all samples (Tarrab, Recamales, Gonzalez-Miret, & Heredia, 2005), seven elements were very abundant (Ca, K, Mg, Na, P, S and Si), five were not abundant (Al, Cu, Fe, Li and Zn) and 12 were trace elements (As, Ba, Cd, Co, Cr, Mo, Ni, Mo, Pb, Se, Sr and V). Avocado is a good source of bioactive compounds such as monounsaturated fatty acids and sterols. The main fatty acid identified and quantified in avocado was oleic acid (about 57% of total content), and linoleic, palmitoleic, cis-vaccenic, and γ-linolenic acids; β-sitosterol was found to be the major sterol.
Volatile compounds of two cultivars of avocado fruits (California and Haas) were isolated by simultaneous steam distillation and solvent extraction. Both cultivars had 227 and 289 μg/kg of total volatile compounds, respectively. Major components were (E)- and (Z)-β-ocimene (16%) and valencene (16%) were the most abundant compounds in the oil. Other quantitatively significant constituents (Ogunbinu, Ogunwande, Flamini, & Cioni, 2007) were germacrene D (6%), α-humulene (5%) and δ-cadinene (5%).

Volatile components of two cultivars of avocado fruits (California and Haas) were isolated by simultaneous steam distillation and solvent extraction. Both cultivars had 227 and 289 μg/kg of total volatile compounds, respectively. Major components were (E)-nerolidol, with lesser amounts of β-caryophyllene, β-pinene, trans-α-bergamotene and β-bisabolene (Pino, Rosado, & Aguero, 2000). Hydrocarbons (mainly sesquiterpenes) and alkanals were the predominant constituents present. In the immediate extraction of the avocado mesocarp, β-caryophyllene (60%) was the main sesquiterpene, followed by α-humulene (5.9%), caryophyllene oxide (4.8%), α-copaene (4.5%) and α-cubebene as the main hydrocarbons; alkanals were present, but only in low concentrations. The β-caryophyllene (29%) was the main sesquiterpene, followed by α-copaene (11%), a cadinenne isomer (8.5%), α- and β-cubebene (7.7%), α-larnesene (5.3%) and octane (4.8%) as principal hydrocarbons; decanal (6.3%) and heptenal (3.2%) were the main aldehydes (Sinyinda & Gramshaw, 1998). The n-alkane composition of avocado pulp oil (cv. Hass) was investigated during fruit ripening. Fourteen compounds were detected ranging from n-C21 to n-C34; mainly n-C24, followed by n-C25 and then by n-C23. Quantities of n-C21, n-C22, n-C23, n-C27 and n-C28 progressively increased during ripening, whereas n-C24, n-C25, n-C26, n-C29, n-C30 and n-C34 decreased from the first harvest date to the third harvest date. While odd-numbered carbon n-alkanes increased (52.38%, 52.85% and 53.06% for the three samples, respectively), even-numbered carbon n-alkanes decreased as the fruit ripened (47.62%, 47.15% and 46.94%). The total n-alkane content (Giuffre, 2005) decreased during ripening, from 25.20 mg/kg (first harvest date) to 17 mg/kg (third harvest date). As it was described (Bezahib, Pellikaan, Tolerá, & Hendriks, 2011), n-alkanes can be used as diet composition markers. The major bioactive compounds and antioxidant potential of avocado were studied and compared with durian and mango (Elez-Martinez et al., 2005; Gorinstein, Leonowicz, et al., 2011; Poovarodom et al., 2010) and was reported for this purpose HPLC, three-dimensional fluorescence (3D-FL), several radical scavenging assays and multivariate factor analysis were used. In durian, mango and avocado the following major nutritional components were observed: total fiber (g/100 g FW), 3.2 ± 0.3, 2.9 ± 0.2 and 6.2 ± 0.5; total proteins, 1.4 ± 0.1, 0.8 ± 0.06 and 1.9 ± 0.2; total fats, 5.3 ± 0.4, 0.4 ± 0.03 and 21.2 ± 1.3; carbohydrates, 27.1 ± 1.6, 28.2 ± 1.6 and 8.3 ± 0.6. It was reported that the contents of total fiber, proteins and fats were significantly higher (p < 0.05) in avocado than in the other two fruits. It was found a similarity in acetone extracts between durian and mango in the contents of polyphenols (1.66 ± 0.08, 1.48 ± 0.05, mg GAEE/g DW, respectively), and in some antioxidant assays such as ABTS (11.98 ± 0.5, 12.24 ± 0.5, μM TE g⁻¹ DW, respectively) and DPPH (5.61 ± 0.3, 5.22 ± 0.2, μM TE g⁻¹ DW, respectively). Durian and avocado were similar in the contents of polyphenols, ABTS and DPPH values in water and in methanol extracts. The nutritional and bioactive properties of avocado are comparable with those indices in mango and durian. In order to obtain the best results, a combination of these fruits has to be included in diets as was shown by Gorinstein et al. (2011-this issue) and Poovarodom et al. (2010).

2.4. Dragon fruit

Dragon fruit (Hylocereus sp) or red pitaya (or pitahaya), is the fruit of the cactus species Hylocereus undatus. The plant is named Queen of the Night, Moonflower and/or Lady of the Night, because the large flowers only bloom at night time. The skin of the dragon fruit is a thin rind and usually covered in scales, and the center of the fruit is made up of a red or white, sweet tasting pulp which remembers kiwifruit. The flesh is mildly sweet. Because of its exotic and impressive appearance, this fruit enjoys growing popularity in Europe and the United States. The fruit is also converted into juice or used to flavor other beverages. The availability of the fruit is April–May and September–November, but year round according to variety. This exotic fruit is native to Mexico and Central and South America and is also cultivated in Southeast Asian countries. H. undatus and Hylocereus polyrhizus are two varieties of the commonly called pitaya fruits. Essential fatty acids, namely, linoleic acid and linolenic acid form a significant percentage of the unsaturated fatty acids of the seed oil extract. Both pitaya varieties exhibit two oleic acid isomers. Both pitaya varieties (Ariffin et al., 2009) contain about 50% essential fatty acids: oleic acid (C18:1, 21–24%), linoleic acid (C18:2, 48–50%) and linolenic acid (C18:3, 1.0–1.5%), and cis-vaccenic acid (C18:1, 2.8–3%). Fast protein liquid and ion-exchange chromatography, fluorescence, Fourier transform IR (FT-IR) spectra, elemental and electrophoretic analyses were described to characterize proteins from 7 species of Cactaceae, which can be divided into 3 groups based on their chemical and biochemical properties. Ammonium sulfate precipitation yielded complex of electrophoretic patterns with the major bands of 24 and 32 kDa. The SDS-polyacrylamide gel electrophoretic (PAGE) patterns did not differ by the year of sample collection (1986 and 1992). It was disclosed that protein characterization of cactus juices may be useful in cactus taxonomy at the family level. Differences in the emission peak response and fluorescence intensity in fluorescence emission, as well as the changes in amide band content in FT-IR spectra were reported (Gorinstein, Zemser, Vargas-Albores, & Ochoa, 1995). Characterization of three cactus proteins (native and denatured) from Machaerocereus gommosus (Pitahaya agria), Lophocereus schottii (Garambullo), and Cholla opuntia (Cholla), was based on electrophoretic, fluorescence, CD, DSC (differential scanning calorimetry), and FT-IR measurements. The stated results of intrinsic fluorescence, DSC, and CD were dissimilar for the three species of cactus, providing evidence of differences in secondary and tertiary structures. It was verified by Gorinstein et al. (1995) that cactus proteins may be situated in the following order corresponding to their relative stability: M. gommosus (Pitahaya agria)>C. opuntia (Cholla)>L. schottii (Garambullo). Thermodynamic properties of ‘proteins and their changes upon denaturation (temperature of denaturation, enthalpy, and the number of ruptured hydrogen bonds) were correlated with the secondary structure of proteins and disappearance of α-helix (Gorinstein, Zemser, Vargas-Albores, et al., 1999). From the studies shown below (Gorinstein, Zemser, Vargas-Albores, et al., 1999; Gorinstein et al., 1995) the most useful from the Cactaceae family are Pitaya agria or Sour Pitaya (M. gommosus) and Pitaya Dulce (Stenocereus thurberi). The fruit of Pitaya Agria is even sweeter than the fruit of Pitaya Dulce. Pitaya is a perennial plant with triangular cactus genus, of which fruit is rich in nutritive value and can be eaten directly, flowers can be used as vegetables, but the pitaya stems are not being used (Guo, Dai, Li, & Li, 2010). H. undatus and H. polyrhizus are two varieties of the commonly called pitaya fruits. Dragon fruit (H. polyrhizus) is well known for the rich nutrient contents and it is available worldwide for improving many health problems. Maximum antioxidant capacity, total phenolic...
and betalain contents were observed in the genotype ‘Lisa’ of 5 different Costa Rican genotypes of purple pitaya (Hylocereus sp.) and of H. polyrhizus fruits. While non-betalinic phenolic compounds contributed only to a minor extent, betalains were responsible for the major antioxidant capacity of purple pitaya juices evaluated (Esquivel, Stintzing, & Carle, 2007; Kugler, Stintzing, & Carle, 2007). The bioactive compounds in red dragon fruit were the following: 86.10 mg GAE of total polyphenolic compound in 0.50 g of dried dragon fruit; tannins of 2.30 mg CE/g (catechin equivalents); DPPH showed that the effective concentration (EC50) for dragon fruit was 2.90 μm vitamin C equivalents/g dried extract (Rebecca, Boyce, & Chandran, 2010). Total phenol (R² = 0.97) and ascorbic acid (R² = 0.79) concentrations were correlated with the antioxidant capacity of four pitaya cactus (Stenocereus stellatus Riccobono) fruit types (red, cherry, yellow and white), but the contribution of ascorbic acid accounts for only 4–6% of antioxidant capacity. White and yellow types contained a higher amount of phenol compounds and ascorbic acid than the cherry and red types. The antioxidant capacity displayed by the four pitaya types is similar to those reported for some fruits of the Vaccinium genus, regarded as the fruits having the highest antioxidant capacity. The consumption of pitaya fruits could provide the same protective effect against free radicals as berries of the Vaccinium genus, reducing risk of chronic diseases; thus pitaya fruits can be considered as potential nutraceutical food (Beltran-Orozco, Oliva-Coba, Gallardo-Velazquez, & Osorio-Revilla, 2009). The total phenolic contents of red pitaya flesh (42.4 ± 0.04 mg GAEE/100 g flesh FW) and peel (39.7 ± 0.53 mg GAEE/100 g peel FW), flavonoid contents of flesh and peel did not vary much (7.21 ± 0.02 mg vs. 8.33 ± 0.11 mg CE/100 g flesh and peel matters); betacyanins were 10.3 ± 0.22 and 13.8 ± 0.85 mg betanin equivalent per 100 g of fresh flesh and peel; the antioxidant activity, measured by the DPPH method at EC50, was 22.4 ± 0.29 and 118 ± 4.12 μmol vitamin C equivalent/g of flesh and peel dried extract. The ABTS assay showed 28.3 ± 0.83 and 175 ± 15.7 μM TE/g of flesh and peel dried extracts, respectively (Wu et al., 2005). The antiprofiterative study on B16F10 melanoma cells revealed that the peel (EC50 25.0 μg of peel matter) component was a stronger inhibitor of the growth of B16F10 melanoma cancer cells than the flesh. The results indicated that the flesh and peel were both rich in polyphenols and were good sources of antioxidants. The red pitaya peel fulfilled its promise to inhibit the growth of melanoma cells (Wu et al., 2005). Several studies show the proximity value of red pitaya fruits but the nutrient composition of the fruit which may be helpful in preventing the risk factors of certain diseases. The organic components in the stems of pitaya were identified by GC–MS and the contents of their mineral elements were determined by ICP-MS. The results showed that it contained many kinds of mineral elements which played an important role in our health. It contained phytol, vitamin E, β-sitosterol, taraxasterol and other kinds of phytosterols (Guo & Zhou, 2007). Valuable oil in the seeds of H. undatus and H. polyrhizus pitaya varieties was extracted by different methods (Ariffin et al., 2009; Rui, Zhang, Li, & Pan, 2009). Essential fatty acids are important acids that are necessary substrates in animal metabolism and cannot be synthesized in vivo: both pitaya varieties contain (Ariffin et al., 2009) about 50% essential fatty acids [C18:2 (48%) and C18:3 (1.5%)]. The phytosterol compounds identified in oils were cholesterol, campesterol, stigmasterol, and β-sitosterol. Seven phenolic acid compounds were identified, namely, gallic, vanillic, syringic, protocatechuic, p-hydroxybenzoic, p-coumaric, and caffeic acids. This study reveals that pitaya seed oil has a high level of functional lipids and can be used as a new source of essential oil (Lim, Tan, Karim, Ariffin, & Bakar, 2010). Red pitaya collected from Hepei in Guangxi province was used as...
durian (Weenen, Koolhaas, & Apriyantono, 1996). Thirty-eight volatile compounds were identified in the fresh durian flesh, of which eleven were esters, ten alcohols, six carboxylic acids, six sulfurous and nitrogenous compounds, and five hydrocarbons. Processed durian fruit leather retained most of the aroma components of fresh durian fruit. During storage, the relative proportion of acids in the product increased. Esters, alcohols and aldehydes during storage decreased, while hydrocarbons, phenolic, sulfurous and nitrogenous compounds fluctuated (Jasvir, Man, Selamat, Ahmad, & Sugisawa, 2008). Among exotic fruits durian is less known, and the content of bioactive compounds and the in vitro antioxidant capacities determined by FRAP and CUPRAC (Fig. 4A and B) were lower than for total polyphenols (R^2 = 0.865 and 0.711, respectively). The bioactivity of ripe durian was high and the total polyphenols were the main contributors to the overall antioxidant capacity (Arancibia-Avila et al., 2008). The antiproliferation has to be mentioned (Haruenkit et al., 2010) among the important activities of durian Mon Thong. The antiproliferative activities of methanol extracts of Mon Thong durian at different stages of ripening on human cancer cell lines (Calu-6 for human pulmonary carcinoma and SNU-601 for human gastric carcinoma) were determined by MTT (3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide) assay. The antiproliferative activities of the methanol extracts of immature, mature, ripe and overripe durian samples on two cell lines (Calu-6 for human pulmonary carcinoma and SNU-601 for human gastric carcinoma) were reported (Fig. 5). The cell survival rate [%] for concentrations of 2000 μg/mL for mature durian was 86.8 ± 1.5, and 88.5 ± 2.5%, on Calu-6 and on SNU-601, respectively, showing the highest antiproliferative activity in comparison with other samples. This investigation (Haruenkit et al., 2010) reported that antioxidant activity of the studied samples was not always correlated with their antiproliferative activity. The effectiveness of durian as a diet’s supplement was investigated in vivo (Leontowicz et al., 2008). Five groups of rats were fed diets supplemented with cholesterol and different durian cultivars. Diets supplemented with durian cv. Mon Thong and to a lesser degree with Chani and Kan Yao significantly reduced the best as a supplement to human diets. Total polyphenols are higher in Mon Thong, Chani, Kan Yao, Pung Manee and Kradam (Toledo et al., 2008). The antioxidant substances in ripe durian. Methanol extracts contained a relatively high capacity of 74.9 ± 7.1% inhibition by 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide assay. The antiproliferative activities of the methanol extracts of immature, mature, ripe and overripe durian samples on two cell lines (Calu-6 for human pulmonary carcinoma and SNU-601 for human gastric carcinoma) were reported (Fig. 5). The cell survival rate [%] for concentrations of 2000 μg/mL for mature durian was 86.8 ± 1.5, and 88.5 ± 2.5%, on Calu-6 and on SNU-601, respectively, showing the highest antiproliferative activity in comparison with other samples. This investigation (Haruenkit et al., 2010) reported that antioxidant activity of the studied samples was not always correlated with their antiproliferative activity. The effectiveness of durian as a diet’s supplement was investigated in vivo (Leontowicz et al., 2008). Five groups of rats were fed diets supplemented with cholesterol and different durian cultivars. Diets supplemented with durian cv. Mon Thong and to a lesser degree with Chani and Kan Yao significantly

**Fig. 4.** Correlation between measures of antioxidant capacities (AC) and total phenolics (TPOL). A. (●) ACFRAP (μMTE/100 g FW, X) and TPOL (μgGAE/100 g, Y1); (■) ACFRAP (μMTE/100 g, X) and TFLAV (mg CE/100 g FW, Y2); B. (○) ACCUPRAC (μMTE/100 g, X) and TPOL (μgGAE/100 g, Y1); (●) ACCUPRAC (μMTE/100 g, X) and TFLAV (mg CE/100 g FW, Y2). Abbreviations: FRAP, ferric-reducing/antioxidant power; CUPRAC, cupric reducing antioxidant capacity; TPOL, total polyphenols; TFLAV, total flavonoids.

This figure is adapted from Arancibia-Avila et al. (2008).
hindered the rise in the plasma lipids due to cholesterol containing diet: the TC to 8.7%, 16.1% and 10.3% and the LDL-C to 20.1%, 31.3% and 23.5% respectively. And also significantly hindered the decrease in plasma antioxidant activity in all diet groups (P < 0.05). Nitrogen retention remained significantly higher in Chol/Mon Thong than in other diet groups. Diet supplemented with Mon Thong affected the composition of plasma fibrinogen in rats and showed intensive protein bands around 47 kDa. No lesions were found in the examined tissue of heart and brains. Mon Thong cv. is preferable for the supplementation of the diet as positively influenced the lipid, antioxidant, protein and metabolic status. It was reported that durian fruit till now was not investigated extensively, therefore based on the results of shown study (Leontowicz et al., 2007) durian cultivars can be used as a relatively new source of antioxidants.

### 2.6. Graviola

Graviola (A. muricata, guanábana (Spanish), graviola (Portuguese), Brazilian pawpaw, corossolier, guanavana, tage-banreisi, durian benggala, nangka bland, and nangka londa) has been one of the first fruit trees. It was imported from America in the tropical regions of the Old World and widely distributed from southeastern China to Australia and the warm lowlands of eastern and western. Graviola is popular in Cuba, Bahamas, Puerto Rico, Colombia and northeastern Brazil (Lorenzi et al., 2006). Fruit is oval, sometimes having an irregular curved shape, grows to 10–30 cm in length and up to 15 cm in width, and thus has a weight of 4.5–6.8 kg. The fruit is covered with mesh, tough looking, but soft to the touch and has inedible bitter shell with lots of soft spikes. In immature fruit hull has a dark green color, and when the fruit ripens, it becomes slightly yellow and is easily separated from the set inside the white fibrous juicy segments surrounding a soft spongy core. The availability is the following: in Hawaii the early crop occurs from January to April; midseason crop is from June to August, with peak in July; and there is a late crop in October or November. Graviola contains carbohydrates, proteins, folic acid, calcium, phosphorus, iron, vitamin C, large amounts of vitamins B1 and B2. The fruit – a white, creamy and stringy – has a unique tart taste and fresh aroma, reminiscent of the smell of pineapple and a good thirst quencher.

A. muricata (soursop) and A. squamosa (sweetsop) are edible tropical fruits which are common, readily available and cheap in the producing country. The moisture content of fruits was >70%. The approximate nutritional compositions of unripe soursop and sweetsop were (%): total carbohydrates 84.8, 86.5; proteins 7.34, 7.09; lipids 1.68, 0.99; ash 4.02, 2.28; fiber 4.33, 10.81, respectively. Contents (g/L) in ripe soursop and sweetsop juices were as follows: carbohydrates 12.52, 10.56; glucose 6.14, 4.32; proteins 2.91, 0.22; lipids 3.25, 1.05; fiber 0.0; citrate 8.82, 3.53, respectively. The pH of fruit juices was acidic and the epicarp, mesocarp and juice of both fruits contained potassium, sodium, iron, magnesium, calcium, chloride and bicarbonate. The juices also contained phosphorus, zinc and copper (Enweani, Obroku, Enahoro, & Omoifo, 2004). The plant produces a wide range of secondary chemicals, some already known to be toxic, but the discovery here of the imino acetogenins as a new group of chemicals, including the neurotoxin swainsonine, raises questions about the safety of consumption of this plant (Mohanty et al., 2008). A methylene chloride extract of the pulp of A. muricata L. was fractionated and Annonaceous acetogenins (type E) have been isolated. Previously known C-35 and C-37 mono-epoxy unsaturated compounds, epomuricenins-A and -B (8+9) and epomusenins-A and B (10+11), were obtained (Fig. 6). Two new mono-epoxy saturated C-35 representatives, epomurinins-A and -B (12+13) were also isolated (Melot, Fall, Gleye, & Champy, 2009). The essential oil of the exotic fresh fruit (pulp) A. muricata (Annonaceae) from Cameroon was

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**Fig. 5.** Cytotoxic effect of methanol extracts from durian samples on human cancer cell lines Calu-6 (for human pulmonary carcinoma) and SNU-601 (for human gastric carcinoma): (A) DI, durian immature; (B) DM, durian mature; (C) DR, durian ripe; (D) ORD, overripe durian. This figure is adapted from Haruenkit et al. (2010).
investigated by GC/FID and GC/MS. Esters of aliphatic acids were especially dominating (total amount 51%), with 2-hexenoic acid Me ester (23.9%), 2-hexenoic acid Et ester (8.6%), 2-octenoic acid Me ester (5.4%), and 2-butenoic acid Me ester (2.4%) as main compounds. Additionally, mono- and sesquiterpenes such as β-caryophyllene (12.7%), 1,8-cineole (9.9%), linalool (7.8%), α-terpinol (2.8%), linalyl propionate (2.2%), and calarene (2.2%) were highly concentrated in the essential oil of the fresh fruit of A. muricata (Jirovetz, Buchbauer, & Ngassoum, 1998). GC/MS analysis of the leaf, peel and fruit pulp oils of A. muricata L. showed the presence of 68 compounds of which 59 were identified. The main components of the leaf oil were β-caryophyllene (31.4%) and other sesquiterpenes, while the fruit oil contained essentially aliphatic acids and esters, in particular, methyl(E)-2-hexenoate – 39.8% (Pelissier et al., 1994). The plant is traditionally used for the treatment of epilepsy, dysentery, cardiac problems, worm infestation, constipation, hemorrhage, antibacterial infection, dysuria, fever, and ulcer. It also has anti-fertility, antimutur and abortifacient properties. Ethanolic extracts of leaves and stem are reported to have an anticancerous activity. A. squamosa has as well phytopharmacological properties (Saleem et al., 2009). Graviola has very broad medicinal claims and is also widely consumed as a food and in drinks in the tropics. For therapeutic purposes graviola is used in diseases of the colon to maintain intestinal flora. Juice of the mature fruit is a good diuretic, promotes weight loss and is used to treat diseases of the liver, to normalize the acidity of the stomach, having anti-rheumatic and anti-inflammatory properties. Such juice is necessary for people suffering from rheumatism, arthritis and gout. Graviola is commonly promoted as a cancer treatment (Cassileth, 2008). Matrix metalloproteinases (MMP) may exert important roles in both physiologic and pathologic extracellular matrix remodeling. They have been implicated in tumoral progression of many human malignancies interfering on angiogenic, invasive, and metastatic events. Specifically, the gelatinases MMP-2 and MMP-9 have been intensively studied in connection with tumor invasion and metastasis, and have been considered as promising targets for cancer treatment. The inhibition of the MMP-2 and MMP-9 gelatinolytic activity was investigated in Aloe vera, black tea, and A. muricata aqueous extracts (AE), diluted in activation buffer (AB, with calcium). It was reported that the antitumoral effects verified for A. vera, A. muricata, and black tea AE may be partially explained by their inhibitory activity on MMP (Ribeiro et al., 2010).

2.7. Guava

Guava (Psidium guajava L., also known as goiaba, goiabeira), locally known as Klom sali, is an important fruit, which originated in the tropics of America. Guava has a globular shape, with the texture crispy when served raw; with sweet and sour taste, composed of 200 to 300 g/fruit. The fruit is available all year around, as fresh, and processed as juice. Guava has a smooth surface, round or pear-shaped small size. Ripe fruit should be consumed with the skin to improve digestion and to stimulate the heart. Daily consumption of guava normalizes blood pressure, so is vital for the human body. When the fruit is ripe it becomes yellow and has a bitter-sweet taste. Depending on the type of guava pulp may be white or pink color. The fruit consists of water, contains proteins, fats, calcium, phosphorus, iron, fruit sugar, vitamin A, and fiber. Guava contains vitamin C to 5 times more than oranges (240 mg per 100 g). The sugar content of the fruit is combined with sweet, sour-sweet fruit, as well as dairy products. For the first time Lima, Fernandes, and Lima (2010) reported that Edessa scarbridensis Stal on Eugenia uniflora (Brazilian-cherry) and on P. guajava (guava) (Myrtaceae) fruit trees have an economic value. Guava has high antioxidant effect (Isabelle et al., 2010; Kongkachuchai, Charoenrisi, & Sungpua, 2010). The antioxidant capacity and phenol content of 3 tropical fruits pulps, namely, honey pineapple, banana and Thai seedless guava, were studied by Alothman et al. (2009). The polyphenol of Thai seedless guava was 123 to 191 mg GAE/100 g, that of pisang mas was 24.4 to 72.2 GAE/100 g, and that of honey pineapple was 34.7 to 54.7 GAE/100 g. High phenol content was significantly correlated with high antioxidant capacity. Three solvent systems were used (methanol, ethanol and acetone) at three different concentrations (50%, 70% and 90%) and with 100% distilled water. The efficiency of the solvents used to extract phenols from the 3 fruits varied considerably (Alothman et al., 2009). Natural products have recently become the focus of increased research interest due to their potential pharmacological activities. The acetone extracts of guava (P. guajava L.) branch (GBA) had cytotoxic effects on HT-29 cells. The GBA showed highly cytotoxic effects via the MTT reduction assay, LDH release assay, and colony formation assay. In particular, the 250 μg/ml of GBA showed 35.5% inhibition against growth of HT-29 cells (Lee & Park, 2010). The chemical constituents from the fruit of P. guajava were reported. Nine triterpenoids, ursolic acid, 3β,19α,23α,24-α-tetrahydroxy-urs-12-en-28-oic acid, 2α,3β-dihydroxy-urs-12-en-28-oic acid, 1β,19α-dihydroxy-urs-12-en-28-oic acid, 19α-hydroxy-urs-12-en-28-oic acid, 3α-O-α-L-arabinopyranoside, 3β,23-dihydroxy-urs-12-en-28-oic acid, 3β,19α,23α-trihydroxy-urs-12-en-28-oic acid, 2α,3β,19α,23α-tetrahydroxy-urs-12-en-28-oic acid, and 3α,19α,23α-tetrahydroxy-urs-12-en-28-oic acid were isolated by means of chromatography, and their structures were elucidated on the basis of MS, 1H NMR and 13C NMR spectra (Shu, Yu, & Wang, 2009). The chemical composition of mature fruits isolated from six different cultivars of guava (P. guajava L.) grown in Taiwan has been studied by headspace solid-phase microextraction (HS-SPME) coupled with GC–MS. A total of 35

Fig. 6. Several biological active acetogenins were isolated from Annona fruits (Annona muricata L.). This figure is adapted from Melot et al. (2009).
compounds were identified, including 24 terpene hydrocarbons, 2 terpene alcohols, and minor constituents including 1 alcohol, 2 aldehydes, 3 esters, 1 terpene ester and 2 terpene oxides. Although the volatile constituents of the six cultivars were similar, with β-caryophyllene (47.7–58.3%) and aromadendrene (7.1–14.6%) as the major constituents in all cultivars, quantitative differences in the composition of some constituents were observed. P. guajava L. cv. Chan-Shan Bar contained higher percentages of 3-hexenyl acetate, 1,8-cineole, and allo-oicenine than other species (Chen, Sheu, Lin, & Wu, 2008).

Characterization of the aromatic profile in commercial guava essence and fresh fruit puree by GC-MS yielded a total of 51 components quantified. Commercial essence was characterized to present a volatile profile rich in components with low molecular weight, especially alcohols, esters, and aldehydes, whereas in the fresh fruit puree terpenic hydrocarbons and 3-hydroxy-2-butanone were the most abundant components. New compounds were described as active aromatic constituents in pink guava fruit (3-penten-2-ol and 2-butynyl acetate) as well as known compounds: 3-hydroxy-2-butanone, 3-methyl-1-butanol, 2,3-butanediol, 3-methylbutanoic acid, (Z)-3-hexen-1-ol, 6-methyl-5-hepten-2-one, limonene, octanol, ethyl octanoate, 3-phenylpropanol, cinnamyl alcohol, and α-copaene (Jordán, Margaría, Shaw, & Goodner, 2003).

The chemical composition of the volatile oil of guava fruits from trees grown in Nigeria was investigated by GC-MS. A total of 25 compounds, accounting for 80% of the oil, were identified. Free fatty acids (mainly lauric and myristic acids) were the most abundant group of constituents (34%). Large amounts of β-caryophyllene and O-containing sesquiterpenes (25%) also were typical for Nigerian guava (Ekundayo, Ajani, Seppanen-Laakso, & Laakso, 1991). A total of 88 volatiles were identified and detected. The data showed that hydrocarbons were more prominent in the white fleshed guava and oxygenated compounds were predominant in the pink fruit. Myrcene, cis- and trans-oicenine and β-caryophyllene were the most important hydrocarbons in guava aroma. The carbonyl compounds were the main polar group in pink guava. The alcohols were the main polar group in white guava. Hexanal was the major abundant constituent in both cultivars. C6-aldehydes, alcohols and esters were important aroma compounds in guava (Askar, El-Nemr, & Bassiouny, 1986).

2.8. Kiwano

The kiwano (Cucumis metuliferus) is a member of the Cucurbitaceae and like the rest of its genus, is native to Africa (in particular, Nigeria). It became acclimatized in Australia several decades ago. The fruits are ellipsoids, approximately 12 cm long by 8 cm in diameter, and of a green color which during ripening changed to orange. The cortex is covered in conical protruberances, whose tips bear sharp prickles that can easily be removed when the fruit is ripe. Internally, the fruit is composed of a juicy green mucilaginous mass containing numerous smooth white seeds. The horned melon (C. metuliferus), also called African horned cucumber or kiwano, is an annual vine in the cucumber and melon family. The fruit of this plant is edible, but it is used more for decoration as for food. It has a yellow-orange skin and a lime green jelly-like flesh in the ripe stage. The availability is about three and a half months in two seasons (early spring and autumn). The horned melon is native to Africa, and it is now grown in Australia, California, Chile, and New Zealand as well (Hutchman, 2008).

Correlations among the indices of fruit ripeness Brix, Brix/total acidity, soluble sugars/total acidity and color, were studied for different fruits (whortlberry, raspberry, red and black currant, elderberry, sour cherry, babaco, feijoa, kiwano, persimmon and passion fruit). The correlation between Brix/total acidity and soluble sugars/total acidity was high for all the fruits studied (r = 0.985), indicating therefore a linear equation, in order to find the fruit sugar content with known values of Brix and total acidity (Rodriguez, Oderiz, Hernandez, & Lozano, 1993).

Weight, length, firmness, degrees Brix, color, pH, total acidity, vitamin C, moisture, proteins, total fat, sucrose, D-glucose, D-fructose, neutral detergent fiber, quinic acid, malic acid, citric acid, ash, Na, K, Ca, Mg, Fe, Cu, Zn, Mn, and phosphates were detected in kiwano fruit (C. metuliferus) samples. Citric acid was the main organic acid and K was the main mineral element (Romero-Rodriguez, Vazquez-Oderiz, Lopez-Hernandez, & Simal-Lorano, 1992). Total polyphenol content and antioxidant activities of non-edible parts (seed and peel) of eight tropical fruits were analyzed and compared with those of their edible parts. Total polyphenol content in seed, peel and pulp ranged from 0.2 to 153, 5.0 to 124, and 1.0 to 12 mg/g DW, respectively. Kiwano and papaya peels showed strong ferrous ion-chelating capacity, although they did not have high polyphenol content and DPPH and ABTS radical scavenging activities (Matsusaka & Kawabata, 2010). Lutein ester formation in kiwano was detected (Breithaupt, Wirt, & Bamedi, 2002). Kiwano fruits have high levels of water, vitamin C and minerals (K, Mg, and P) and low levels of glyc erides. Flavonoids, which were detected, revealed high levels of rutin and small amounts of myricetin and quercetin. The presence of high levels of rutin with antioxidant, anti-inflammatory, spasmytic, capillary protective, and blood platelet aggregation inhibitory activities may be pharmacologically important (Ferrara, 2006). Lactic, ascorbic, benzoic, salicylic, citric, tartaric, fumaric, glutaric, shikimic, oxalic, caffeic, hippuric, cinnamic, malic, and quinic organic acids were isolated (Fig. 7) from kiwano fruits (Pero, 2006).

2.9. Kiwifruit

Kiwifruit (Actinidia deliciosa) is native to Southern China. Other species of Actinidia are also found in India and Japan and north into southeastern Siberia. Cultivation spread from China in the early 20th century, when seeds were introduced to New Zealand. The kiwifruit is a large, woody, deciduous vine. Kiwifruit has an oval shape, typically the size of a large hen’s egg, and a fibrous, dull brown-green skin, and bright green or golden flesh with rows of tiny, black, edible seeds, soft texture and a unique flavor. Usually the availability is November–April. The chemical constituents of volatile oil from cadexes of A. deliciosa were extracted by distillation with water vapor, and then were separated and identified by GC-MS. Totally 19 compounds were identified accounting for 97.37% of all quantity. The principal chemical constituents in volatile oil were tri-Bu phosphate, bis(2-methylpropyl) phthalate, 3,7-dimethyl-3-hydroxy-1,6-octadiene, 2,4-bis[1,1-dimethylethyl] phenol and trans-2-dimethyl-5-[1-(methylethyl) cyclohexanone (Ge et al., 2008). Volatiles of kiwifruit pulp were stripped with N2, trapped on activated charcoal, eluted with C50, and separated and identified by GC-MS. Major components were 2-hexenal, ethyl (Et) butanoate, and Et hexanoate. Compounds identified in kiwifruit were Et 3-methylbutanoate, di-Et carbonates, Et 2-butenoates, 1,5-heptadiene-3,4-diol, 2,2-diethyl-1-pentanol, 7-methyl-1-octene, (E)-4-hexen-1-ol, 2-methylcyclopentanol, and Et octanoate (Cossa, Trova, & Gandolfo, 1988).

Glycosidically bound volatiles in kiwifruit have been isolated from kiwifruit juice by adsorption onto a column of Amberlite XAD-2 followed by washing with pentane and elution with methanol. Volatiles
were released by enzymic hydrolysis with β-glucosidase. Major components found and identified by GC–MS were E-hex-2-enal and benzaldehyde. Compounds not previously identified in kiwifruit include octan-3-ol, camphor, 4-methylbenzaldehyde, 2-hydroxybenzaldehyde, neral, geranial, Me 2-hydroxybenzoate, nerol, geraniol and 2-phenylethanol (Young & Peterson, 1995). Analyses of 8 flavon-3-ols (catechin, catechin gallate, epicatechin, epicatechin gallate, epigallocatechin, epigallocatechin gallate, gallic acid, and gallic acid galate), 6 anthocyanins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin, and petunidin), 2 flavanones (hesperetin and naringenin), 2 flavones (apigenin and luteolin), and 2 flavonols (myricetin and quercetin) were identified in more than 60 fresh fruits (Harney et al., 2006). Flavonols of kiwifruits (Actinidia chinesis Planch.) cultivated in Georgia were studied. Kaempferol-3-β-rhamnoside (afzelin), kaempferol-3-β-glucoside (astragalin), quercetin-3-β-rhamnoside (quercitrin), quercetin-3-β-glucoside (lsoquercitrin) and quercetin-3-β-glucuronyl-rhamnoside (rutin) were isolated and identified (Kalandiya, Vanidze, Papunidze, Chkhikvishvili, & Shalashvili, 2001). Phenolic compounds in kiwifruit pulp were separated and characterized. Strongly acidic compounds were identified as derivatives of coumaric and caffeic acids, including chlorogenic acid, protocatechuic acid, and a derivative of 3,4-dihydroxybenzoic acid. The weakly acidic fraction contained epicatechin, catechin, and procyanidins (B3, B2, or B4 and oligomers). Flavonoids are present as the glycosides of quercetin (glucoside, rhamnoside, and rutinoside) and kaempferol (rhamnoside and rutinoside). Phenolic compounds were present, at levels of <1–7 mg/L in clarified juice (Dawes & Keene, 1999). Kaempferol-3-O-rutinoside, kaempferol-3-O-galactoside, kaempferol-3-O-rhamnoside, quercetin-3-O-rhamnoside, and quercetin-3-O-glucoside were isolated from kiwifruit and mombin plum (MP). Quercetin-3-O-rhamnoside was as the major flavonoid in kiwifruit (1.0–2.8 mg/kg) and rutin in MP (25–120 mg/kg) (Mareck, Galensa, & Herrmann, 1990). Kiwifruit is one of the most popular fruits in the USA and Europe. However, this fruit is not edible even at the maturation stage due to hard firmness and high acidity (Haruenkit et al., 2007; Park, 2002; Park, Jung, Kang, Delgado-Licon, Katrich, et al., 2006; Park, Jung, Kang, Drzewiecki, et al., 2006). There are different proposals to eliminate the hard firmness and high acidity of the kiwifruit (Antunes & Sfakiotakis, 2002; Park, 2002), and the ethylene treatment seems preferable. Ethylene treatment decreases the firmness and acidity, and increases contents of fructose, glucose, sucrose and soluble solids and enhances the edible quality of kiwifruits. The best results could be achieved when the ripening process takes place at 20 °C (Park et al., 2009; Park, Jung, Kang, Delgado-Licon, Katrich, et al., 2006; Park, Jung, Kang, Drzewiecki, et al., 2006; Park, Jung, & Gorinstein, 2006; Park, Jung, Kang, Delgado-Licon, Katrich, et al., 2006; Park, Jung, Kang, Drzewiecki, et al., 2006). Ethylene-treated kiwifruit samples were randomly divided into two groups: treated and untreated. Flesh firmness, sensory value, visual score, free sugars, soluble solids, ethylene biosynthesis, proteins, dietary fibers, total polyphenols and antioxidant potential were determined in both groups. Ethylene (100 ppm) at 20 °C for 24 h was used in the treated group. The flesh firmness and acidity in treated samples decreased significantly in the early stage of ripening simultaneously with significant increase in the contents of free sugars, soluble solids, endogenous ethylene production, sensory value, 1-aminoxypropyl-1-carboxylic acid (ACC) content, ACC synthase and ACC oxidase activities, total polyphenols and related antioxidant potential, and was significantly higher than in untreated samples (P < 0.05). Proteins were extracted from kiwifruit and separated by modified sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). The separation was resolved into 14 protein bands. Some minor quality changes were achieved when the ripening process takes place at 20 °C (Park et al., 2009). It was reported that the contents of these bioactive compounds determined by UV spectroscopy and fluorometry were higher in ethylene-treated kiwifruit than in the non treated ones. Antioxidant capacity in total polyphenol extracts of treated kiwifruit measured by FRAP and TEAC assays was significantly higher than that of non-treated. Correlation coefficients between polyphenols and antioxidant activity were significantly higher than between antioxidant activity and ascorbic acid. FRAP produced the most consistent measurements for ethylene-treated kiwifruit. The content of total polyphenols, and related total antioxidant capacities by Fe(III)-TP and ABTS significantly increased in ethylene-treated (Fig. 8B) than in the air-treated (non-treated with ethylene) kiwifruit samples (Fig. 8A) after the first half of the treatment, starting from the 5th day (Fig. 8, P < 0.05). The Fe (III)-TP and ABTS values for each extract were compared and correlated with the total phenolic contents. The relationships between the values of total polyphenol concentrations of non-treated samples vs. antioxidant capacities for Fe (III)-TP and ABTS were 0.8845, 0.7229, respectively. For ethylene-treated samples, the calculations showed the following order between the polyphenols and the antioxidant capacities determined by the two methods: 0.9321 and 0.7423, respectively. The results are rather interesting, as there is an excellent linear response, especially for the ethylene-treated samples only for Fe (III)-TP (R² = 0.93). The overall estimation of the presented data showed that after ethylene treatment, the correlation coefficients were higher than in the non-

![Fig. 8. Changes in radical scavenging capacity (RSC) of total polyphenol extracts of kiwifruit during 10 days of ripening using two antioxidant tests during different periods of time: A, RSC (μMTE/g) by ABTS and Fe(III)-TP in NT kiwifruits; B, RSC (μMTE/g) by ABTS and Fe(III)-TP in T kiwifruits; Abbreviations: NT, air-treated samples; T, ethylene treated samples; ABTS, 2, 2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); Fe (III)-TP, ferric-tripiprinostazine; RSC, radical scavenging capacity, expressed as μMTE (Trolox equivalent)/g DW. This figure is adapted from Park et al. (2009).](image-url)
treated kiwifruits (Fig. 8). The ascorbic acid showed lower correlation of about 0.76 in comparison with 0.93 of polyphenols. During ethylene treatment the bioactivity of kiwifruit is increasing and reaches its maximum at the 6th day and therefore it is the optimum time for kiwifruit consumption; total polyphenols were the main contributor to the overall antioxidant activity of kiwifruit; the most sensitive test for antioxidant activities determination is FRAP. The investigated samples showed similar protein bands during the whole period of treatment. Main protein bands appeared in the range of 20–35 kDa. The radical scavenging capacity of the kiwifruit can be used for the determination of the ripening. As was mentioned, the ethylene treatment of kiwifruits seems preferable (Antunes & Sfakiotakis, 2002). Latocha, Krupa, Wolosiak, Worobiej, and Wilczak (2010) compared different cultivars with kiwifruit (cv. 'Hayward'). The comparison was based on the amount of bioactive compounds in order to evaluate their compositional characteristics, especially as a possible “healthy fruit.” The highest concentrations of vitamin C and total phenolic content (TPC), were found for Actinidia kolomikta fruit (1008.3 and 634.1 mg/100 g fresh weight [FW], respectively). Among phenolic compounds, seven phenolic acids and three flavonoids were identified. The 2,5-dihydroxybenzoic acid prevailed in A. kolomikta (425.54 mg/100 g FW), while tannic acid dominated in other species (4.63 ± 0.7 mg/100 g FW). The largest amounts of chlorophylls and carotenoids were identified as Actinidia macroasperma (4.02 and 2.09 mg/100 g FW, respectively). The antioxidant activity (AAC) of fruit extracts decreased in the order of A. kolomikta > Actinidia purpurea > Actinidia melanandra > A. macroasperma > Actinidia arguta > A. deliciosa according to the DPPH assay. In very recent research (Park et al., 2011) four different cultivars of kiwifruit ('Hayward', 'Daheung', 'Haenam' and 'Bidan') were compared in order to find the best for human consumption. It was registered significantly highest contents (P<0.05) of polyphenols and ascorbic acid (R² =0.988) in 'Daheung', and the best for human consumption (De Assis et al., 2009; Prasad et al., 2010). The antioxidant activity (De Assis et al., 2009; Prasad et al., 2010) significantly highest contents (P<0.05) of polyphenols and ascorbic acid (R² =0.988) and the anti-oxidant activity in the studied cultivars. The overall bioactivity of the cultivars was as follow: 'Bidan' > 'Haenam' > 'Daheung' = 'Hayward'. 'Bidan', newly released cultivar, can be recommended for consumption (Park et al., 2011).

2.10. Litchi

Litchi (Litchi chinensis Somn.) is also known as Hong Hua, lychee, originated in the Kwantung province in southern China with a shape of round or oval, up to 40 mm in diameter, with a single seed in the middle of the fruit, occupies up to half of the fruit and composed of approximately 50 g/fruit. Red peel needs to be removed before eaten, and aril is edible part. The texture is juicy, translucent aril and the taste is sweet and slightly sour. It can be used in processed form as canned lychee in syrup. The availability of litchi is June and July. Sodium orthovanadate suspended in a lychee black tea decoction effectively regulates blood glucose levels in rats with insulin-dependent, streptozotocin (STZ)-induced diabetes (Edel et al., 2006). Volatile components of nine litchi cultivars (10 samples) with high compositional value from Southern China were investigated by means of GC–MS combined with headspace solid phase micro-extraction. A total of 96 volatiles were detected, of which 43 were identified. Seventeen common volatiles in all the samples included linalool, cis-rose oxide, α-terpineol, β-citronellol, geraniol, p-cymene, ethanol, 3-methyl-3-buten-1-ol, 3-methyl-2-buten-1-ol, 1-hexanol, (E)-2-hexen-1-ol, 2-ethyl-1-hexanol, 1-octen-3-ol, 1-octanol, Ethyl acetate, p,α-dimethylstyrene and 3-tert-butyl-4-hydroxyanisole. Although the volatile composition and concentration varied between these cultivars, the components with the highest odor activity values (OAVs) in most cultivars were still cis-rose oxide, trans-rose oxide, 1-octen-3-ol, and geraniol. Sulfur compounds usually have low contents to detect by MS but are responsible for garlic character of litchi flavor for their extremely low odor thresholds. Excitingly two sulfur volatiles, 2,4-dithiapentane and 2,3,5-trithiahexane, were observed using GC–MS and noticeably they were only detected in Guangzhou HuaiZhi or other cultivars. One of the sulfides, 2,4-dithiapentane, was reported to present cabbage notes (Mahattanatawee, Perez-Cacho, Davenport, & Rouseff, 2007), while the other one, 2,3,5-trithiahexane, has not been noted in previous reports about litchi volatiles (Wu, Pan, Qu, & Duan, 2009). Both free and glycosidically-bound fractions of lychee aroma were by GC–MS. Generally, the two fractions exhibited similar volatile profiles, except for some quantitative differences. These volatile compounds were primarily identified by their Kovats indices, using C₅–C₂₅ n-alkanes. Totally, 25 compounds (24 peaks) were identified in both fractions, including one ester, 14 aldehydes, four acids, two ketones and two terpenes. The total amounts of volatile compounds in lychee juice in the free and bound fractions were 2907 and 1576 mg/ kg FW of pulp, respectively. The amount of volatile compounds in the bound fraction was half the amount of volatile compounds in the free fraction, indicating that the aroma would be enriched by 50% as the volatile compounds in the bound fraction were released by enzymatic hydrolysis (Chayu, Ko, Chang, & Mau, 2003). A large number of polysaccharides were present in the pericarp tissues of harvested litchi fruits. The purified product was a neutral polysaccharide, with a molecular weight of 14 kDa, comprised mainly of 65.6% mannose, 33.0% galactose, and 1.4% arabinose. Analysis by Smith degradation indicated that there were 8.7% of (1→2)-glycosidic linkages, 83.3% of (1→3)-glycosidic linkages and 8.0% of (1→6)-glycosidic linkages in the polysaccharide (Yang et al., 2006). Two purified polyphenol oxidase (PPO) substrates were identified as (−)-epicatechin and procyanidin A2. The results showed that (−)-epicatechin exhibited stronger antioxidant capability than procyanidin A2, in terms of reducing power and scavenging activities of DPPH radical, hydroxyl radical and superoxide radical. Furthermore, (−)-epicatechin content in pericarp tissue tended to decrease with increasing skin browning index of litchi fruit during storage at 25 °C. Thus, these two compounds can be used as potential antioxidants in litchi waste and the fresh pericarp issue of litchi fruit exhibited a better utilization value (Sun, Jiang, et al., 2010, Sun, Seeberger, et al., 2010).

2.11. Longan

Longan (Dragon Eye) – the fruit of an evergreen tree longan (Euphoria longana, syn. Dimocarpus longan), is a member of the unusual and diverse Soapberry Family (Sapindaceae), widespread in China, Taiwan, Vietnam and Indonesia. The name comes from the Vietnamese province of Longan where this plant was cultivated until now. Juicy Longana has a sweet, very fragrant, similar to the lychee flavor with a unique flavor. Color solid inedible outer shell of the fruit varies from spotted-yellowish to reddish. As the Chinese lychee, fruit Longana contains a solid dark red or black seed. The following varieties of longan exist: Biew Kiewu, Dagelman, Diamond River, Kohala and Sri Chompoo. The availability of this fruit is late July to September, according to variety. Three phenolic compounds, namely gallic acid, corilagin and ellagic acid, were identified and quantified using HPLC method. Compared with conventional extraction and ultrasonic extraction samples, high pressure extraction samples exhibited higher extraction efficiency in terms of extraction yield, phenolic content and antioxidant activity (De Assis et al., 2009; Prasad et al., 2010).
The high pressure extraction technology provided a better way of utilizing longan fruit pericarp as a readily accessible source of natural antioxidants in food and pharmaceutical industries. The phenol contents and the antioxidant activities of 12 Chinese longan cultivars were studied (He et al., 2009). The polyphenols of longan pericarp and seed demonstrated significantly higher antioxidant capacities than did the pulp. The ferric reducing antioxidant powers of longan fruits were closely correlated with the polyphenol contents. Gallic acid and ellagic acid were not the major contributors to the antioxidant activity of longan pericarp. Other 15 phenolic profiles in longan pericarp along with a number of unknown structures were revealed. The rich array of phenolic compounds of several different types in longan pericarp extract might form a synergistic multilevel defense system against oxidation (He et al., 2009). Anthocyanins found in certain flowers have been shown to act as strong antioxidants in various systems, exhibiting multiple biological actions. The antioxidative effects of water extract and ethanolic extract of longan (D. longan Lour.) flowers were evaluated by radical scavenging activity and compared to those of gallic acid, myricetin, and epigallocatechin gallate. Abundant levels of phenolic compounds including flavonoids, condensed tannins, and proanthocyanidins were found in water or ethanolic extracts prepared from dried longan flowers. The results suggested that longan flower crude extracts, especially ethanolic extract, have antioxidant and anti-inflammatory effects, and the probable mechanism involves inhibition of inflammation by proanthocyanidins. Preliminary observations suggest that longan flower extract, especially alcoholic extract, could be another potential source of natural dietary antioxidant and anti-inflammatory agent (Ho, Hwang, Shen, & Lin, 2007). Longan fruits contain a significant amount of polyphenols (Sun, Shi, Jiang, Xue, & Wei, 2007). Polyphenols were extracted from longan pericarp tissues. Two compounds were identified as 4-O-methylgallic acid and (−)-epicatechin, respectively. In terms of reaction with longan polyphenol oxidase (PPO), (−)-epicatechin was further identified as the PPO substrate that caused longan fruit to brown. The results of antioxidant activity showed that 4-O-methylgallic acid had higher reducing power and DPPh+, hydroxyl radical-, and superoxide radical-scavenging activities than (−)-epicatechin (Sun et al., 2007). The protective effects of fruits and vegetables against chronic diseases have been attributed to the antioxidant properties of some secondary metabolites present in these foods (Rangkadilok et al., 2007). Plant polyphenols have been reported to exhibit bioactive properties, and in particular antioxidant activities. Longan seeds are found to contain high levels of some secondary metabolites such as corilagin, gallic acid and ellagic acid. The present study examined the free radical scavenging activity of longan seed extract by using three different assay methods. Longan extracts contained corilagin ranging from zero to 50.64 mg/g DW, gallic acid from 9.18 to 23.04 mg/g DW, and ellagic acid from 8.13 to 12.65 mg/g DW depending on the cultivars. Dried longan seed extracts of cultivar Edor contained high levels of gallic and ellagic acids and also exhibited the highest radical scavenging activities when comparing fresh seed and dried pulp extracts. For scavenging activity of DPPh and superoxide radicals, longan seed extract was found to be as effective as Japanese green tea extract while dried longan pulp and mulberry green tea extracts showed the lowest scavenging activities. In the ORAC assay, both fresh and dried longan seed also had higher activity than dried pulp and whole fruit. However, the results demonstrate that three polyphenolics may not be the major contributors of the high antioxidant activity of longan water extracts but this high activity may be due to other phenolic/flavonoid glycosides and ellagitannins present in longan fruit. In addition, longan seed also showed tyrosinase inhibitory activity with IC_{50} values of 2.9–3.2 mg/ml. Therefore, the preliminary observations suggest that longan seed extract could be another potential source of potent natural dietary antioxidants and also in an application as a new natural skin-whitening agent (Rangkadilok et al., 2007). From the pulp of E. longana (Longan Arillus), three cerebroside molecular species have been isolated (Fig. 9). Six known cerebrosides, soyacerebrosides I and II, 1-O-beta-D-glucopyranosyl-(2 S,3R,4E,8E)-2-(2-lignoceroylamino)-4,8-octadecadiene-1,3-diol (longan cerebroside I) and its 8Z isomer (longan cerebroside II), momor-cerebroside I, and phytolacca cerebroside, were identified as major components of these cerebroside molecular species. All the cerebrosides were shown to be a mixture of geometrical isomers (8E and 8Z) of sphingosine-type or phytosphingosine-type glucocerebrosides possessing 2-hydroxy fatty acids (Ryu, Kim, & Kang, 2003). Longan fruit contains significant amounts of bioactive compounds such as corilagin, ellagic acid and its conjugates, 4-O-methylgallic acid, flavone glycosides, glycosides of quercetin and kaempferol, ethyl gallate 1-O-galloyl-β-glucopyranose, grevifolin, and 4-O-α-D-rhamnopyranosyl-ellagic acid (Yang et al., 2011—this issue). Longan (D. longan Lour.) is used as a traditional edible and medicinal material in China (Zhong, Wang, He, & He, 2010). The effects of polysaccharides from longan pulp with ultrasonic extraction (UELP) on the radicals scavenging, immunity-modulatory and anti-tumor activities in S180 tumor mice models were investigated. UELP with medium-dose (200 mg/kg) and low-dose (100 mg/kg) had potent immune-modulatory effects in S180 tumor mice model and exhibited significant effect on delayed-type hypersensitivity (DTH) response, macrophage phagocytosis and ConA-stimulated splenocyte proliferation as compared with model control treatment (p < 0.01). The results of this report showed that UELP had great antitumor effects, and maximum inhibition rate was obtained at medium-dose and low-dose (200 and 100 mg/kg). The petroleum ether, chloroform and ethyl acetate fractions of ethanol extract of leaf and stem from the plant Nephelium longan (Fam-Sapindaceae) were subjected (Ripa, Haque, & Bulbul, 2010) to antioxidant, antibacterial and cytotoxic activities. All the fractions showed potent antioxidant activity, of which the ethyl acetate and chloroform fraction of leaf demonstrated the strongest antioxidant activity. Both the stem and leaf of the experimental plant have considerable antibacterial, cytotoxic and antioxidant properties which indicates that the plant have potent bioactive principles.
2.12. Mango

Mango (M. indica L.) is one of the most important tropical fruits with a global production exceeding 27 million tons (FAOSTAT, 2008), being the 2nd largest tropical crop next to banana. Mango cv. “Ataulfo” is grown in Mexico. Mango, locally known as Kew, originated in the Indo-Burma area thousands years ago. The shape is ovate-oblong, the weight is up to 1 kg; texture: firm when raw, rubbery when ripe; taste: sour when raw and sweet when ripe. Mango in processed form is pickle, juice and jam. There are four main groups of mango varieties. The availability is May to January, according to variety. In addition to its attractive color and taste, the high content of ascorbic acid, β-carotene, and phenolics are intrinsic characteristics of this cultivar (Gil, Aguayo, & Kader, 2006; González-Aguilar et al., 2008). Consumption of mango as other fruits could provide significantly higher in bioactive compounds with antioxidant activity to the human diet (Liu, 2003). Minimally processed fruits are one of the major growing segments in the food retail market. However, the greatest hurdle to the commercial marketing is the limited shelf life, which is due to excessive tissue softening and cut-surface browning (Soliva-Fortuny & Martín-Belloso, 2003). One approach to achieve this goal is the inhibition of browning reactions by excluding oxygen, adding antioxidants, or inhibiting the activity of the responsible enzyme polyphenol oxidase (Saltveit, 2003). Researchers have reported the effectiveness of dip treatment containing calcium to delay deterioration of fresh-cut mango (González-Aguilar et al., 2008). The bioactive compounds and the antioxidant potential in four different extracts of mango (M. indica L.) were determined and characterized by HPLC, 3D-FL, several radical scavenging assays and multivariate factor analysis (Poovarodom et al., 2010). The results of the determination of the contents of polyphenols, flavonoids, flavanols and tannins in methanol, water, acetone and hexane extracts are reported in Table 3. The results of the determination of the antioxidant potential in methanol, water, acetone and hexane extracts by ABTS, CUPRAC, FRAP and DPPH tests are summarized in Table 4. As can be seen, the antioxidant potential according to all four tests is higher in methanol and water extracts (P < 0.05). Mango contains high amounts of bioactive compounds and its antioxidant potential is significantly higher in methanol and water extracts (P < 0.05, Robles-Sanchez et al., 2007; Robles-Sanchez et al., 2009; Poovarodom et al., 2010). The major polyphenols in mango in terms of antioxidative capacity and/or quantity were: mangiferin, catechins, quercitin, kaempferol, rutin, anthocyanins, gallic and elagic acids, propyl and methyl gallate, benzoic acid, and protocatechuic acid. The mutatcultural and pharmaceutical significance of mangiferin, which was a special polyphenol in mango, have been extensively demonstrated and continued to attract much attention, especially in its potential to combat degenerative diseases like heart diseases and cancer. The amounts of the different polyphenolic compounds in the mango vary from part to part (pulp, peel, seed, bark, leaf, and flower) with most polyphenols being found in all the parts. Mango polyphenols, like other polyphenolic compounds, work mainly as antioxidants, that enable them to protect human cells against damage due to oxidative stress leading to lipid peroxidation, DNA damage, and many degenerative diseases (Masibo & He, 2008). Several carotenoids (β-carotene, luteoxanthin, neochrome, 9-cis-violaxanthin, and unusual carotenoid ester violaxanthin dibutyrate (Fig. 10) of mango cv. ‘Kent’) were isolated (Pott, Breithaupt, & Carle, 2003). Five quercetin (Q) glycosides and one kaempferol glycoside were unambiguously identified. The predominant flavonol glycosides were Q-3-galactoside (22.1 mg/kg FW), Q-3-glucoside (16 mg/kg), and Q-3-arabinoside (5 mg/kg). Among the phenolic acids, gallic acid was predominant (6.9 mg/kg). Quantification of the C-glycoside mangiferin (4.4 mg/kg) was also achieved by the HPLC (Schieber, Ullrich, & Carle, 2000). Glucose was the most important sugar constituent of the glycoside saccharic moiety, while significant amounts of arabinose and trace amounts of rhamnose were detected. Several aglycons ([Z]-hexen-3-ol, hexanol, hexanoic acid, 2,5-dimethyl-4-hydroxy-3-(2H)-furanone (furanol), linalool oxides, α-terpineol, carvacrol, vanillin, cis- and trans-6-p-menthen-2,8-diol, 1,8-p-menthadien-7-ol, 1-p-menthen-7,8-diol, and 9-hydroxy-megastigma-4-en-3-one) were identified. Ten glycosides [benzyl, 2-phenylethyl, and α-terpinyl glucosides and rutinose, eugenyl, vanillyl and furanyl glucosides and α-terpinyl arabinoglucoside] were identified. Linalyl oxide glucosides (4 isomers) and C13 norisoprenoid derivatives [9-hydroxymegastigma-4,6-dien-3-one (2 isomers), 9-hydroxy-megastigma-4,7-dien-3-one, and vomifoliol glucosides and arabinoglucosides] were also identified (Sakho, Chassagne, & Crouzet, 1997).

2.13. Mangosteen

The purple mangosteen (Garcinia mangostana), colloquially known simply as “the mangosteen”, is a tropical evergreen tree believed to have originated in the Sunda Islands and the Moluccas of Indonesia. The fruit is round, diameter 3.4–7.5 cm from the top is covered with a thick (up to 1 cm), maroon-purple inedible containing coloring gummy latex skin, beneath which is a 8.4 segment of white edible flesh from skintight to her seeds. The fruit is widely cultivated in Thailand, Myanmar, Vietnam, Cambodia, Malaysia, India, Sri Lanka, Philippines, Netherlands Antilles, Central America, Colombia, and tropical Africa. At low altitudes in Ceylon the fruit ripens from May to July; at higher elevations, in July and August or August and September. In India, there are 2 distinct fruiting seasons, one in the monsoon period (July-October) and another from April through June. However, snake fruit, salacca (Salacca edulis Reinw) and mangosteen (G. mangostana) are less known and also less investigated (Ketsa & Atantee, 1999; Setiawan, Sulaeman, Giraud, & Driskell, 2001; Shui & Leong, 2005; Supriyadi et al., 2002). Cyanidin-3-sophorose and cyanidin-3-glucoside were the major compounds and the only ones that increased with fruit color development (Palapol et al., 2009). Firmness and lignin content increased while total phenolics decreased in damaged mangosteen pericarp following impact. The phenolic compounds associated with lignin synthesis in damaged pericarp of mangosteen fruit after impact were separated and identified by UV

### Table 3

<table>
<thead>
<tr>
<th>Pol</th>
<th>Flavon</th>
<th>Flav</th>
<th>Tan</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Value</td>
<td>Value</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>MangoMe</td>
<td>3.79 ± 0.2x</td>
<td>0.412 ± 0.029</td>
<td>2.03 ± 0.11</td>
<td>1.86 ± 0.009</td>
</tr>
<tr>
<td>MangoW</td>
<td>3.79 ± 0.2x</td>
<td>0.412 ± 0.029</td>
<td>2.03 ± 0.11</td>
<td>1.86 ± 0.009</td>
</tr>
<tr>
<td>MangoAc</td>
<td>1.48 ± 0.05x</td>
<td>0.872 ± 0.047</td>
<td>17.22 ± 0.9</td>
<td>0.12 ± 0.01</td>
</tr>
<tr>
<td>MangoHe</td>
<td>0.16 ± 0.008</td>
<td>0.381 ± 0.029</td>
<td>18.19 ± 0.6</td>
<td>2.05 ± 0.1</td>
</tr>
</tbody>
</table>

The values are means ± SD of five measurements. Values in columns with different superscript letters differ significantly (P < 0.05).  
Abbreviations: Pol, polyphenols; Flav, flavonoids; Fl, flavones; Tan, tannins.

### Table 4

The antioxidant potential (μM TE g −1 DW) of mango in methanol (Me), water (W), acetone (Ac) and hexane (He) extracts.

<table>
<thead>
<tr>
<th>Source</th>
<th>ABTS</th>
<th>CUPRAC</th>
<th>FRAP</th>
<th>DPPH</th>
</tr>
</thead>
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<tr>
<td>MangoMe</td>
<td>27.31 ± 1.3</td>
<td>20.06 ± 1.1</td>
<td>7.45 ± 0.4</td>
<td>10.00 ± 0.5</td>
</tr>
<tr>
<td>MangoW</td>
<td>25.54 ± 1.3</td>
<td>19.34 ± 0.9</td>
<td>11.85 ± 0.5</td>
<td>27.31 ± 1.3</td>
</tr>
<tr>
<td>MangoAc</td>
<td>22.12 ± 0.5</td>
<td>16.26 ± 0.8</td>
<td>1.43 ± 0.1</td>
<td>5.31 ± 2.1</td>
</tr>
<tr>
<td>MangoHe</td>
<td>5.28 ± 0.3</td>
<td>1.18 ± 0.009</td>
<td>0.86 ± 0.04</td>
<td>2.01 ± 0.1</td>
</tr>
</tbody>
</table>

The values are means ± SD of five measurements. Values in columns with different superscript letters differ significantly (P < 0.05).  
Abbreviations: ABTS, CUPRAC, FRAP, DPPH.
isolates possess strong inhibitory activity of fatty acid synthase with the
G. mangostana neosmitilbin, and garcinone E were isolated from α-trihydroxyxanthone, egonol, fidi dibutyrate have been isolated from mango fruits.

Glucopyranosyl-1,3,6,7-tetrahydroxyxanthone; Alpizarin; Alpizarine; Aphloiol; Chinomin; Chinonin; Hedysarid; and/or shamimin as well as unusual carotenoid ester violaxanthin dibutyrate have been isolated from mango fruits.

Fig. 10. Mangiferin known as 9H-Xanthen-9-one, 2-β-D-glucopyranosyl-1,3,6,7-tetrahydroxy-xanthen-9-one (Garcinia mangostana) (Garcinone D; Garcinone C; Garcinone B; Chinomin; Chinonin; Hedysarid; and/or shamimin). This figure is adapted from Pott et al. (2003).

Fig. 11. Several xanthones isolated from Garcinia mangostana. This figure is adapted from Zhao et al. (2010).

IC₅₀ values ranging from 1.24 to 91.07 μM (Jiang et al., 2010). The crude ethanol extract (CEM) of the fruit hull of G. mangostana L. contains oxygenated and prenylated phenol derivatives, such as xanthones or xanthen-9H-ones, and is used by people in Southeast Asia as a traditional medicine for the treatment of abdominal pain, dysentery, wound infections, suppurative, and chronic ulcer. α-Mangostin, and γ-mangostin in each dose dependently demonstrated the ability to scavenge reactive oxygen species. CEM and mangostins possess potent peripheral and central antinociceptive effects in mice and suggest that xantheines may be developed as novel analgesics and anti-inflammatory drugs (Cui et al., 2010).

2.14. Passiflora

Passiflora (Passiflora edulis) is a Brazilian passion fruit or granadilla, peyshn, passion fruit and ripe fruit is with greenish-brown skin and juicy yellow-orange flesh, one of the most delicious varieties of passion fruit. Passion fruit is a yellow-orange or dark purple fruit, oval in shape and size of about 6–12 cm. The availability for passion fruit is spring through late summer (May to October). The varieties are the following: Panama, Passum Purple, Sweet Sunrise and Quadrangularis. The preferred fruits are with smooth shiny skin, but are sweeter with a rough, chapped skin. Known names include Granadilla (South America), Lilikoi (Hawaiian), Magrandera Shona (Zimbabwe), Maracuja (Brazil), Passion Fruit (UK and US), Passionfruit (Australia and New Zealand), Passiflora (Israel), Parchita (Venezuela), and Lac tien, Chanh day or Chanh leo (Vietnamese). It is cultivated commercially in frost-free areas for its fruit and is widely grown in Australia, Caribbean, California, Colombia, Brazil, Ecuador, East Africa, Indonesia, India, Israel, Hawaii, Florida, Mexico, New Zealand, Peru, Sri Lanka, and South Africa. The volatile oil was extracted from P. edulis. The main constituents were 2,4-dimethy-heptane (35.13%), trans-cinnamaldehyde (16.71%), trans-anethole (12.52%), α-cubebene (11.45%). The results gave basis for total exploration of CEM and mangostins possess potent peripheral and central antinociceptive effects in mice and suggest that xantheines may be developed as novel analgesics and anti-inflammatory drugs (Cui et al., 2010).
plants. The total properties. It has been suggested recently that anxiolytic-like activity without compromising motor activity. Kava characterizes luteolin-7-O-[2-rhamnosylglucoside], which showed an activity. Through fractionation of TFF it was possible to isolate and identify various passion fruits. The different species of passion fruit showed a typical composition. Purple passion fruit was characterized by a big number of identified compounds. The dominant compounds found in this variety of Passiflora were the hexyl butanoate (23.2%), hexyl hexanoate (18.4%), ethyl hexanoate (9.3%), cis-edulan I (5.6%), 1-methylhexyl butanoate (3.9%), ethyl butanoate (3.3%) and (Z)-3-hexenyl butanoate (3.0%). In banana passion fruit aroma, 22 volatile compounds were identified. The biggest peaks correspond to (Z)-β-ocimene (56.6%), hexyl butanoate (16.8%), hexyl hexanoate (13.9%) and hexanol (3.1%). Eight compounds, butyl acetate, butan-1-ol, β-myrcene, eucalyptol, (E)-β-ocimene, 3-carene, 3-methylhexyl butanoate, and hexyl-2-butozate, have been detected only in these species with the same experimental conditions. In yellow passion fruit 24 volatile compounds were detected and tentatively identified. The major compounds found in this variety were methyl hexanoate (32.9%) followed by (E)-methyl-2-hexenoate (11.7%), methyl benzoate (11.3%), methyl dihydrojasmonate (6.2%), and dihydro β-ionone (4.9%). This presents fewer compounds than purple passion fruit. Some of the identified volatiles were found only in these species of passion fruit such as (E)-methyl-2-hexenoate, methyl benzoate, 3-hydroxymethyl hexanoate, 2-(2-butoxyethoxy) ethanol, β-ionone, methyl dodecanoate, isopropyl miristate, ethyl cinnamate, isopropyl miristate, nonanoic acid, methyl hexadecanoate and methyl dihydrojasmonate (Pontes, Marques, & Camara, 2009). Passion fruit is known for many ethno-pharmacological properties and contains a strong allelopathic potential. In a bioassay, aqeous extracts of *P. edulis* strongly suppressed germination and growth of lettuce, radish and other plants (Khanh, Chung, Tawata, & Xuan, 2006). The extract of passion fruit had the effect of lowering blood pressure and serum nitric oxide levels in mammals. The extract also provides a hepatoprotective effect, as well as antioxidant and anti-inflammatory effects in mammals. Novel compounds were identified in the extract (Fig. 12) and named *E* or *Z*-edulic acid fruits (Foo, Lu, & Watson, 2005). *P. edulis* Sims together with several other plants of the genus *Passiflora* has been reported (Coleta et al., 2006) to possess anxiolytic properties. It has been suggested recently that flavonoids may be partly responsible for the neuropharmacological activity of these plants. The total flavonoid fraction (TFF) presented an anxiolytic-like activity. Through fractionation of TFF it was possible to isolate and characterize luteolin–7-O-[2-rhamnosylglucoside], which showed an anxiolytic-like activity without compromising motor activity. Kava kava extract, Passiflora extract and a combination of both extracts (due to a synergism) administered to mice, caused a significant decrease of the amphetamine-induced hypermotility and significant prolongation of sleeping phase induced by subcutaneous injection of barbiturates (Capasso & Sorrentino, 2005). Due to a synergism of both extracts, simultaneously administered the pharmacologically registered effect in both in vivo experiments was found to be superior over the sum of the single separately administered extracts. Anti-inflammatory activity of *P. edulis* hydroalcoholic extract, similar to non-steroidal anti-inflammatory drugs, has been described (Gomes et al., 2006). Forty male Wistar rats were randomly allocated into two groups to either receive *P. edulis* extract (study group, P) or saline (control group, C) intraperitoneally, in a single isovolumetric dose, after a standardized ventral midline laparotomy had been performed. *P. edulis* extract enhances the healing of midline abdominal incisions in rats, especially the histological and tensiometric aspects. The plants more frequently used with therapeutic purposes to treat emotional problems are: alpiste, azahar, damiana de California, biebra de san Juan, flor de manita; flor de tila, lechuga, malva, pasiflora, tumbaraquero, toronjil and valeriana (Berenson & Saavedra, 2002).

Persimmon (*Diospyros kaki* L.) is originated in Japan with two widespread varieties: ‘Fuio’, which has seeds, and ‘Triumph’, which is seedless, the shape-round, texture — crispy, taste — ripesweet, if not astringent. The processing of persimmon is a sweetening ingredient in baked products and fruity ice creams, jellies, nectars, in dry form. The availability of persimmon is from September through December. Persimmon is used in its fresh form as a source of polyphenols, which serves as natural antioxidants, dry and also as a beverage. It was shown that persimmon can be used for the production of liqueur. The amount of phenolics and the antioxidants is relatively high (Gorinstein et al., 1993; Gorinstein et al., 1994). Persimmons resulted rich in sugars (about 12.5 g/100 g FW), being fructose, glucose and sucrose the major components, and in total vitamin C, for which 100–150 g of fresh persimmon supplies the recommended daily amount. The main carotenoid components are β-cryptoxanthin (193 μg/100 g FW), β-carotene (113 μg/100 g FW) and β,e-carotene (30 μg/100 g FW). Persimmons are also a good source of polyphenolic compounds such as p-coumaric acid, catechin, epicatechin, epigallocatechin, and condensed proanthocyanidins (Giordani, Doumett, Nin, & Del Bubba, 2011). The most common varieties are Fuyu and Triumph. Calli of *D. kaki* Thumb. were induced on MS solid medium supplemented in the dark and successfully subcultured on the same medium. A new phenolic metabolite, 7-methyl-1,4,5-trihydroxynaphthalene 4-O-[β-D-glucopyranosyl-2-cyclopenten-1-ylidene]-E-carotene (Fig. 13) was isolated from MeOH extract of the callus cultures (Gondo et al., 1999). In an evaluation of the relationship between volatile compounds and flavors in persimmons, such compounds from the flesh of different astringent persimmon cultivars were analyzed, and the changes in these compounds after removal of astringency with CO2 were reported. Volatiles from Hiratanenashi, Yokono, and Atago persimmon fruit were...
A component was isolated and identified including n-BuOH, 3-Me butanol, n-hexanol, (2)-3-hexen-1-ol, 2-Me hexanol, acetoin, and AcOH were common to the 3 cultivars. The degree of quality change in the volatile compounds during treatment differed depending on the cultivar; it was the largest in Yokono and the smallest in Hiratanenashi (Taira, Ooi, & Watanabe, 2005). Persimmon bioactivity was compared with some other fruits (Gorinstein, Zemser, Haruenukit, et al., 1999; Gorinstein et al., 1994; Gorinstein et al., 2001). Fluorometric analysis was used to compare the contents of phenolics in two cultivars of persimmon: seedless 'Triumph' and seed contain 'Fuio'. It was reported that seedless Triumph possess significantly higher amount of total phenolics and that the main component was p-coumaric acid (Gorinstein et al., 1994). Fluorometry and atomic absorption spectrometry following microwave digestion were reported for the determination of major phenolics and minerals and show that total, soluble, and insoluble dietary fibers, total phenols, epicatechin, gallic and p-coumaric acids, and concentrations of Na, K, Mg, Ca, Fe, and Mn in whole persimmons, their pulps, and peels were significantly higher than in whole apples, pulps, and peels. Conversely, the contents of Cu and Zn were higher in apples than in persimmons. In persimmons and apples all of the above components were higher in their peels than in whole fruits and pulps. The relatively high contents of dietary fibers, total and major phenolics, main minerals, and trace elements make persimmon preferable for an antiatherosclerotic diet (Gorinstein, Bartnikowska, et al., 1998). Phenolic metabolite

\[
\text{ Phenolic metabolite }
\]

Fig. 13. Novel phenolic compound 4,8-dihydroxy-6-methyl-1-naphthalenyl 6-O-β-D-xylopyranosyl-β-D-glucopyranoside was isolated from Diospyros kaki. This figure is adapted from Gondo et al. (1999).

steam-distilled under reduced pressure before and after the removal of astringency. At least 9 out of 23 volatile compounds which were isolated and identified including n-BuOH, 3-Me butanol, n-hexanol, (2)-3-hexen-1-ol, 2-Me hexanol, acetoin, and AcOH were common to the 3 cultivars. The degree of quality change in the volatile compounds during treatment differed depending on the cultivar; it was the largest in Yokono and the smallest in Hiratanenashi (Taira, Ooi, & Watanabe, 1996). Persimmon bioactivity was compared with some other fruits (Gorinstein, Zemser, Haruenukit, et al., 1999; Gorinstein et al., 1994; Gorinstein et al., 2001). Fluorometric analysis was used to compare the contents of phenolics in two cultivars of persimmon: seedless ‘Triumph’ and seed contain ‘Fuio’. It was reported that seedless Triumph possess significantly higher amount of total phenolics and that the main component was p-coumaric acid (Gorinstein et al., 1994). Fluorometry and atomic absorption spectrometry following microwave digestion were reported for the determination of major phenolics and minerals and show that total, soluble, and insoluble dietary fibers, total phenols, epicatechin, gallic and p-coumaric acids, and concentrations of Na, K, Mg, Ca, Fe, and Mn in whole persimmons, their pulps, and peels were significantly higher than in whole apples, pulps, and peels. Conversely, the contents of Cu and Zn were higher in apples than in persimmons. In persimmons and apples all of the above components were higher in their peels than in whole fruits and pulps. The relatively high contents of dietary fibers, total and major phenolics, main minerals, and trace elements make persimmon preferable for an antiatherosclerotic diet (Gorinstein, Bartnikowska, et al., 1998). Another study compares the hypolipidemic and antioxidant effects of two diets in rats fed cholesterol (Gorinstein et al., 2000) and shows that both diets fortified with 7% of whole dry persimmon and with 7% of phenol-free dry persimmon improve lipid levels. But only diet supplemented with whole persimmon exerts an antioxidant effect. Therefore, the antioxidant effect of this fruit is associated mainly with persimmon phenols and not with the persimmon fiber. Another study in vivo compared two diets supplemented with 7% of dry persimmon peel and dry persimmon pulp (Gorinstein, Kulasek, et al., 1998) in rats fed cholesterol. A diet fortified with dry persimmon peel is more efficient than the same diet fortified with dry persimmon pulp. Therefore the persimmon peel showing the effectiveness of its antioxidant activity can be used by individual consumers and in industrial processing. The nutraceutic value of persimmon (D. kaki Thunb. cv. Triumph) and its influence on some indices of atherosclerosis were studied in vivo (fibers, polyphenols, and phenolic acids) and in experiment on rats fed cholesterol-containing diet (Park, Jung, Kang, Delgado-Licon, Ayala, et al., 2006; Park, Leontowicz, et al., 2008). Addition of persimmon to the diets did not affect diet intake, its efficiency or body weight gains of rats. Diets supplemented with whole fruit positively influenced some indices of atherosclerosis in serum of rats fed a cholesterol-containing diet: it hindered the rise of lipid levels and the decrease in the antioxidant activity (Park, Jung, Kang, Delgado-Licon, Ayala, et al., 2006; Park, Leontowicz, et al., 2008). Other persimmon cultivars ('Fuyu' and 'Jiro') were compared with cv. 'Triumph' in vitro and in vivo studies. 'Fuyu' was more effective than 'Jiro' in the contents of polyphenols, flavonoids, flavanols, tannins, carotenoids, ascorbic acid and antioxidant potentials. Supplementation with 5% of the lyophilized Fuyu and Jiro hindered the increase in plasma lipids vs. the Chol group (total cholesterol 19.4% and 9.5%, low-density lipoprotein cholesterol 25.6% and 13.1%, respectively, P < 0.05) and hindered the decrease in plasma antioxidant activity vs. the Chol group by 40.0% and 16.8% and by 39.6% and 11.3% for the ABTS and DPPH assays, respectively. The atherosclerotic lesions in the aortas of the Chol/Fuyu and Chol/Jiro groups were significantly less than in the Chol group (P < 0.05) during a period of 47 d (42 d of feeding and 5-d adaptation before the experiment). The histological investigation of aortas showed that the Chol containing diet led to changes in the aorta. The highest concentration of lesions was in the arch of aorta (Fig. 14).
The Chol diet group showed the greatest aortic changes compared with the control diet and the groups supplemented with persimmon (Fig. 14II). Electrophoresis of the proteins from rats' liver tissue reported changes in 14-kDa bands after persimmon supplementation. A shift in maximum wavelengths in three-dimensional fluorescence of serum protein fractions after persimmon supplementation was found in comparison with the control group and an increase in fluorescence intensity compared with the Chol groups (Gorinstein, Leontowicz, et al., 2011). Primary metabolites (sugars, organic acids) and secondary metabolites (phenolics and carotenoids) were quantified by HPLC in fully ripe fruit of 11 kaki cultivars Amankaki, Cal Fuyu, Fuji, Hana Fuyu, Jiro, O'Gosho, Tenjin O'Gosho, Thiene, Tipe, Tone Wase and Triumph (Veberic, Jurhar, Mikulic-Petkovsek, Stampar, & Schmitzer, 2010). Tone Wase stands out as the richest in sugars, particularly glucose, and cultivars Tipe and Triumph contained the highest amounts of organic acids. Cultivars O'Gosho, Cal Fuyu and Hana Fuyu contained the least sugars and cultivar 'Jiro' the least organic acids. Catechin and gallic acid were present in the highest concentration. The predominant carotenoid in both skin and pulp of ripe persimmon fruit was \( \beta \)-carotene. The highest content was measured in skin of cultivar Hana Fuyu, which also contained the highest level of total carotenoids. In persimmon pulp, much lower values for carotenoids were obtained in fruit of cultivar Cal Fuyu (Gondo et al., 1999; Taira et al., 1996).

### 2.16. Pineapple

Pineapple (Ananas comosus Merr.), known as Queen variety, Phuket, is native to South America and has now spread throughout the tropical world. It is a big fruit of about 1 to 2 kg/fruit, conical with a crown; texture is juicy and fibrous; and the taste is sweetened sour. The fruit is used as fresh and processed (canned juice or canned slices, jam, and glaze) and available all year around. Pineapple cultivars are divided into five groups. It was reported that two types of the fruit were investigated: the smooth Cayenne, which is characterized by pale yellow to yellow flesh, and the Queen, which is characterized by deep yellow flesh (Gorinstein, Zemser, Vargas-Albores, et al., 1999). The phenolic contents of the extracts as caffeic acid equivalents were found to be the highest in methanol (51.1%), followed by ethyl acetate (13.8%) and water extract (2.6%). Antioxidant capacity of the extracts as equivalent to ascorbic acid (\( \mu \)mol/g DW) was in the order of methanol extract > ethyl acetate extract > water extract. In comparison with butylated hydroxyanisole (BHA), at 100 ppm of concentration, the antioxidant and free radical scavenging activities of the extracts assayed through \( \beta \)-carotene-linoleate and DPPH method were also found to be the highest with methanol extract followed by ethyl acetate and water extracts. The results indicated that the extent of antioxidant activity of the extract is in accordance with the amount of...
phenolics present in that extract and the pineapple fruit being rich in phenolics may provide a good source of antioxidant (Hossain & Rahman, 2011). The antioxidant content of fruit was compared as pre-packed fresh-cut vs. whole fruit (Opara & Al-Ani, 2010). The obtained results of the contents of phenolic compounds in peel, core and pulp of pineapple by HPLC showed that there were four phenolic compounds in the peel of pineapple: gallic acid, catechin, epicatechin and ferulic acid. While in pulp and core of pineapple, only low concentrations of epicatechin and ferulic acid were detected (Yi, Wei, Teng, & Gao, 2006). Among the 187 isolated volatile components of Philippine pineapple were identified the following: 2,5-dimethyl-4-methoxy-3(2H)-furaneone, Me 3-(methylthio)propanoate, and γ-hexalactone were accounting for approximately 55% of the total volatiles. In addition, 11 sulfur-containing compounds were found in the aroma extract, including 8 components newly identified such as Me 5-Me thiomalonate and Et 5-(methylthio)pentanoate. The estimation on the sensory relevance of volatiles by AEDA indicated 2,5-dimethyl-4-hydroxy-3(2H)-furaneone, 2,5-dimethyl-4-methoxy-3(2H)-furaneone, γ-octalactone, 3- (methylthio)propanal, and Me 5-Me thiomalonate as the major odor-active components of Philippine pineapple aroma (Akioka, 2008). One hundred and eighteen volatile compounds from fresh pineapple pulp were identified according to their retention time on polar and apolar capillary columns and their mass spectra. These compounds were divided as follow: seven hydrocarbons (3.3%), nine sulfur compounds (10.3%), 42 esters (44.9%), 10 lactones (11.5%), 11 carbonyl compounds (4.7%), 14 acids (7.3%), 11 alcohols and phenols (3.8%), and 14 miscellaneous components (14.3%). Four compounds were found at a level higher than 1 mg/kg, Me octanoate (1.49 ppm), Me 3-(methylthio) propanoate (1.14 ppm), Me hexanoate (1.1 ppm) and 3-methyl-2,5-furandione (1.07 ppm), three others were detected at a level between 0.5 ppm and 1 ppm, and 25 compounds at a level between 0.1 ppm and 0.5 ppm. From the reported 118 compounds, 71 have already been described in the literature to be present in pineapple aroma (Teai, Claude-Lafontaine, Schippa, & Cozzolino, 2001). Sixty-seven free volatiles of pineapple var. perolera were identified with Me 2-Me butanoate, Me hexanoate, Me 4-acetoxy-hexanoate, Me 5-acetoxy-hexanoate and Me 3-methyl-thiopropanoate as major components. Total 2,5-dimethyl-4-hydroxy-3(2H) furanone (DMHF) (free and glycosidically bound) in pineapple were detected in the juice of crushed pineapple with ETOAc after treatment with almid β-glucosidase (Wu et al., 1990). Glycosidically 17 bound aroma compounds (aglycons) were also identified. These aglycons mainly consisted of phenolic compounds, carboxylic acids and furanic compounds of which coniferyl alcohol, hexadecanoic acid, furanone and 4-vinylguaiacol are the most representative (Sinuco, Morales, & Duque, 2004). Several sterols were detected in the juices of pineapple, passion fruit and the two citrus fruits, orange and grapefruit such as β-Sitosterol, Stigmastosterol, Citrostadienol, Campesterol, Isofucosterol, Stigmaster-4-en-3-one, Valencene, Nootkatone and Ergostanol. Ergostanol and stigmastanol were found to be the sterol markers for pineapple juice, while passion fruit juice was characterized by the presence of an unidentified but unique sterol referred to as compound C. Juices of orange and grapefruit yielded very similar sterol profiles (Na & Hup, 1998). Tokimoto, Steinhaus, Buttner, and Schieberle (2005) showed that 12 selected odorants revealed the following compounds as key odorants in fresh pineapple flavor: 4-hydroxy-2,5-dimethyl-3(2H)-furaneone (HDF, sweet, pineapple-like, caramel-like), ethyl 2-methylpropanoate (fruity), ethyl 2-methylbutanoate (fruity) followed by methyl 2-methylbutanoate (fruity, apple-like) and 1-(E)-2,3-5-undecatriene (fresh, pineapple-like). The phytochemical screening was conducted in order to detection the biological active compounds present in the exocarp of papaya (Carica papaya), pineapple (A. comosus), and star apple (Chrysophyllum cainito). These bioactive compounds which have shown remarkable importance in the field of medicine are the following: alkaloids, saponins, cardenolides and bufadienolides, flavonoids, tannins, anthraquinones and cyanogenic glycosides. Findings of this experimental research showed that flavonoids, tannins, cardenolides, bufadienolides and alkaloïds were present in the exocarp of star apple (C. cainito). The exocarp of papaya (C. papaya) contains saponins, tannins, cardenolides and bufadienolides (Gundran et al., 2001). Bromelain, a pharmacologically active compound, is present in stems and fruits of pineapple (endozed with anti-inflammatory, anti-invasive and anti-metastatic properties). The antitumor-initiating effects of bromelain in mouse skin tumorigenesis model were reported (Bluji, Prasad, George, & Shukla, 2009). Pre-treatment of bromelain resulted in reduction in cumulative number of tumors per mouse. The basis of antitumour-initiating activity of bromelain was revealed by its time dependent reduction in DNA nick formation and increase in percentage prevention. Modulation of inappropriate cell signaling cascades driven by bromelain is a coherent approach in achieving chemoprevention (Bluji et al., 2009).

2.17. Rambutan

Rambutan (Nephelium lappaceum L.), known as Rongroen, is native to Malaysia. Shaped as bright-red oval fruit is about the size of a small hen’s egg with a seed, hairy peel with long, soft spines, aril is edible part; with the texture of juicy, translucent aril and the taste — sweet with a tasty acid pulp. The processed rambutan is canned in syrup. The availability is from June through August. Over 100 volatile compounds from the red-skinned cultivar of rambutan, Jittlee (N. lappaceum L.), a tropical fruit native to Southeast Asia, were detected by GC/MS. Sixty compounds in the extracts had some odor activity. The 20 most potent odorants included β-damascone, (E)-4,5-epoxy-(E)-2-decenal, vanillin, (E)-(E)-2-nonenal, phenylacetic acid, cinnamic acid, Ethyl 2-methylbutyrate, and 6-decalactone, β-Damascone, Et 2-methylbutyrate, 2,6-nonadicol, (E)-(E)-2-nonenal, and nonanal were detected as the main compounds among the fruit aroma (Ong, Acree, & Lavin, 1998). The peel of N. lappaceum possesses antioxidant properties. Methanolic and aqueous extracts of lyophilized rambutan peels and seeds were evaluated for phenolic contents, antioxidant and antibacterial activities (Thitiledecha, Teerawutgulra, & Rakariyatham, 2008). High amounts of phenolic compounds were found in the peel extracts and the highest content was in the methanolic fraction (542.2 mg/g dry extract). The peel extracts exhibited higher antioxidant activity than the seed extracts in all methods determined. The methanolic fraction was found to be the most active antioxidant as shown by their 50% DPPH center dot inhibition concentration, 4.94 µg/ml. This fraction exhibited higher DPPH center dot radical scavenging activity than BHT and ascorbic acid (0.32 g dry extract/g BHT or ascorbic acid). All peel extracts exhibited antibacterial activity against five pathogenic bacteria. The most sensitive strain, Staphylococcus epidermidis, was inhibited by the methanolic extract (MIC 2.0 mg/ml). Experiments on the isolation and identification of the active constituents were conducted, and on their antioxidant activity using a lipid peroxidation inhibition assay. The methanolic extract of N. lappaceum peels exhibited strong antioxidant properties. The isolated compounds (Fig. 15) were identified as ellagic acid (EA), corilagin, and geraniin. These compounds accounted for 69.3% of methanolic extract, with geraniin (56.8%) as the major component, and exhibited much greater antioxidant activities than BHT in both lipid peroxidation (77–186 fold) and DPPH (42–87 fold) assays. The results suggest that the isolated ellagitannins, as the principal components of rambutan peels, could be further utilized as both a medicine and in the food industry (Thitiledecha, Teerawutgulrag, Kilburn, & Rakariyatham, 2010). The rind of rambutan, which is normally discarded was found to contain extremely high antioxidant activity when assessed using several methods. Although having a yield of only 18%, the ethanolic
rambutan rind extract had a total phenolic content of 762 ± 10 mg GAE/g extract, which is comparable to that of a commercial preparation of grape seed extract. Comparing the extract’s prooxidant capabilities with vitamin C, α-tocopherol, grape seed and green tea, the rind had the lowest prooxidant capacity. In addition, the extract at 100 μg/ml was seen to limit oxidant-induced cell death (DPPH at 50 μM) by apoptosis to an extent similar to that of grape seed. The extracts were not cytotoxic to normal mouse fibroblast cells or splenocytes while the powderized rind was seen to have heavy metal contents far below the permissible levels for nutraceuticals. These findings for the first time reveal the high phenolic content, low prooxidant capacity and strong antioxidant activity of the extract from rind of N. lappaceum. This extract, either alone or in combination with other active principles, can be used in cosmetic, nutraceutical and pharmaceutical applications (Palanisamy et al., 2008). The ability of ethanolic N. lappaceum L. rind extract to act as anti-hyperglycemic agent was reported. Geraniin, an ellagittannin, was identified as the major bioactive compound isolated from the ethanolic N. lappaceum L. rind extract. In addition to its extremely high antioxidant activity and low prooxidant capability, geraniin possesses in vitro hypoglycemic activity (alpha-glucosidase inhibition: IC50 = 0.92 μg/ml and alpha-amylase inhibition: IC50 = 0.93 μg/ml), aldol reductase inhibition activity (IC50 = 7 μg/ml) and has the ability to prevent the formation of advanced glycation end-products (AGE). Geraniin was observed to exhibit these properties at more significant levels compared to the positive controls acarbose (carbohydrate hydrolysis inhibitor), quercetin (aldol reductase inhibitor) and green tea (AGE inhibitor). Geraniin (Fig. 15) has the potential to be developed into an anti-hyperglycemic agent. These findings also strongly support the use of a geraniin-standardized N. lappaceum extract in the management of hyperglycemia (Palanisamy, Teng, Manaharan, & Appleton, 2011).

Salak (S. edulis), snakes on a fruit — a fruit tree plant palm family (Areaceae, Palmae, and Palmaeae) (Fig. 16). The snake fruit in Thailand — sala, rakum, in Malaysia and Indonesia — salak, with a diameter of 3–4 cm, weight 50–100 g. The fruit is with an oval shape (the ends are elongated). It has a size of a kiwifruit with a scaly brown rind that is easily removed. The beige flesh consists of one or several segments. The fruit is distributed mainly in Southeast Asia. The season in Thailand and Malaysia is from June to August, in Indonesia — all year round. It is popular in Indonesia and Malaysia, and the fruit is rarely found in other countries. It is believed that the most delicious fruits grow in Bali and around Yogyakarta in Java. The findings (Ikram et al., 2009) showed that fruits (58 underutilized fruits of 32 different species from 21 genera) of Pomelia, Averrhoa, Syzygium, Sallaca, Phyllanthus, Garcinia, Sandoricum and Maipigia had higher antioxidant activity compared to other studied genera. Among the underutilized fruits, Sandoricum and Phyllanthus contained the highest total phenolics (>2000 mg/100 g edible portion). The study indicated that some of these underutilized fruits have the potential to be sources of antioxidant components. Forty-six volatile constituents of the salak fruit (Wong & Tie, 1993) were identified by GC–MS and 1H NMR which Me esters of branched-chain alkenoic and β-hydroxy acids predominated and terpenoids were completely absent. The most abundant components were Me 3-hydroxy-3-methylpentanoate (25.0%) and Me (E)-3-methylpent-2-enoate (23.4%). A total of 24 odor-active compounds from three cultivars of snake fruits (Pondoh, Hitam, Pondoh Super, and Gading) were freshly extracted and associated with the aroma of snake fruit. Me 3-methylpentanoate was regarded as the character impact odorant of typical snake fruit aroma. 2-Methylbutanoic acid, 3-methylpentanoic acid, and an unknown odorant with very high intensity were found to be responsible for the snake fruit’s sweaty odor. Other odorants including Me 3-methyl-2-butoenoate (overripe fruity, ethereal), Me 3-methyl-2-pentenoate (ethereal, strong green, woody), and 2,5-dimethyl-4-hydroxy-3(2H)-furanone (caramel, sweet, cotton candy-like) contribute to the overall aroma of snake fruit. The main differences between the aroma of Pondoh and Gading cultivars could be attributed to the olfactory attributes (metallic, chemical, rubbery, strong green, and woody), which were perceived by most of the panelists in the Pondoh samples but were not detected in the Gading samples (Wijaya, Ulrich, Lestari, Schippel, & Ebert, 2005). The compounds of 3β-hydroxy-sitosterol and 2-methyl-ester-1-H-pyrrrole-4-carboxylic acid were isolated from ethyl acetate extract of snake fruit (S. edulis Reinw) cv. Bongkok (Fig. 17). Inhibition of xanthine oxidase by the two compounds was evaluated against enzyme of xanthine oxidase. 3β-Hydroxy-sitosterol could be regarded as inactive, while 2-methyl-ester-1-H-pyrrrole-4-carboxylic acid was found to be active with IC50 Value of 48.86 μg/ml (Priyatno, Sukandar, Ibrahim,
Snake fruit was compared with mangosteen and kiwifruit in investigations in vitro and in vivo (Gorinstein et al., 2009; Leontowicz et al., 2006; Leontowicz et al., 2007). It was reported that the content of polyphenols (14.9 ±1.5 and 9.2±0.8 mg GAE/g) and antioxidant potential (46.7±4.7 and 72.9±7.4 μmol TE/g) in snake fruit was significantly higher than in mangosteen (P<0.05). After 4 weeks of the experiment on Wistar rat diets supplemented with snake fruit and to a lesser degree with mangosteen significantly hindered the rise in plasma lipids and hindered a decrease of antioxidant activity. Changes were found in fibrinogen fraction, such as solubility and mobility by the number of protein bands detected in SDS-electrophoresis: Chol/Snake differed from Chol/Mangosteen. In rat’s plasma of the Chol/Snake diet group, the fibrinogen fraction showed a decrease in the amounts and compositions of electrophoretic protein bands in the range of 110 and 14 kDa. However, all the positive results of this experiment on animals could not be automatically applied to humans. It was reported that a less known snake fruit was compared with kiwifruit, using fluorometry, FTIR spectroscopy, several radical scavenging and proliferative assays and statistical evaluation (Gorinstein et al., 2009). Similarity between snake fruit (cultivar ‘Sumalee’) and kiwifruit (cultivar ‘Hayward’) in the contents of polyphenols (8.15–7.91, mg GAE/g DW), antioxidant values by DPPH (11.28–10.24, μMTE g−1 DW), and antiproliferative activities on both human cancer cell lines (Calu-6 for human pulmonary carcinoma, and SMU-601 for human gastric carcinoma, 90.5–87.6 and 89.3–87.1%, cell survival, respectively) was found. Snake fruit cultivar ‘Sumalee’ is comparable with kiwifruit cultivar ‘Hayward’. Two fruits can be used as supplements to the normal diet. Consumption of a combination of both fruits could be recommended in order to receive the best results. The results of principal component analysis (PCA) are depicted on a three-dimensional plot (Fig. 18B), which is able to explain 99.8% of total variance. Box and dot plots in

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**Fig. 17.** 2-methylester-1-H-pyrrole-4-carboxylic acid isolated from Solacca edulis. This figure is adapted from Priyatno et al. (2007).

**Fig. 18.** A. Box and dot plots of the frequency distribution of the snake fruit, and two kiwifruit samples: conventional ‘Hayward’ (CHE) and organic ‘Hayward’ ethylene treated; B, Principal component analysis of FRAP parameters of snake fruit (S), kiwifruit OHE (Ko) and kiwifruit CHE (Kc) extracts (5–25 mg/ml). This figure is adapted from Gorinstein et al. (2009).
Fig. 18A show the frequency distribution of the snake fruit, and two kiwifruit samples: conventional 'Hayward' ethylene treated (CHE) and organic 'Hayward' ethylene treated (OHE). The antioxidant activities (μMTE/g DW) were determined according to FRAP assay in the wide-ranking interval of fruit extract concentrations from 5 to 25 mg/ml. FRAP data vary widely and all box plots have approximately the same variation (Gorinstein, Leontowicz, et al., 2011). There is a degree of resemblance between these two kiwifruits (CHE and OHE), but the largest similarities exist between snake and kiwifruits. It was shown that 3D-FL spectrum provides the change in the conformation of proteins (Fig. 19). The main peak (Fig. 19A) of bovine serum albumin (BSA) at λ<sub>em/ex</sub> = 340/280 was quenched in the presence of methanol extracts of studied exotic fruits, (example of snake fruit), as well as in the presence of pure catechin as a standard. Different proportions of polyphenols and BSA were investigated. The strongest intensity (Fig. 19D) was for BSA at extract:BSA (1:1) and the lowest (Fig. 19C) for extract:BSA (5:1). The decrease in the fluorescence intensity (Fig. 19E) showed the conformation of the BSA changes in the presence of extracts. There are few publications on applications of 3D fluorescence spectra (Shi et al., 2010; Zhang, Chen, Zhou, & Wang, 2009), therefore the conclusions that 3-D fluorescence can be used as an additional tool for the characterization of the polyphenol extracts during different stages of ripening and different exotic fruits cultivars correspond with the previous data (Gorinstein et al., 2011-this issue; Gorinstein et al., 2010). The results revealed that polyphenol extracts caused the fluorescence quenching of BSA by the formation of polyphenol–BSA complex.

2.19. Star fruit

The star fruit or carambola (Averrhoa carambola) is a tropical fruit that is gaining popularity in the United States. This fruit acquired its name from the five pointed star shape when cut across the middle of the fruit. It has a waxy, golden yellow to green color skin with a complicated flavor combination that includes plums, pineapples, and lemons. The following varieties of this fruit are Arkin, Fwang Tung, Kari, and Sri Kembangan. The juicy fruits are yellow inside when ripe and have a crisp texture and when cut in cross-section are star shaped. The fruits have an oxalic acid odor, which varies between plants from strong to mild, the taste also varies from very sour to mildly sweetish. Each fruit may have up to twelve 6–12.5 mm long seeds, which are flat, thin and brown. The flowers are often produced year round under
tropical conditions. The availability is August–March. Carambola (star fruit) is a popular tropical fruit consumed fresh or as juice. Carambola is one of two species in the genus *Averrhoa* (family Oxalidaceae), the other species is *Averrhoa bilimbi*. *A. carambola* or star fruit is a juicy tropical fruit grown in Thailand and throughout Southeast Asia (Shui & Leong, 2004a, 2004b).

The optimized extraction conditions for total phenolic contents (TPC) of star fruit residues using response surface methodology (RSM) are with acetone (60%), during 180 min, at 40 °C. The highest TPC values of star fruit residues were 2366.71, 2436.03, and 2510.95 mg GAE/100 g DW, respectively. The results showed that the acetone concentration was statistically the most significant factor (p < 0.01) and the optimal extraction conditions obtained were: acetone concentration, 65.34%; extraction temperature, 43.18 °C; and extraction time, 233.51 min. The experimental TPC was 965.65 ± 30.87 mg GAE/100 g DW, which was well matched with the predicted value, 965.52 mg GAE/100 g DW (Yap et al., 2009).

Phytochemical studies on the leaves and fruits of *A. carambola* yielded anthraquinones, flavone C-glycosides, anthocyanins and dihydroabscisic alcohols. Recently, it was reported the isolation of two new alkyl phenols, 2,5-dimethoxy-3-undecylphenol and 5-methoxy-3-unecylphenol, together with two known benzoquinones, 5-0-methylumbellin and 2-dehydroxy-5-0-methylumbellin (Arah et al., 2005; Xu et al., 2004; Chakthong, Chiraphan, Jundee, Chawalit, & Voravuthikunchai, 2010). It was indicated that star fruit is a very good source of natural antioxidants, and it was reported the identification of compounds that contribute to total antioxidant activity in star fruit using HPLC and MS (Fig. 20). The major antioxidants were initially attributed to singly-linked proanthocyanidins that existed as dimers, trimers, tetramers and pentamers of catechin or epicatechin (Shui & Leong, 2004a, 2004b). The toxic effect of star fruit juice at different storage conditions in Sprague Dawley (SD) rats (Khoo, Teh, Rao, & Chin, 2010; Chakthong et al., 2010) was evaluated. Increment of ALT levels (P < 0.05) was reported in those rats treated with *A. carambola* juice stored for 3 h. It was concluded that *A. carambola* juice stored for 0 h and 1 h are safe to be consumed. However, juice stored for 3 h exerts toxic effect on rat liver at hepatocellular level. Pre-treatment of mice with the fruit extract of *A. carambola* significantly reduced serum levels of alkaline phosphates (ALP), aspartate aminotransferase (AST), and alkaline phosphates (ALP), enzyme and significantly increased the liver reduced glutathione levels 24 h after the administration of carbon tetrachloride. A marked improved in the enzyme activities and the liver reduced glutathione level was observed in the pre-treated mice 4 days after the administration of carbon tetrachloride. Histopathological studies provided supportive evidence for the biochemical analysis. The aqueous extract of the fruit of *A. carambola* has hepatoprotective effect against carbon tetrachloride induced liver damage in mice (Azeema, Mathew, Dilip, & Nair, 2010). It was reported (Shui & Leong, 2006) that the residue of star fruit, which is normally discarded during juice drink processing, was found to contain much higher antioxidant activity than the extracted juice using several methods for assessing antioxidant activity. The residue accounted for around 70% of total antioxidant activity (TAA) and total polyphenolic contents, however only contributed 15% of the weight of whole fruit. Freeze-dried residue powder, which accounted for around 5% of total weight, had total polyphenolic content of 33.2 ± 3.6 mg GAE/g sample and total antioxidant activity of 5270 ± 468 and 5152 ± 706 mg TEAC/g sample ABTS and DPPH scavenging assays, respectively. HPLC/MS shows that major proanthocyanidins in star fruit were different from their isomers in pyconogelon. The high content of phenolics and strong antioxidant activity of residue extracts indicate that residue powder may impart health benefits, when used in functional food products. The residue extracts should also be regarded as potential nutraceutical resources in future. It was found that among 96 detected volatile components from the pericarp of star fruit, 1,Phenyl dodecanol and 1-Phenyl undecane were the major identified hydrocarbons (17% and 11% respectively). The oxygenated constituents were dominated by a mixture of aldehydes (14%), among which cyclohexyl octadecanal (8%) was the major one. The crude protein content was 11% on DW bases. The amounts of vitamin C and β-carotene reached 28 mg/100 g and 623 μg/100 g, respectively, while α-tocopherol and vitamin D were not detected. The major minerals were potassium (222 mg/100 g) and calcium (41 mg/100 g). The tannin content was 1.04% on DW. The alcohol extract exhibited anti-inflammatory, antipyretic, analgesic, anticonvulsant, antioxidant, hypolipidemic and hypoglycemic activities of variable potency as compared to referred drugs. In addition, both the alcohol extract and the volatile constituents exerted significant antimicrobial activities on selected bacteria and fungi (El Aly, Tadros, Ibrahim, & Sleem, 2004). The fruit is a good source of natural antioxidants (Pino, Marbot, & Aguero, 2000). The major antioxidants are phenolic compounds, such as gallic acid (in gallotannins), catechin, or epicatechin. Folk medicine in India uses the ripe fruits to halt hemorrhages and dried fruits or juices to counteract fever; jams may mitigate liver problems, diarrhea, and hangover after excessive alcohol consumption. In Brazil, carambola is used as a diuretic and for treatment of eczema, but in patients on dialysis the consumption of carambola fruits can lead to altered consciousness. The constituents responsible for these effects remain uncertain, but carambola contains large amounts of oxalate which can induce brain functions depression and stroke. In addition some bioactive compounds, such as glycin, l-alanine, l-serine, l-aspartic acid, l-glutamic acid, thiamin, niacin, l-valine, l-threonine, citric acid, riboflavin, tartaric, succinic, fumaric, oxalic acids, proline, α-ketoglutaric, and malic acids. Volatile components of star fruit were isolated by simultaneous steam distillation and stored in their pure state. The major components found in star fruit were 2-methylpropan-2-ol, 2-methyl-1-propanol, 2,3-dimethyl-1-butanol, ethyl hexanoate, ethyl and butyl acetate, and ethyl octanoate. Star fruit (*A. carambola L*) is a very good source of natural antioxidants. The major antioxidants were initially attributed to singly-linked proanthocyanidins that existed as dimers, trimers, tetramers and pentamers of catechin or epicatechin (Ferrara, 2009).

### 2.20. Wax apple

Wax apple (*Syzygium samarangense* Merr. & Perry, *Javaicium*) known as Chompu Keiw, is originated in the Indo-Burma area. The shape of the fruit is bell-like, texture is crispy and juicy, when served raw. The taste of the fruit is mild, slightly sweet; the processing is not available, and the availability is from June through September. Red color plays a very important role when wax apple fruits are purchased. Temperature is one of the key factors among those influencing red color development. The effects of temperature on color formation and other quality characteristics of ‘Pink’ wax apple fruit disks by using constant, slow-increase, fast-increase, transient shifting to high temperature, shifting to high temperature for different lengths of time and different day/night temperature regimes were...
evaluated. Wax apple fruit skin disks from different fruit development stages incubated with and without sucrose showed differential effects on diameter, weight, soluble solids (SSs) and skin color. Diameter, weight and chlorophyll content declined, while SSs and anthocyanin concentrations increased in a sucrose medium. Both SSs and anthocyanin concentrations in the sucrose-added disks were higher than in the non-sucrose controls. Fruits from the rapid growth stage to red stage, i.e. from 4 to 8 weeks after anthesis, had greater anthocyanin induction in the presence of sucrose. Temperature has pronounced effects on quality attributes of wax apple fruit disks. Anthocyanin and total soluble solid (TSS) were the greatest in the 20 °C treated disks under constant temperatures. In the slow-increase and fast-increase treatments, quality attributes in disk were better in treatments with a final temperature of 25 °C than of 30 °C. Pigmentation of disks exposed to high temperature treatment was worse than in uncultured controls. Both protein and FAA concentrations decreased after culture. Among the 5 different day/night temperature combinations, disks under 25/20 °C had the highest anthocyanin and TSS concentrations, while those under 30/15 °C had the worst (Pan & Shu, 2007). Changes in the quality of stored wax apple were evaluated during storage at 100 °C and ambient temperature. The wax apple fruits were packed using stretch film wrapping and low density polyethylene (LDPE) bag. Unwrapped fruits were treated as control. Changes in fruit quality were evaluated at two days interval at both storage temperatures. Observation was made on color, firmness, weight loss, moisture loss, disease infection, pH, TTA, TSS, total sugars and vitamin C. However, the ethylene level at ambient storage increased which probably related to the early senescence process (Parvathy, Abdullah, Latifah, & Tarmizi, 2003). Color is one of the most commonly used parameter for consumers to evaluate the quality of wax apple fruits. Sucrose is proved to be crucial for anthocyanin biosynthesis in the fruit skin of wax apples. As the optimum developmental period for sucrose utilization for color development in wax apple fruit is from rapid stage to big red stage. Adequate crown management, including pruning for even distribution of sunlight, controlling new shoots development and balanced nutrition and sufficient water supply, at this period is essential for best color development for wax apple fruits (Chang, Chung, Tseng, Chu, & Shü, 2003).

3. Comparison between different exotic fruits

Comparison of exotic fruits was described in many reports (Gorinstein, Zemser, Hartuenkit, et al., 1999; Gorinstein, Zemser, Vargas-Albores, et al., 1999; Chen, Chen, Yang, Wei, & Su, 2010; Mahattanatawewee et al., 2006; Lang & Ke, 2006; Cho, 2010). Reported comparison of some exotic fruits by 3D-FL showed one main peak in methanol extracts at the approximate location of 346/225 nm and a minor one at 352/225 nm. There were some red shifts in the peak location and their intensity. The wavelength numbers of FTIR spectra for catechin at 831, 1040, 1112, 1144, 1285, 1478, 1512 and 1611 cm⁻¹ were assigned to –C–H alkenes, –C–O alcohols, –OH aromatic, –C–O alcohols, –C–H alkenes, –OH aromatic ring and –C–C alkenes, respectively. Gallic acid showed the following wavelength numbers (cm⁻¹): 866, 1026, 1237, 1451, 1542 and 1619. A shift in the difference between the standards and the investigated samples can be explained by the method of extraction of the main polyphenols, but the main bands in FTIR spectra (1637, 1415, 1137, 1103, 1056, 995 and 923 cm⁻¹) of different exotic fruits were from 1700 to 800 cm⁻¹ (Gorinstein et al., 2010; Poovarodom et al., 2010). Tropical Thai fruits (pineapple, wax apple, rambutan, lichi, guava, and mango) were compared with persimmon. It was found that lichi, guava, and ripe mango (cv. Keaw) have 3.35, 4.95, and 6.25 mg of total polyphenols/100 g FW, respectively. These results were significantly higher than in persimmon, pineapple, wax apple, mature green mango, and rambutan [P < 0.0005 for pineapple (Smooth Cayene variant)], wax apple, persimmon, rambutan, mature green mango (cv. Keaw). The value of P < 0.001 is found only for pineapple (Phuket, Queen variant). The same relationship was observed for the contents of gallic acid and of dietary fiber. Among the studied fruit, lichi, guava, and ripe mango may be preferable for dietary prevention of atherosclerosis (Gorinstein, Zemser, Haruenkit, et al., 1999; Gorinstein, Zemser, Vargas-Albores, et al., 1999). Dietary fiber content in 21 varieties of Thai fruits ranged from 0.71 to 3.58 g/100 g edible portion, with all five varieties of durian, guava, ripe banana and papaya being good sources of dietary fiber. Durian (Chanee, Kradom, and Puang maneey variety) having
yellow to deep-yellow color pulp had the highest carotenoid content. Durian, pomelo, guava and ripe banana were good sources of flavonoids, pomelo (Tong deong and Tuptimsayam variety) showed the greatest total flavonoid content (13,994.21 and 15,094.99 µg/100 g edible portion). Data in this study reported that Thai fruits are not only a good source of dietary fiber but also a good source of carotenoids and flavonoids (Kongkachuchai et al., 2010). The ethanol extracts from 24 samples plant species commonly found in Thailand were reported and compared on their antioxidant activity by ABTS assay (Tachakkittirungrod, Okonogi, & Chowwanapoonpohn, 2007). The ethanol extract from the leaves of guava (P. guajava) showed the highest antioxidant capacity with the TEAC value of 4.905 ± 0.050 mM/mg, followed by the fruit peels of rambutan (N. lappaceum) and mangosteen (G. mangostana) with the TEAC values of 3.074 ± 0.003 and 3.001 ± 0.016 mM/mg, respectively. The methanol fraction possessed the highest antioxidant activity, followed by the butanol and ethyl acetate fractions, respectively. The hexane fraction showed the lowest antioxidant activity. The results demonstrated that the mechanism of antioxidant action of guava leaf extracts was free radical scavenging and reducing of oxidized intermediates. The phenolic content in guava leaf fraction played a significant role on the antioxidant activity via reducing mechanisms (Tachakkittirungrod et al., 2007). The potential of fruit waste materials, from peels of eight kinds of fruits commonly consumed and grown in Thailand, as sources of powerful natural antioxidants, was reported (Okonogi, Duangrat, Anuchpreeda, Tachakittirungrod, & Chowwanapoonpohn, 2007). Results from ethanolic fruit peel extracts of DPPH and ABTS radicals showed that the top three markedly high free-radical-scavenging power was from the peel extracts of Punicia granatum (pomegranate), N. lappaceum (rambutan), and G. mangostana (mangosteen). The IC50 values to quench the DPPH free radicals of these three species were 0.003, 0.006, and 0.023 mg/ml, respectively. The IC50 values of 3.074 ± 0.003 and 3.001 ± 0.016 mM/mg, respectively. The extract of mangosteen peel showed moderate toxicity to Caco-2 cells and high toxicity to peripheral blood mononuclear cells (PBMC) with the IC50 values of 3.20 and 4.9 µg/ml, respectively. Peel extract of rambutan exhibited extremely high value of IC50 (> 100 µg/ml) against both cell types indicating non-toxic activity to the cells. The peel of rambutan may be considered potentially useful as a source of natural antioxidants for food or drug product because of its high antioxidant activity and non-toxic property to normal cells (Okonogi et al., 2007). Chen et al. (2010) compared the content of vitamin C in 7 kinds of southern fruit, included litchi, mango, papaw, actinidia, banana, musa, pitaya: actinidia was the highest, banana was the lowest (1.86 mg/100 g). Six (6) tropical fruits (guava, red pitaya, white pitaya, green mango, ripe mango and immature Citrus grandis Osbeck) and two leaves (C. grandis Osbeck and guava) from Jeju Island of Korea were evaluated for antiproliferative activities (Cho, 2010). The total antioxidant capacity (TAC) of 32 fruits purchased from three local markets in Pingtung country was divided into four groups: the first group, containing the highest antioxidant capacity (> 10 mM TE/g), included Szjou persimmon, durian, strawberry, guava and pomegranate. The second group, (5–10 mM TE/g), included atemoya, sweet cherry, passion-fruit, delicious apple, Granny smith apple, carambola, kiwifruit, golden kiwifruit and Fuji apple. The third group, (3–5 mM TE/g), included shaddock, sweet orange, nectarine, Indian jujube, ponkan, pitaya (red pulp), banana, tomato, wax apple, papaya and fuju persimmon. The fourth group, (< 3 mM TE/g), included pitaya (white pulp), melon, pineapple honeydew melon, grape, sand pear and watermelon (Lang & Ke, 2006). Fourteen tropical fruits from south Florida (red guava, white guava, carambola, red pitaya (red dragon), white pitaya (white dragon), mamey sapote, sapodilla, lychee, longan, green mango, ripe mango, green papaya, and ripe papaya) were evaluated for bioactive compounds. Total soluble phenolics (TSP), ORAC and DPPH radical scavenging activity assays ranged from 205.4 to 2316.7 g GAE/g puree, <0.1 to 16.7 µmol TE/g puree, and 2.1 to 620.2 µg GAE/g puree, respectively. The total ascorbic acid (TAA), total dietary fiber (TDF), and pectin ranged from 7.5 to 188.8 mg/100 g, 0.9 to 7.2 g/100 g, and 0.20 to 1.04 g/100 g, respectively. The antioxidant activities, TSP, TAA, TDF, and pectin were influenced by cultivar (papaya, guava, and dragon fruit) and ripening stage (papaya and/or mango). Antioxidant activity showed high correlations with levels of TSP compounds (r = 0.96), but low correlations with levels of ascorbic acid (r = 0.35 and 0.23 for ORAC and DPPH data, respectively). The antioxidant activities evaluated by both ORAC and DPPH showed similar trends where red guava and carambola exhibited the highest and sapodilla and green papaya exhibited the lowest levels. Guava and mamey sapote exhibited the highest TDF and pectin levels (Mahattanatawee et al., 2006). The highest content of vitamin C between the 10 exotic fruits from Brazil (abiu, acerola, wax jambu, cashew, mamey sapote, carambola or star fruit, Surinam cherry, longan, sapodilla and jaboticaba) of 1525 mg/100 g pulp occurred in acerola. The total phenol content was higher in abiu, acerola, Surinam cherry and sapodilla. In relation to antioxidant activity, acerola has shown the greatest values in all three different methods tested. The sample concentration also influenced its antioxidant power (De Assis et al., 2009).

A total of 27 fruit pulps, obtained in the Singapore markets, were tested for their general antioxidant capacity based on their ability to scavenge 2,2′-azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) free radical. According to the ascorbic acid equivalent antioxidant capacity (AEAC) values of binary extract solution of fruits in the ABTS model, chiku shows the highest antioxidant capacity, followed by strawberry, plum, star fruit, guava, seedless grape, salak, mangosteen, avocado, orange, solo papaya, mango, kiwifruit, cempedak, pomelo, lemon, pineapple, apple, foot long papaya, rambutan, rambutan king, banana, coconut pulp, tomato, rockmelon, honeydew, watermelon and coconut water. The ascorbic acid contribution to AEAC of fruits varied greatly among species, from 0.06% in chiku to 70.2% in rambutan (Leong & Shui, 2002). Among the thirty-eight fruits commonly consumed in Singapore tested guava had the highest ascorbic acid (AA)/g FW, durian and mangosteen were high in tocochromers and tocotrienols. As fruits are a rich source of diverse antioxidants, efforts to promote consumption of a variety of fruits should be continued for public health benefits (Isabelle et al., 2010).

The volatile composition of selected Brazilian exotic fruits (Brazilian cherry (E. uniflora), acerola (Malpighia glabra L., M.unicifolia L., Malphigia emarginata DC.), jackfruit (Artocarpus heterophyllus), star fruit (A. carambola) and fruits from the genera Annona (chirimoya, soursop, and sugar apple) and fruits from the genera Spindias (S. purpurea, S. mombin and S. tuberosa) was reviewed (Bicas et al., 2011-this issue). The comparison of volatile compounds of different exotic fruits is important for flavor industry, which uses different aroma compounds for the formulation of fragrances and flavorings to be applied in foods, cosmetics and perfumes (Bicas et al., 2011-this issue). Major of the total 43 volatiles in longan (Lansium domesticum Corr, var Dongon) were 1,3,5 trioxane, (E)-2-hexenal, 3-carene, α-cubebene, isolone, β-selinene, and α-calacorene. Major volatiles mangosteen (G. mangostana L var Native) were 2, 2-dimethyl-4-octanal, E-2-hexenal, benzaldehyde, (Z)-3-hexen-1-ol, heylx-n-valerate, 1,4-pentadiene, and 2-methyl-1,3-butenen-2-ol. Volatile compounds durian (D. zizibhus L var Mon Thong) consisted of a large number of sulfur-containing compounds, which included diethyltrisulfide, diethylsulfide, diethylamine, di- Me sulfide, and 3-methyl-thiizoloidine. Nonsulfur compounds 2-Me butanoate, butenedioic acid, and propyl-2-ethylbutanoate were also abundant. Isocitonellol, 3-hydroxy-2-butanone, pentanal, and 4-tridecyl valerate were most abundant in 'Ron-rong' rambutan (Laohakunjit, Kerdhchoechuen, Matta, Silva, & Holmes, 2007). The volatile constituents in total, 48, 39, 61 and 44 constituents were identified in rambutan (N. lappaceum L.), pulasan (N. ramboutan-ake (Labill.) Leenh.), longan (D. longan Lour.), and mata kucing (D. longan ssp. malesianus Leenh.), respectively (Wong, Wong, Loi, & Lim, 1996). Among rambutan volatiles, aliphatic alcohols (49.0%), sesquiterpenoids (20.5%) and carbonyl compounds (19.5%) predominated, 2-methylbut-
3-en-ol (21.9%) and β-caryophyllene (10.4%), constituting the major components. In contrast, pulasan fruit yielded mainly aliphatic hydrocarbons (70.2%), particularly pentadecane (61.4%), and aliphatic alcohols (19.4%). Esters (68.4%) and terpenoids (27.1%) were quantitatively the most significant among longon volatile, and ethyl acetate (66.2%) and (E)-cinnamic (20.7%) were clearly dominant. Mata kucing differs from longon in producing much lower levels of esters (0.5%) and terpenoids (4.7%), but significantly larger proportions of aliphatic alcohols (53.2%) and carbonyl compounds (34.7%).

Exotic fruits are important component in the antioxidant capacity and related parameters of different fruit formulations, including smoothies, fruit purees, concentrates, juices and new beverages (Müller, Gnoyle, Popken, & Böhm, 2010). Vitamin C content ranged from 31 ± 3 mg/100 g in drinkable pomegranate concentrate to 1373 ± 125 mg/100 g in acerola puree. Total phenolics content was quantified between 89.51 ± 3 mg/gallic acid equivalents (GAE)/100 g in the mango-peach smootie, 51 ± 1 mg/gallic acid equivalents (GAE)/100 g in the mango-peach smoothie and 116.80 ± 1.32; 91.15 ± 1.25; 75.83 ± 2.30; and vitamin C (mg/100 g) in the same smoothies: 89.51 ± 3.83; 66.61 ± 2.90, respectively. Very good correlations between total phenolics content and antioxidant capacity were found in the single fruit products, however not in the fruit and vegetable smoothies (Müller et al., 2010).

4. Conclusions

The review presents the bioactivity in general and biologically active metabolites in particular derived from avocado, dragon fruit, durian, kiwifruit, mango, mangosteen, persimmon, snake and other exotic fruits. The polyphenols, flavonoids, flavanols, tannins, ascorbic acid, anthocyanins and volatile compounds were described by various analytical methods.

Most of the reported exotic fruits contain high amounts of bioactive compounds and possess high antioxidant potential. The supplementation of diets with the reviewed fruits positively affects plasma lipid profile, antioxidant activity and histology of aorta and liver in rats fed cholesterol-containing diets. The emphasis was done to show the relationship between the volatile composition (natural flavors), and the bioactive metabolites in these fruits, to demonstrate the potential of exotic whole fruits as a rich source of antioxidants, therefore efforts to promote consumption of a variety of fruits should be continued for public health benefits and this is the purpose of this review.

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