8 Tropical Fruit Flavour

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8.1
Introduction

The characteristic exotic flavour of fruits from the tropics is one of the most attractive attributes to consumers. Nowadays, food industries are looking at how to use these volatiles to produce amazing new products that can accommodate this new demand. The following sections report some of the relevant research data on volatiles of some important tropical fruits.

8.2
Guava (Genus *Psidium*)

Guava is native to Central America. It was distributed into other parts of tropical and subtropical areas such as Asia, South Africa, Egypt, and Brazil by the early seventeenth century [49]. Some examples of impact-flavour compounds have already been identified in guava: β-ionone [58], terpene hydrocarbons [63], and esters [43] could be mentioned.

Essences of pink and white fresh guava obtained by direct extraction of flesh juices with dichloromethane revealed that the total amount of C_6 aldehydes, alcohols, and acids comprised 20 and 44% of the essence of fresh white and pink guavas, respectively [49]. The flavour of the Costa Rican guava has been described as sweet with strong fruity, woody-spicy, and floral notes [53]. One hundred and seventy-three volatile compounds were isolated by simultaneous steam distillation–solvent extraction. The terpenes and terpenic derivatives were found in this fruit in major concentrations and were strong contributors to tropical fruit notes (Fig. 8.1). The aliphatic esters contributed much to its typical flavour.

Characterisation of the aromatic profile in commercial guava essence and fresh fruit puree extracted with solvent yielded a total of 51 components [29]. Commercial essence was shown to be 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.

Volatile compounds isolated from strawberry guava fruit by simultaneous steam distillation–solvent extraction were identified by capillary gas chromatography–mass spectrometry (GC-MS) and were characterised sensorially by sniffing GC [52]. Terpenes and terpenic derivatives were identified and were shown to contribute much to the typical strawberry guava flavour. The presence of many aliphatic esters and terpenic compounds is thought to contribute to the unique flavour of the strawberry guava fruit.

Some plagues that jeopardise guava cultivars are caused by *Timocrata albella*, which attacks the stalk, and *Conotrachelus psidii* (a beetle that attacks the fruits). Diseases in guava are also caused by *Puccinia psidii*, a fungus that attacks leaves, flowers, and fruits (http://www.seagri.ba.gov.br).
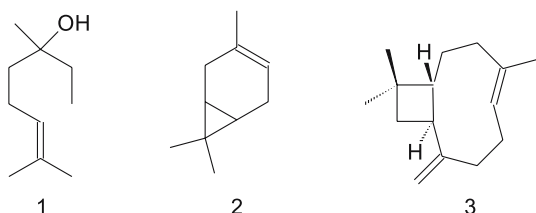

Fig. 8.1 Acyclic, monocyclic, and bicyclic terpenes contribute to tropical fruit flavours; **1** linalool to papaya; **2** Δ³-carene to mango; **3** *ß*-caryophyllene to guava fruit

8.3
Banana (Genus *Musa*)

Banana (*Musa sapientum* L.) is one of the most common tropical fruits, and one of Central America's most important crops. It is grown in all tropical regions and is one of the oldest known fruits [45]. From a consumer perspective, bananas are nutritious with a pleasant flavour and are widely consumed throughout the world [57]. Esters predominate in the volatile fraction of banana (Fig. 8.2). Acetates are present in high concentrations in the fruit and generally possess a low threshold. Isopentyl acetate and isobutyl acetate are known as the two most important impact compounds of banana aroma. Alcohols are the second most important group of volatiles in banana extracts. 3-Methyl-1-butanol, 2-pentanol, 2-methyl-1-propanol, hexanol, and linalool are the alcohols present in higher concentrations in the fresh fruit [45].

The concentrations of acetates and butanoates seemed to increase during ripening of Valery bananas [40]. This was confirmed by an investigation in which bananas were treated with the ethylene antagonist 1-methylcyclopropene (1-MCP) [22]. The volatiles were recovered by a Tenax TA trap. The 1-MCP treatments caused quantitative changes in the amounts and the composition of

the aroma volatile compounds, resulting in a substantial increase in the concentration of alcohols and a decrease in the concentration of their related esters.

Later, another research group suggested that not all of the volatile components found in large concentration in the commercial banana essence contributed to the aroma, such as 2-pentanone, 2-pentanol, butanol, and isobutyl acetate. However, isoamyl acetate, 2-pentanol acetate, 2-methyl-1-propanol, 3-methyl-1-butanol, 3-methylbutanal, acetal, isobutyl acetate, hexanal, ethyl butanoate, 2-heptanol, and butyl butanoate contributed and defined the aroma in the commercial fruit essence [30]. Isoamyl alcohol was the most abundant compound found in headspace flavour compounds of Taiwanese banana recovered by solid phase microextraction [39].

Aroma compounds of fresh banana from different countries (Martinique, Canary Islands, and Côte d'Ivoire) were examined using the same extraction technique. As expected, differences in aroma composition were detected in the fruits of different origins. Isoamyl alcohol, isoamyl acetate, butyl acetate, and elemicine were detected by olfactometric analyses as characteristics of banana odour [7].

Among the diseases of banana cultivars, yellow sigatoka (caused by *Mycosphaerella musicola*), black sigatoka (caused by the ascomycete *Mycosphaerella fijiensis*) and mal-do-Panamá (caused by *Fusarium oxysporum* strains) are the most important. Damage caused by yellow sigatoka can reach a loss of 50–100%. But the black sigatoka is a more severe disease, causing destruction of the leaves leading to a loss of 100%. The damages caused by mal-do-Panamá vary with soil and cultivar (http://www.embrapa.br).
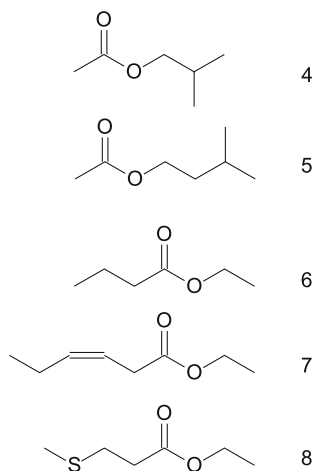

Fig. 8.2 Esters as character-impact compounds: **4** isobutyl acetate in passion fruit; **5** isopentyl acetate in banana; **6** ethyl butanoate in cupuacu; **7** ethyl (3Z)-hexenoate and **8** ethyl-3-(methylthio)propanoate in pineapple

8.4
Mango (*Mangifera indica*)

Mango is one of the most popular and best known tropical fruits [44] and possesses a very attractive and characteristic flavour. Some authors reported great differences in flavour compounds (including esters, lactones, monoterpenes, and sesquiterpenes) [14].

A wide range of volatile compounds from Indian mango were identified by pioneer group research [20, 21]. Esters, lactones, monoterpenes, sesquiterpenes, and furanones were among the volatiles. It has been suggested that the ratio of palmitic to palmitoleic acids determines the flavour quality of the ripe fruit, a ratio of less than 1 resulting in strong aroma and flavour [44].

Terpenes were identified as the most abundant compounds (over 54% of the solvent-extracted volatiles) from Venezuelan mangoes [44]. Figure 8.1 shows structures of some monoterpenes found in tropical fruits. Car-3-ene, described as having the characteristic aroma of mango leaves, was the major contributor with 26% of volatiles in the sample. This result was confirmed for African mangoes [55]. The acids, esters, and lactones found were considered to be produced by the lipid metabolism in the development of the aroma and flavour of mango fruit during ripening.

Volatiles of three cultivars of mango (Jaffna, Willard, and Parrot) from Sri Lanka were analysed, and among the 76 components identified, monoterpenes and sesquiterpenes hydrocarbons were described as the major contributors [42]. Variations in the amounts of esters, ketones, and alcohols were also related.

The importance of glycosidically bound volatile compounds (GBVC) and their contribution to fruit aroma were evidenced in African mango [54]. Some terpenes (like α-terpineol and linalool oxide isomers), phenolic compounds, carotenoid aroma derivatives like 9-hydroxymegastigma-4,7-dien-3-one, and acids (like palmitic and stearic) were reported. In the same way, another investigation reported that the composition and concentrations of GBVC in pulp and skin of the Kensington Pride variety were strongly influenced by the fruit part and maturity stages [36]. Most of the GBVC increased in the pulp as maturity progressed.

Fifteen Brazilian varieties of Mango fruit were divided in three groups according to the component present in the greatest concentration [3]. The first group comprised the varieties rich in α-terpinolene: Cheiro (66.1% of α-terpinolene), Chana (62.4%), Bacuri (57.0%), Cametá (56.3%), Gojoba (54.8%), Carlota (52.0%), Coquinho (51.4%), and Comum (45.0%). The second group, with the varieties rich in car-3-ene, was represented by Haden (71.4%), Tommy (64.5%), and Keith (57.4%) and the third group, rich in myrcene, was composed of the varieties Cavalo (57.1%), Rosa (52.4%), Espada (37.2%), and Paulista (30.3%).

The changes in the production of volatile aroma compounds during fruit ripening seemed to be mediated by ethylene. The production of most terpenes during ripening of the Kensington Pride mango has been reported to occur parallel

to the production of ethylene; however, the exact role of ethylene in biosynthesis of volatiles was not well established. Experiments carried out with ethylene inhibitors clearly suggested that biosynthesis of monoterpenes, esters, and aldehydes in the mango fruit were strongly dependent on ethylene production and action [36–38].

In mango cultivation, the tree may be attacked by several plagues (mosquitoes and mites). Two particular species of mosquitoes (*Anastrepha* spp. and *Ceratitis capitata*) can severely damage the tree, causing a great decrease in the production. Other plagues that result in minor damage are caused by *Eriophyes mangiferae*, *Selenothrips rubrocinctus*, and *Aphis gossypii* (hpp://www.embrapa.br).

8.5
Melon (*Cucumis melo*)

The species *Cucumis melo* comprises a great number of varieties that exhibit considerable diversity in their biological characteristics [65]. The dessert melons of commercial importance exhibit a wide variation in flavour and aroma profiles [66].

Charentais cantaloupe melon (*Cucumismelo* L. var. *cantalupensis* Naud.) was characterised by abundant sweetness and a good aromatic flavour [68]. The aroma volatiles of Charentais-type cantaloupe melons, as with other cantaloupes, comprise a complex mixture of compounds including esters, saturated and unsaturated aldehydes and alcohols, as well as sulfur compounds [26, 65]. Among these compounds, volatile esters were quantitatively the most important and therefore represent key contributors to the aroma [68]. The linear saturated and unsaturated aldehydes seem to originate from the degradation of linolenic and linoleic acids [26, 32, 33, 67].

The aroma volatiles of some melon species consist of a complex mixture of esters together with other components, including C9 unsaturated aldehydes, alcohols, and acetates whose sensory properties have been described as "melon-like" [10, 31–33, 35]. Several esters and alcohols were described among the volatiles of muskmelons [33, 34].

Melons stored at low temperatures showed different relative amounts of volatiles recovered by solvent extraction [34]. Some of the C9 unsaturated esters and alcohols presumably originated as a result of lipoxygenase activity. The previous results together with some investigations of the C9 unsaturated esters and alcohols suggested that the activity of lipoxygenase on melons seems to be dependent on cultivar, age, storage conditions, and sample location [65].

More recently, static headspace GC analysis of eight cultivars of melons detected esters as the major volatile components. Differences among the compositions of the volatiles of the cultivars studied were also reported and are probably due to different efficiencies of biosynthetic pathways of each variety [56].

Sulfur compounds are also likely to be of considerable sensory importance in melon aroma. Dimethyl sulfide and ethyl (methylthio)acetate were found to

be sulfur volatiles from Golden Crispy melons [65]. 2-(Methylthio)ethyl acetate was present in greater amounts in the majority of the melon cultivars analysed. The structures of the sulfur volatile compounds suggested that they may have been derived from methionine [66].

The extraction technique can play an important role in the recovery of volatiles, resulting in different profiles of volatiles for the same variety [67]. The direct extraction of *Cucumis melo* L. var. *cantaloupensis* with Freon 11 under low temperature was capable of recovering compounds never found before in melons [26]. The authors attributed this to the non-destructive extraction at low temperatures and the very efficient capillary chromatographic system used for the analysis.

It has been shown that suppression of ethylene production results in a strong inhibition of aroma volatiles in Charentais-type melons [4, 68].

Cultivars of *Cucumis melo* L. can be attacked by *Didymella bryoniae* Auersew, which can cause considerable losses, because fruits attacked by this organism do not have commercial value anymore. Mosquitoes, mainly *Bemisia tabaci*, also attack melon cultivars. Reductions in weight, size, and sugar content are evident consequences of mosquitoes attack. *Diaphania nitidalis* attacks flowers and fruits, whereas *Diaphania hyalinata* generally attacks the leaves of the melon tree.

8.6
Papaya (*Carica papaya*)

Papaya is a native fruit from America and is widely planted throughout the tropics [41], and is a crop of economic importance to tropical countries [11]. It has become a commercially important fresh fruit crop, particularly in the USA and Europe [51]. Papaya possesses a characteristic aroma, which is due to several volatile components, such as alcohols, esters, aldehydes, and sulfur compounds [11].

Several volatile components of papaya (Solo variety) were recovered by four methods: vacuum trapping train (distillation under low temperatures with liquid nitrogen traps), codistillation–extraction (vacuum), vacuum distillation, and codistillation–extraction (1 atm) [17]. In spite of great variations due to the recovery method, the results showed that linalool was always the major compound detected for all the methods.

In another investigation, linalool (Fig. 8.1) was detected in relatively low concentration in the solvent-extracted volatiles of fresh papaya pulp from Sri Lanka [41]. The authors attributed the characteristic sweaty note of this papaya fruit mainly to methyl butanoate. Phenylacetonitrile was also found in high amounts (17.7%), which, according to the authors, combined with lesser concentrations of benzyl isothiocyanate (1.5%) can play a role in the aroma of papaya.

The concentrations of linalool and benzyl isothiocyanate in papaya are clearly affected by the addition of Hg^{2+}. It is suggested that the mercurous ion could

block the activity of different enzymes taking part in monoterpene formation [25]. Oxygenated terpenoids derived from linalool can play an important role in Brazilian papaya aroma [64]. Several oxygenated derivatives of linalool were identified in the solvent-extracted samples, such as the two diasteroisomers of 6,7-epoxy-linalool: 2,6-dimethyl-octa-1,7-diene-3,6-diol and 2,6-dimethyl-octa-3,7-diene-2,6-diol. The terpenes linalool and terpinen-4-ol showed an increased production ratio in a Cuban papaya variety (*Carica papaya* L. var. *maradol roja*) [1].

Fifty-one volatile components from intact Hawaiian papayas in different ripeness stages were recovered by trapping with Tenax [18]. As expected, the greatest number of components were found in the fully ripe fruits. Linalool, followed by linalool oxide A, linalool oxide B, and ethyl acetate were the major components in the fully ripe fruits. Several compounds were also present in the four ripeness stages: linalool and all aldehydes can be mentioned.

Another investigation reported the esters as the predominant volatile components of the Maradol variety (about 41% w/w of the total volatiles) [51]. The major representative compounds in the simultaneous steam distillation–solvent extraction were methyl butanoate and ethyl butanoate. Previous work described the esters as the predominant compounds among the volatiles; papayas, for example, from Sri Lanka and Colombia had 52 and 63% of esters in the total volatiles respectively [25, 41].

Plagues in papaya cultivation are generally mites (*Polyphagotarsonemuis latus*, *Tetranychus urticae*). *Polyphagotarsonemuis latus* is known as "tropical mite" and attacks the leaves causing death of the tree. Other diseases are caused by *Phytophthora palmivora* and *Colletotrichum gloesosporioides*. The fruits do not possess commercial value after the attack (http://www.seagri.ba.gov.br).

8.7
Passion Fruit (*Passiflora edulis*)

Owing to their unique and delicate flavour, species of the genus *Passiflora* have been the subject of intensive research on their volatile constituents [13]. The purple passion fruit (*Passiflora edulis* Sims) is a tropical fruit native to Brazil but is now grown in most tropical and subtropical countries [50]. Purple passion fruit is cultivated in Australia, India, Sri Lanka, New Zealand, and South Africa [48]. Yellow passion fruit (*Passiflora edulis* f. *flavicarpa*) is one of the most popular and best known tropical fruits, having a floral, estery aroma with an exotic tropical sulfury note [62]. Yellow passion fruit is cultivated in Brazil, Hawaii, Fiji, and Taiwan [48]. Because of its more desirable flavour, the purple passion fruit is preferred for consumption as fresh fruit, whereas the yellow passion fruit is considered more suitable for processing [28].

The first report about volatile constituents in purple passion fruit (*Passiflora edulis* Sims) described the identification of 20 volatiles in the solvent extract of passion fruit juice from New Guinea [50]. The author attributed the unique

aroma of the purple passion fruit to the several esters (Fig. 8.2) identified (about 80% of neutral essence). Similarly, the volatile fraction of passion fruit juice (*Passiflora edulis* Sims) was reported as a complex mixture of components [47], but the majority was esters derived largely from various combinations of alkanols with acids. Sulfur compounds can play an important role in the overall flavour characteristics of passion fruit [13]. The attractive tropical flavour note of ripe yellow passion fruits has been shown to be associated with trace levels of sulfur volatiles [62].

The analyses of the flavour composition of yellow passion fruits were performed by four different isolation techniques, namely vacuum headspace sampling (VHS), the dynamic headspace method, simultaneous distillation and extraction at atmospheric pressure, and simultaneous distillation and extraction under reduced pressure [62]. Significant differences were found not only in the chemical composition of the resultant extracts but also in their sensory properties. The most representative and typical extract was obtained by VHS.

Later, the chemical characterisation of the volatiles from yellow passion fruit essence and from the juice of the fruit was done by GC-MS and GC–olfactometry (GC-O) [27]. Esters were the components found in the largest concentrations in passion fruit juice and essence extracted with methylene chloride. Analysis by GC-O yielded a total of 66 components which appeared to contribute to the aroma of passion fruit juice and its aqueous essence. Forty-eight compounds were identified in the pulp of Brazilian yellow passion fruits (*Passiflora edulis* f. *flavicarpa*) [48]. The predominant volatile compounds belonged to the classes of esters (59%), aldehydes (15%), ketones (11%), and alcohols (6%).

Plagues in passion fruit are mainly caterpillars (*Dione juno juno* and *Agraulis vanillae vanillae*), which attack mainly the leaves, decreasing the growth and the production of fruits. Passion fruit rot and withering can be caused by *Colletotrichum*, *Rhizopus*, *Cladosporium*, *Fusarium*, *Lasiodiplodia*, *Phomopsis, Alternaria alternata*, *A. passiflorae*, *Septoria passiflorae*, and *Sclerotinia sclerotium.* (http://www.seagri.ba.gov.br)

8.8
Pineapple (*Ananas comosus*)

Pineapple, one of the most popular tropical fruits in the world, has been cultivated in South America since the fifteenth century [61]. It has been very popular throughout the world for many years [16]. Native to Central America and South America, pineapples grow in several tropical countries, such as Hawaii, India, Malaysia, the Philippines, and Thailand [12]. Owing to its attractive sweet flavour, pineapple is widely consumed as fresh fruit, processed juice, canned fruit, and as an ingredient in exotic foods. The volatile constituents of pineapple have been studied for over 60 years by many researchers. More than 280 compounds have been found among volatiles of pineapples so far [60].

The earliest investigations concerning pineapple volatiles date from 1945 [23, 24]. The great majority of pineapple components are contributed by ethyl and

methyl esters (Fig. 8.2) In 1970, a North American group reported that aliphatic esters were the predominant compounds among the solvent extract of Smooth Cayenne pineapple. Monoterpene alcohols (linalool, α-terpineol, and terpinen-4-ol) were also identified [16].

Sesquiterpenes recovered by solvent extraction were identified in pineapple fruit (*Ananas comosus* Merr.) from Côte d'Ivoire. The authors suggested that some of the sesquiterpenoids found were derived from germacrene precursors [6]. The same authors studied the identification of trace compounds with impact character in pineapple fruit (*Ananas comosus* Merr.). Some potent compounds were an undecatriene, an undecatraene, and ethyl esters [5].

The sulfur components ethyl *S*-(+)-2-methylbutanoate and dimethyl trisulfide (with 0.006 and 0.01 µg/L odour thresholds in water, respectively) were reported as impact-flavour compounds in fresh Hawaiian pineapple essence prepared by solvent extraction. The major volatile components were methyl and ethyl esters [59].

The volatile compounds of juices made from freshly cut pineapple fruits from different cultivars from Costa Rica, Ghana, Honduras, Côte d'Ivoire, the Philippines, Réunion, South Africa, and Thailand were studied in comparison to that of commercial water phases/recovery aromas, juice concentrates as well as commercially available juices [12]. The qualitative pineapple fruit flavour profile showed several methyl esters, some characteristic sulfur-containing esters, and various hydroxy esters were responsible for the typical pineapple flavour profile.

Twenty-nine odour-active compounds were detected by using aroma extract dilution analysis (AEDA) [60]. The results of AEDA together with GC-MS analysis showed ethyl 2-methylbutanoate (described as 'fruity' flavour), followed by methyl 2-methylbutanoate and 3-methylbutanoate (fruity, apple-like), 4-hydroxy-2,5-dimethyl-3(2*H*)-furanone (sweet, pineapple-like, caramel-like), δ-decalactone (sweet, coconut-like), 1-(*E,Z*)-3,5-undecatriene (fresh, pineapple-like), and a unknown compound (fruity, pineapple-like) as the most odour-active compounds.

The most common plagues in pineapple cultivation are caused by *Thecla basalides* and *Dysmicoccus brevipes*. *Fusarium subglutinans* also causes an important disease, leading to the most significant losses. (http://www.seagri.ba.gov.br).

8.9
Cupuacu (*Theobroma grandiflorum*)

Cupuacu is an Amazonian forest tree from Para state, Brazil. The fruits are 15–25 cm in length, 10–12 cm in diameter, and weigh between 0.8 and 2 kg. They are oblong fruits with a hard skin. The seeds contain caffeine and theobromine, alkaloids with stimulant properties. The seeds contain about 48% of a white fat similar to cocoa butter. The creamy-white pulp has an attractive and characteristic aroma and flavour. The fruits are consumed mainly as juice.

Volatile constituents of cupuacu were isolated by steam distillation–extraction of pulp or juice [2].The identification of volatile constituents was based on mass spectral analysis. The pleasant aroma compounds were mainly esters (Fig. 8.2). Large amounts of ethyl butanoate and small amounts of ethyl acetate, butyl acetate, and butyl isobutanoate were described.

More recently, several aroma compounds were isolated from cupuacu pulp by vacuum distillation, solid-phase extraction, and simultaneous steam distillation–extarction and were analysed by GC, GC-MS, and GC-O [8]. The olfaction of the extracts obtained by solid-phase extraction indicated linalool, α-terpineol, 2-phenylethanol, myrcene, and limonene as contributors of the pleasant floral flavour. In this study, the esters ethyl 2-methylbutanoate, ethyl hexanoate, and butyl butanoate were involved in the typical fruity characteristics.

In another investigation, the volatile compounds were isolated [19] using a Porapack Q trap by vacuum for 2 h and were then eluted with hexane. The esters were the chemical class of compounds that predominated in the samples among 21 volatile compounds detected. Ethyl butanoate, ethyl 2-methylbutanoate, 1-butanol, ethyl hexanoate, 3-hydroxy-2-butanone, ethyl octanoate, acetic acid, linalool, palmitic acid, and oleic acid were identified in cupuacu pulp by solid-phase extracton [15].

Plagues in cupuacu cultivation are mainly caused by beetles (*Costalimaita* sp.) which attack the leaves, grasshoppers and ants. Vassoura de bruxa disease is caused by the fungus *Crinipellis perniciosa* (http://www.seagri.ba.gov.br)

8.10
Bacuri (*Platonia insignis* M. or *Platonia sculenta*)

The bacuri tree grows in the south of the Amazonian forest in Para state, Brazil. The fruits are ovoid to subglobose, are 7–15 cm in diameter and weigh 200–1,000 g. They have a creamy white mucilaginous, fibrous, juicy pulp with a very attractive exotic flavour. The fruit is consumed as such, as a juice, or in ice cream or jellies.

The first study on the volatile composition of bacuri revealed linalool, 2-heptanone, and *cis*-3-hexenyl acetate as the most important flavour compounds [2]. Volatiles were isolated by a steam distillation–extraction of pulp.

The main volatile components isolated from bacuri shells using various isolation methods, such as steam distillation and supercritical CO_2 extractions were (Z)-linalool oxide, (E)-linalool oxide, 2-pentanone, 2-nonanone, *cis*-hexenyl acetate, methyl dodecacanoate, and several hydrocarbons, including bisabolene [46].

The free and bound flavour components of bacuri fruits were analysed by GC and GC-MS using XAD-amberlite separation. Seventy-five components were identified in the free volatile fraction, and the most abundant components were terpene alcohols. Among the saturated and unsaturated alcohols present in the

volatile fraction of bacuri, hexanol and (*Z*)-hex-3-en-1-ol seemed to contribute to the herbaceous odour detected in intact fruits [8]. Bacuri glycosides identified in this work, like benzyl, 2-phenylethyl, and (*E*)-linalool furanooxides, linalool glucosides, and benzyl, 2-phenylethyl, and linalool rutinosides, were considered by the authors as the most important glycosides. The formation of volatile compounds using heat treatment of the bacuri pulp at its natural pH and at pH 7 was verified during the simultaneous distillation and extraction technique [9]. Increased amounts of oxygenated and hydrocarbon terpenes and of aldehydes were observed after simultaneous distillation and extraction at pH 3. More particularly, linalool, linalaool furanoxides, *α*-terpineol, hotrienol, nerol oxide, nerol, and geraniol were described as the main components. These results were partially explained by the hydrolysis of the glycosidically bound compounds.

8.11
Sustainability of Tropical Cultivation

Tropical soils may seem fertile when covered with luxuriant vegetation, but they are sometimes surprisingly poor in nutrients. The low fertility of tropical areas may result from natural and anthropogenic causes. The soil composition and the pluviometer index are the main factors determining fertility; the flushing out of nutrients is higher at higher temperatures and at higher incidence of rain. The amount of organic matter and nutrient elements accumulated in vegetation relative to that in soil is generally larger in tropical forests than in temperate ones; therefore, exhaustion of nutrients by removing forest vegetation is more serious in the tropics than in temperate regions.

Desertification is caused by overcultivation, overgrazing, and deforestation. This may result in soil exhaustion and erosion. This will in turn decrease the soil productivity, reduce food production, deprive the land of its vegetative cover, and negatively impact areas not directly affected by its symptoms, by causing floods, soil salinisation, deterioration of water quality, and silting of rivers, streams, and reservoirs (http://www.fao.org).

The aroma compounds from the tropical fruits described in this chapter can be very important for consumers and industry as they are exotic and extremely pleasant; however, the production of these compounds by biotechnological processes should be emphasised since the extraction from the fruits is a hard task. Many tropical soils contain less nitrogen and phosphorus, have lower capacity to absorb fertilisers, and therefore have lower conventional productive capacity, but some tropical soils have been very intensively farmed and further intensification is possible in other areas. Thus, the evaluation of a sustainable agriculture in tropical regions requires a sophisticated approach including the estimation of the risk of microbial or insect infestations. As many fruits go directly to fresh markets or to immediate processing, a continuing supply of the flavour manufacturers in the future is not completely assured.

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