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Nutritional Composition and Volatile Compounds in Guava

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ABSTRACT

Guava, *Psidium guajava* L. (Myrtaceae), which has a unique quince and banana–like odor, is native to Central America. It is frequently cultivated as a food for its pleasant fruit that is also used in juice processing. Today, the trees can be found cultivated or growing wild in nearly the entire Mesoamerican geographical area, all the countries of the Tropical World Belt, from the West Coast of Africa to the Pacific Region, including India, China and Taiwan. Guava is a great fruit because it contains key nutrients like vitamin C, vitamin B group, potassium, fiber, calcium and iron. Vitamin C content in guava is second only to acerola (*Malpighia glabra* L.). In guava, the level of total sugar and its major components, glucose and sucrose, increase during growth and development of intact fruits. Guava is popular to consumers because of its aroma. More than 500 volatile compounds have already been found in the guava. Volatile compounds change in guava fruits at different stages of maturity during ripening. Guava leaves also have been used to treat many ailments, including cough and pulmonary disease in Bolivia and Egypt. In Mexico, guava leaves are extensively used to stop diarrhea and for the alleviation of gastrointestinal disorder, a common practice originally inherited from traditional Aztec medicine. In Taiwan, it is also known that leaves and fruit can improve the glucose level in patients with type 2 diabetes.

Keywords: aroma, C, flavor, *Psidium guajava* L.

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INTRODUCTION

Guava, *Psidium guajava* L. (Myrtaceae) is native to Central America. It was distributed worldwide into tropical and subtropical areas in the early 17th century. Today, the trees can be found cultivated or growing wild in nearly all the Mesoamerican geographical area, and in all countries of the Tropical World Belt, from the West Coast of Africa to the Pacific Region, including Sudan, India, China and Taiwan. The tree (**Fig. 1**) grows as a large spreading shrub or a small tree up to 15 m high. The round-oval fruit is green-yellow and shows a light yellow or pink pulp. In Taiwan, the round-oval fruit with white flesh is harvested for processing about 3 months after blooming (**Fig. 2**). The main flowering period occurs in May–June with an autumn harvest period (August–September). Irrigation-induced flowering can occur from February-May with a spring-summer harvest period. During ripening, the color of the peel changed from green during the maturing stage to light yellow during the ripening stage, and the characteristic flavors form gradually (Chyau *et al*. 1992). The aroma impression of the fruit is often described as "quince banana"-like.

The respiration behavior and ethylene production rate of different cultivars of guava fruits were determined at 20°C after harvest. Fruits were found to be climacteric or non-climacteric in their respiratory behavior. The fruit softens very rapidly during ripening, becomes musky and unfit for consumption, and exhibits a typical respiration pattern of climacteric fruit. The firmness of guava is due to the presence of pectic substances. Water-soluble pectin varied from 0.34 to 0.64% (El-Buluk *et al.* 1995). The softening is the result of degradative changes and solubilisation of pectin due to the activity of pectic enzymes (Huber 1983). There are two important pectic enzymes: pectinesterase (PE) and polygalacturonase (PG). Changes in activities of

Fig. 1 Guava tree.

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Invited Review

Fig. 2 Guava flower and fruit.

the cell wall degrading enzymes, PE, PG and cellulase, were studied during the ripening of white-and pink-fleshed guava fruit types. PE activity increased in both guava types up to the climacteric peak of respiration (flesh firmness of 1.21 kg/cm^2) and subsequently decreased. Activities of PG and cellulase increased progressively during the ripening of both guava fruit types with a high correlation between the increase in the activity of the two enzymes and the loss of fruit flesh firmness (Abu-Bakr *et al*. 2003). For all cultivars texture declined gradually during fruit development. The skin colour of the fruit changed gradually from dark green to yellow for all cultivars. Fruits picked before day 106 after fruit set had a reading of more than 30 psi which was outside the range of the pressure tester. Fruit volume increased rapidly with fruit development for all cultivar. Softness and yellowness of fruit were associated with lower protein and alcohol–insoluble solids contents, higher moisture and appreciable amounts of water-soluble pectin (El-Buluk *et al*. 1995). Reyes and Paull (1995) reported guava storage at 15°C delayed deterioration of quarter-yellow and half-yellow fruit and allowed gradual ripening of mature-green fruit to full color in 11 days. Ripening was delayed most by the lowest temperature (10°C) for the mature-green fruit, and decreasingly less for the riper fruit and higher temperatures (20°C). Treating fruit with 100 µL 1^{-1} ethylene (C_2H_4) at 20°C for 24 h resulted in a significant increase in the rate of skin yellowing and softening of immature-green fruit, whereas ethylene-treated mature-green and quarter-yellow fruit did not differ from nontreated control fruit in rate of skin yellowing and softening.

Guava can be consumed either as fresh fruits or as processed into many different foods: jelly, jams, puree, juice, etc. It is one the easiest fruits to process, showing good characteristics for the industry, mainly due to its excellent

Table 1 Nutritional values of *Psidium guajava* L.

Nutrient	Units	Value per 100 grams	Nutrient	Units	Value per 100 grams
Proximates			**Lipids**		
Water	g	80.8	Fatty acids, total saturated	g	0.272
Energy	kcal	68	14:00	g	0.019
Energy	kj	285	16:00	g	0.228
Protein	g	2.55	18:00	g	0.025
Total lipid (fat)	g	0.95	Fatty acids, total monounsaturated	g	0.087
Ash	g	1.39	16:1 undifferentiated	g	0.005
Carbohydrate, by difference	g	14.32	18:1 undifferentiated	g	0.082
Fiber, total dietary	g	5.4	Fatty acids, total polyunsaturated	g	0.401
Sugars, total	g	8.92	18:2 undifferentiated	g	0.288
Minerals			18:3 undifferentiated	g	0.112
Calcium, Ca	mg	18	**Amino acids**		
Iron, Fe	mg	0.26	Tryptophan	g	0.022
Magnesium, Mg	mg	22	Threonine	g	0.096
Phosphorus, P	mg	40	Isoleucine	g	0.093
Potassium, K	mg	417	Leucine	g	0.171
Sodium, Na	mg	2	Lysine	g	0.072
Zinc, Zn	mg	0.23	Methionine	g	0.016
Copper, Cu	mg	0.23	Phenylalanine	g	0.006
Manganese, Mn	mg	0.15	Tyrosine	g	0.031
Selenium, Se	mcg	0.6	Valine	g	0.087
Vitamins			Arginine	g	0.065
Vitamin C, total ascorbic acid	mg	228.3	Histidine	g	0.022
Thiamin	mg	0.067	Alanine	g	0.128
Riboflavin	mg	0.04	Aspartic acid	g	0.162
Niacin	mg	1.084	Glutamic acid	g	0.333
Pantothenic acid	mg	0.451	Glycine	g	0.128
Vitamin B-6	mg	0.11	Proline	g	0.078
Folate, total	mcg	49	Serine	g	0.075
Folate, food	mcg	49	**Other**		
Folate, DFE	mcg_DFE	49	Carotene, beta	mcg	374
Vitamin A, IU	IU	624	Lycopene	mcg	5204
Vitamin A, RAE	mcg_RAE	31			
Vitamin E (alpha-tocopherol)	mg	0.73			
Vitamin K (phylloquinone)	mcg	2.6			

Source: USDA (2005)

source of vitamin C, niacin, riboflavin and vitamin A (Soares *et al*. 2007). In subtropical climates, guava is harvested all year, with excellent processing characteristics. Guava does not show problems of a physical or biochemical nature in relation to texture, shape or pulp browning during processing (Wilson *et al*. 1982).

Guava leaves have been used to treat many ailments including cough and pulmonary disease in Bolivia and Egypt (Batick 1984). In Mexico, guava leaves are extensively used to stop diarrhea and for the alleviation of gastrointestinal disorder is a common practice originally inherited from traditional Aztec medicine (Lozoya *et al*. 2002). In Taiwan, it is also known that leaves can improve the glucose level in patients with type 2 diabetes and used as a traditional therapy for dysentery.

NUTRITIONAL COMPOSITIONS

Guava can be promoted as a health fruit equal or even superior to several other fruits in not only taste and texture but also in overall nutritive quality (Uddin *et al*. 2002) (**Table 1**). It is nutritionally important due to its excellent source of vitamin C, niacin, riboflavin and vitamin A (Soares *et al*. 2007). It is rich in vitamin C (200 ± 300 mg/100 g) (Holland *et al*. 1991), three to six times higher than the content in orange. It has the second richest vitamin C content among all fruits after acerola, which has the highest vitamin C content.

Guava has a quite low energy content of about 68 kcal per 100 g (**Table 1**). El-Buluk *et al*. (1995) reported that crude protein content of guava in Sudan is low (1%), and content decreased markedly with fruit growth and development for all cultivars. Moisture content significantly increased with fruit growth and development in all cultivars. The maximum lever varied from 6.2 to 76.0%. Water–soluble pectin for all cultivars increased gradually with fruit development. The maximum level varied from 0.34 to 0.64%. Chyau *et al*. (1992) showed that the pectin content of guava was obviously higher in the mature stage than in the ripe stage and that the Brix-acid ratio increased inversely (**Table 2**).

In guava, the level of total sugar and its major components, glucose and sucrose, increased during growth and development of intact fruits. Quantitative data (g/100 ml) of major carbohydrates of guava juice, the main sugar components were fructose (2.74 ± 0.26) and glucose (0.95 ± 0.08) Sanz *et al*. (2004). Zainal *et al*. (1997) reported pink guava juice was marked with total soluble solid ranged from 9.9°Brix to 10.63°Brix and pH ranged between 3.46 and 3.98 in Malaysia. Bulk *et al*. (1996) studied the changes in chemical composition of guava fruits during development and ripening. They reported individual sugar contents increased gradually with fruit growth and development. The maximum level varied from 5.64 to 7.67, 1.90 to 8.00 and 6.20 to 7.78 mg per 100 mL of juice for fructose, glucose and sucrose, respectively. Total soluble solids gradually increased with fruit development in all cultivar, which differed in their final value (11.1-13.2°Brix). Mercado-Silva *et al*. (1998) indicated that cv. 'Media China' had the highest content of total soluble solids, titratable acidity and vitamin C on the third day after postharvest (**Table 2**). Polyphenols significantly decreased with fruit growth and development in all cultivars, which differed in their final value (0.20-0.30%) (Bulk *et al*. 1996).

Various functions and actions have been attributed to carotenoids, making determination of their concentrations in foods highly desirable. Pink guava is a fruit with a much higher content of lycopene (44.80-60.6 μg/g) (principal pigment) than mango (*Mangifera indica* L.) or papaya (*Carica papaya* L.) (18.60-28.60 μg/g), however, it has less β-carotene (3.02-5.84 μg/g, major provatamin) than mango (8.20-28.70 μg/g) but higher amount than of papaya (0.80-1.76 μg/g) (Wilberg *et al*. 1995).

VOLATILE COMPOUNDS

Quite a lot of reports have been published covering the volatile compounds of guava fruit (**Table 3**). Guava volatile constituents have been reported since the early 1960s. Stevens *et al*. (1970) reported the identification of 22 compounds with *cis*-3-hexen-1-ol, hexanol, and hexanal predominating in guava puree. Wilson and Shaw (1978) studied the terpene hydrocarbons in guava puree. They identified 12 terpenes and reported β-caryophyllene plays an important role in the aroma. MacLeod and Troconis (1982) analyzed by gas chromatograph-mass spectrometer (GC/MS) using both electron impact (EI) and chemical ionization (CI). They reported that 2-methylpropyl acetate, myrcene, hexyl acetate, benzaldehyde, ethyl decanoate, β-caryophyllene, α-humulene and α-selinene had a guava-like aroma among 40 volatile compounds obtained in essence of fresh guava fruit from Venezuela. Idstein and Schreier (1985) studied the volatile constituents from guava fruit and identified 154 compounds, C_6 aldehydes and alcohols were predominant. Hashinaga *et al*. (1987) studied the production of volatile components of guava during maturation. They reported 85 compounds in fruit and leaf. On immature fruit, the major compounds were ethyl acetate, isobutyl alcohol, β-caryophyllene and α-humulene. Ripe fruit, the major compounds were ethyl acetate, ethyl butyrate, ethyl caproate. Nishimura *et al*. (1989) analyzed the volatile constituents of guava fruits and canned puree. A total of 122 volatile components were identified, the major constituents of fresh fruits were C_6 compounds. Chyau and Wu (1989) analyzed inner and outer flesh peel of guava aroma. They reported the inner flesh was found to especially rich in ethyl acetate and other ethyl esters, whereas (*Z*)-ocimene, β- and γ-caryophyllene existed in larger amounts in the outer portion. C_6 aldehydes were richer in inner portion of the fruit. Vernin *et al*. (1991) analyzed aroma of guava fruit from Egypt. They reported 132 compounds, the major constituents were (*Z*)-3-hexenyl acetate, pentan-2-one, cinnamyl alcohol, 3-phenylpropyl acetate and corresponding alcohols. Ethyl esters may play an important role in the characteristic sweet and vary pleasant flavor of guava. Ekundayo *et al*. (1991) identified 25 compounds in guava. They reported β-caryophyllene and oxygen-containing sesquiterpenes were typical for Nigerian guava. Chyau *et al*. (1992) identified mature and ripe guava fruit aroma. A total of 34 components were identified. The major constituents in mature fruit were 1,8-cineole, (*E*)-2-

Table 2 Quality measurement of mature and ripe fruits.

Measure items	Mature fruits	Ripe fruits	References
diameter of fruits, cm	5.00-5.40	5.90-6.10	Chyau *et al*. 1992
average weight of fruits, g	91.97	123.33	Chyau *et al*. 1992
total pectin, %	3.40	0.67	Chyau *et al*. 1992
reducing sugars , %	3.66	2.90	Chyau *et al*. 1992
total sugars, %	5.62	4.68	Chyau *et al*. 1992
total soluble solids content, %	7.80-12.10	8.5-11.4	Mercado-Silva *et al*. 1998
acidity, % (as citric acid)	0.48	0.31	Chyau *et al*. 1992
titratable acidity, %	0.58-1.21	0.54-1.03	Mercado-Silva *et al*. 1998
ascorbic acid (mg/100 g)	262-341	255-336	Mercado-Silva *et al*. 1998
brix-acid ratio	14.20	20.00	Chyau *et al*. 1992
pH[a]	4.33	4.48	Chyau *et al*. 1992

Table 3 Volatile compounds of guava identified in the literature.

Compound	References	Compound	References
Aliphatic Alcohols		(*E*)-2-octenal	4
acetol	7	pentanal	1, 4, 5, 12, 14
isoamyl alcohol	5	isopentanal	14
1-butanol	4, 5, 14, 15, 16	(*E*)-2-pentenal	4
2-butanol	4	(*Z*)-2-pentenal	4
isobutanol	1, 3, 5, 7, 14, 15, 16	4-pentenal	7
tert-butyl alcohol	11,	3,5,5-trimethylhexenal	12
2,3-butanediol	7	**Aliphatic Ketones**	
cyclopentanol	7, 8	acetone	3, 7
decanol	7	2,3-butanedione	3, 7, 16
1-decanol	15	butanone	3
2-decanol	7	2,4-dimethyl-3-pentanone	7
3-decanol	4	2-heptanone	14
ethanol	10, 12, 14, 15	2-hexadecanone	14
1-heptanol	4, 5, 14	3-hexanone	14
2-heptanol	14	hydroxyacetone	6
3-heptanol	8	3- hydroxy-2-butanone	4, 6, 11, 16
1-hexadecanol	4	3-hydroxy-2-pyranone	14, 15
2-hexadecanol	14	3-methyl 2-butanone	6
1-hexanol	1, 4, 6, 7, 8, ,10, 11, 12, 13, 14, 15, 16, 17	6-methyl-5-hepten-2-one	4, 16, 17
(*E*)-2-hexenol	4, 6, 7, 9, 11, 13	2-methyl-6-heptenone	15
(*Z*)-2-hexenol	7, 14	2-methyl-2-hepten-6-one	14
(*E*)-3-hexenol	1, 3, 4, 6, 7, 8, 14, 15	3-methyl-4-octanone	13
(*Z*)-3-hexenol	4, 5, 7, 8, 10, 11, 14, 15, 16, 17	3-methyl-2,4-pentanedione	16
2-methylbutanol	14, 15, 16	4-methyl-3-penten-2-one	14
3-methylbutanol	15, 16	4-methylheptan-3-one	4
2-methylbutan-2-ol	8	2-nonanone	14
1-nonanol	1, 4, 5	2-octadecanone	14
2-nonanol	8, 16	3-octanone	4
3-nonanol	7	1-octen-3-one	4
1-octadecanol	4	2-pentadecanone	14
1-octanol	1, 3, 4, 5, 6, 7, 8, 14,15, 16	2-pentanone	8, 14, 15, 16
1-octen-3-o1	4, 16	3-pentanone	4, 7
2-octen-1-ol	4, 16	1-penten-3-one	4
2-pentadecanol	14	3-penten-2-one	15
1-pentanol	1, 4, 7, 8, 16	2-tridecanone	14
2-pentanol	4, 8, 14, 16	3,3,5-trimethylcyclohexanone	7, 8
isopentanol	7, 14	4-undecanone	14
1-penten-3-ol	1, 4, 14, 16	**Aliphatic Acids**	
3-penten-2-ol	8	acetic acid	4, 7, 14, 15, 16
3-penten-3-ol	15	butanoic acid	4,7
1-propanol	15	isobutanoic acid	7, 14
2-propenyl-2-phenol	13	decanoic acid	4, 9, 10, 14, 15
phytol	14	dodecanoic acid	9, 10, 14, 15
1-tetradecanol	4	2-ethyl butanoic acid	7, 8
2-tridecanol	14	heptanoic acid	4
5-undecanol	4	hexadecanoic acid	4, 9, 14, 15
Alphatic Aldehydes		hexanoic acid	4, 7, 11, 14, 15, 16, 17
acetaldehyde	3, 5, 7, 14, 15	(*E*)-2-hexenoic acid	4
butanal	14	3-hexenoic acid	16
(*E*)-2-butenal	4	5-hexenoic acid	7
(*E,E*)-2,4-decadienal	4, 16	linoleic acid	15
(*Z,E*)-2,4-decadienal	4	3-methylbutanoic acid	16
(*E,E*)-2,4-heptadienal	4, 7, 14	nonanoic acid	4
(*E,Z*)-2,4-heptadienal	4	octanoic acid	4, 7, 8, 9, 15, 16
decanal	4,	oleic acid	14
(*E*)-2-decenal	4, 14	pentadecanoic acid	14, 15
heptanal	4, 16	pentanoic acid	7
(*E*)-2-heptenal	14	isopentanoic acid	7, 14
(*E,E*)-2,4-hexadienal	4, 13	tetradecanoic acid	4, 9, 14, 15
hexanal	1, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17	undecanoic acid	14
(*E*)-2-hexenal	4, 6, 7, 8, 10, 11, 13, 14, 15, 16, 18	**Aliphatic Esters**	
(*Z*)-2-hexenal	7, 13, 17	ethyl formate	15
(*E*)-3-hexenal	4, 6, 8, 10, 11, 15	isoamyl acetate	14
(*Z*)-3-hexenal	4, 6, 7, 8, 10, 13, 18	2-butenyl acetate	16
2-methyl propanal	12	butyl acetate	3, 14, 15, 16
2-methyl-4-pentenal	4	isobutyl acetate	6, 8, 12, 14, 16
(*E,E*)-2,4-nonadienal	4	2-cyclohexyl acetate	4
(*E,Z*)-2,6-nonadienal	4	5-decenyl acetate	14
(*E*)-2-nonenal	14, 18	ethyl acetate	1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16, 17
nonanal	14, 15	2-heptyl acetate	14
octanal	14, 15	(*E*)-2-hexenyl acetate	4, 14
(*E,E*)-2,4-octadienal	4	(*E*)-3-hexenyl acetate	8, 12, 14, 15, 18

Table 3 (Cont.)

Compound	References	Compound	References
(*Z*)-3-hexenyl acetate	1, 3, 4, 5, 6, 7, 8, 10, 11, 17, 18	epi-α-bisabolol	13, 15
hexyl acetate	3, 4, 5, 6, 8, 10, 17	borneol	13, 14, 15, 16, 17
methyl acetate	14	isoborneol	15
3-methylbutyl acetate	3	α-cadinol	7, 11, 13, 14, 17
2-methylpropyl acetate	3	δ-cadinol	7, 8, 9, 14, 15
octyl acetate	3, 5, 6, 7, 8, 10, 14, 15, 16, 17	γ-cadinol	7
1-pentyl acetate	14	t-cadinol	7, 9, 14, 15, 17
propyl acetate	4, 6, 11,12, 14, 16	α-caryophyllenol	13, 14, 15
9-tetradecyl acetate	7	cubenol	14, 15
ethyl carbonate	6, 14, 15	1-epi-cubenol	13, 14
butyl propanoate	15	epi-α-cubenol	14, 15
methyl 1-propionate	5, 12	1,10-di-epi-cubenol	13
ethyl propanoate	4, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17	cuminyl alcohol	13
(*Z*)-3-hexenyl-methylpropanoate	4	elemol	11
		α-eudesmol	9, 14, 15
ethyl lactate	14, 15	β-eudesmol	9, 13, 14, 15
ethyl butanoate	3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 17	γ-eudesmol	13, 14, 15
ethyl isobutanoate	14	10-epi-γ-eudesmol	13
ethyl (*E*)-2-butenoate	4, 6, 11, 16, 17	farnesol	13
ethyl β-hydroxybutanoate	7	α-fenchol	15
ethyl 3-hydroxybutanoate	14	endo-fenchol	14
methyl 4-hydroxybutanoate	4	gleenol	13
(*Z*)-3-hexenyl butanoate	14	globulol	15, 17
(*Z*)-3-hexenyl methylbutanoate	14	4-oxo-dihydro-β-ionol	4
		ledol	6, 8, 13, 17
hexyl butanoate	14, 15	limonene-4-ol	14
isopentyl butanoate	14, 15	linalool	7, 14, 15, 16, 17
methyl butanoate	6, 7, 12, 13, 14, 15, 16, 17	*cis*-2-ρ-menthene-1-ol	14
3-methylbutyl butanoate	4	ρ-menth-1-en-9-ol	13
propyl butanoate	15	ρ-menth-1(7)-en-9-ol	13
(*Z*)-hexenyl fumarate	12	menthol	7, 12
ethyl pentanoate	4, 14	epi-α-muurolol	12
isopentyl pentanoate	14	t-muurolol	15
methyl hexanoate	3, 4, 12, 13, 14, 15, 16, 17	myrcenol	15
ethyl hexanoate	3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 16, 17, 18	neointermedeol	15
butyl hexanoate	14, 15	nerolidol	7, 8, 9, 13, 14, 17
isobutyl hexanoate	14, 15	5-epi-neointerdeol	15
(*E*)-2-hexenyl hexanoate	4	5-quaien-11-ol	15
(*Z*)-2-hexenyl hexanoate	4	spathulenol	15
(*E*)-3-hexenyl hexanoate	4, 8	**Terpene alcohol**	
(*Z*)-3-hexenyl hexanoate	4, 14, 15, 16	4-terpinenol	4, 14, 15, 16, 17
hexyl hexanoate	14, 15	α-terpineol	1, 6, 7, 11, 14, 15, 16, 17
isopentyl hexanoate	14, 15	γ-terpineol	15
propyl hexanoate	15	α-selina-11-en-4-ol	13, 14
ethyl (*E*)-2-hexenoate	4	veridiflorol	6, 10, 11, 14, 15, 17
ethyl (*E*)-3-hexenoate	14, 15	**Terpene Aldehydes**	
ethyl (*Z*)-3-hexenoate	15	cinnamic aldehyde	6, 7, 8, 10, 11, 16
methyl (*Z*)-3-hexenoate	4	citral	1
ethyl heptanoate	15	geranial	9
(*Z*)-3-hexenyl heptanoate	7, 14	**Terpene Ketones**	
butyl octanoate	15	carvone	4
ethyl octanoate	3, 4, 5, 6, 7, 8, 11, 14, 15, 16, 17	dihydromethylionone	7
(*Z*)-3-hexenyl octanoate	14, 15	β-ionone	1, 7, 17
hexyl octanoate	15	5,6-epoxy-β-ionone	7
methyl octanoate	4, 14, 15, 18	**Terpene Esters**	
octyl octanoate	15	caryophyllene formate	15
ethyl (*E*)-3-octenoate	14	bornyl acetate	14, 17
ethyl decanoate	3, 5, 6, 8, 14, 15, 17	α-campholenyl acetate	15
hexyl decanoate	7	cinnamyl acetate	1, 4, 6, 7, 11, 13
ethyl 9-decenoate	6	linalyl actate	14
ethyl dodecanoate	3, 15, 16	mytenyl acetate	15
methyl hexadecanoate	4, 14	α-terpenyl acetate	14
ethyl hexadecanoate	3, 8, 14, 15, 17	fanesyl butanoate	15
(*Z*)-3-hexenyl hexadecanoate	8	ethyl (*E*)-cinnamate	4, 6, 7, 14
ethyl octadecanoate	8, 14	methyl geraniate	15
methyl octadecanoate	14	**Terpene oxides**	
ethyl linoleate	14, 15	1,4-cineole	15
ethyl linolenate	14	1,8-cineole	6, 8, 10, 11, 12, 14, 15, 16, 17
ethyl sorbate	14	aromadendrene oxide	15
ethyl tetradecanoate	3	caryophyllene oxide	8, 13, 17
(*Z*)-3-hexenyl undecanoate	15	(*E*)-linalool oxide	7
Terpene alcohol		(*Z*) -linalool oxide	7
α-bisabolol	13, 15	*cis*-linalool oxide (furanoid)	14, 15

Table 3 (Cont.)

Compound	References	Compound	References
cis-anhydro linalool oxide	14	4,11-selinadiene	14, 15
trans-anhydro linalool oxide	14	α-selinene	2, 3, 8, 9, 13, 14, 15
caryophyllene epoxide	9, 14, 15	β-selinene	2, 9, 15,17
α-humulene epoxide I	14	α-terpinene	4, 14, 15, 17
α-humulene epoxide II	14	γ-terpinene	7, 12, 14, 15, 17
Terpene Hydrocarbons		α-terpinolene	14, 15, 17
(*E,E*)-allo-ocimene	14, 17	α-thujene	15
aromadendrene	8, 14, 15, 17	β-vetivene	14
alloaromadendrene	11, 13, 15, 17	α-ylangene	14, 15
allo-9-aromadendrene	14	zonarene	15
cis-α-bergamotene	14	**lactone**	
α-bisabolene	13, 17	γ-butyrolactone	13, 16
β-bisabolene	2, 5, 7, 8, 13, 14, 15, 17, 18	γ-decalactone	4, 7, 8
(*Z*)-γ-bisabolene	13	δ-decalactone	7, 8
β-bourbonene	15	γ-dodecalactone	8
1,4,9-cadalatriene	14, 15	γ-hexalactone	7, 8
cadina-1,4-diene	13	jasmine lactone	8
cadinene	14	γ-octalactone	7
α-cadinene	14, 15	γ-undecalactone	8
γ-cadinene	15	**S-Containing Compounds**	
δ-cadinene	2, 11, 13, 14, 15, 17	isobutyl mercaptan	7
α-calarolene	13, 14, 17	dimethyl disulfide	4
α-calacorene	15	dimethyl trisulfide	4
β-calacorene	13, 14	di-isopropyl disulphide	8
cis-calamenene	13	dimethyl sulfone	7
trans-calamenene	14, 15	2-ethylthiophene	4
camphene	14, 15	2-methylthiophene	4
δ-3-carene	14	3-methylthiophene	4
β-caryophyllene	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18	2-methylthiobenzothiazole	4
		3-pentanethiol	4
9-epi-β-caryophyllene	13	**Hydrocarbons**	
γ-caryophyllene	6, 11	decane	4
14-hydroxy-9-epi-(*E*)-caryophyllene	15	dodecane	4, 12
		hexadecane	4
α-copaene	10, 13, 14, 15, 16, 17	methylcyclohexane	4
β-copaene	2	nonane	4
cubenene	14, 15	octane	3, 4
α-cubebene	10, 13, 15, 17	pentadecane	4
β-cubebene	15	tetradecane	4
curcumene	2	(*E*)-theaspirane	4
Terpene Hydrocarbons		(*Z*)- theaspirane	4
dehydroinene	15	tridecane	4
β-elemene	15	undecane	4
eremophilene	14	vitispirane	15
α-farnesene	2	**Aromatic Acids**	
α-fenchene	14, 15	benzoic acid	4, 7
(*E,E*)-α-farnesene	13	cinnamic acid	4
germacrene-D	14, 15	phenylpropanoic acid	4
α-gurjunene	13, 14, 17	**Aromatic Alcohol**	
β-gurjunene	10	benzyl alcohol	7, 8, 12
γ-gurjunene	13	cinnamyl alcohol	4, 6, 7, 8, 11, 16
ar-himachalene	14	ρ-cymen-8-ol	15
γ-himachalene	13	eugenol	4, 7
α-humulene	2, 3, 5, 7, 8, 9, 10, 13, 14, 15, 17, 18	6-mercaptohexanol	7
β-humulene	2	(*E*)-isoeugenol	7, 14
limonene	1, 2, 3, 4, 5, 7, 8, 11, 14, 15, 16, 17, 18	methyl eugenol	7, 12
β-longipinene	14	(*E*)-methylisoeugenol	14
β-maaliene	14	(*Z*)-methyl isoeugenol	14
1 (7),8-ρ-menthene	14	phenol	7, 13
1,3, 8-ρ-menthatriene	14	2-phenylethanol	1, 4, 7, 14, 15, 16
muurola-4 (14)-5-diene	13	3-phenylpropanol	4, 6, 7, 8, 15, 16
α-muurolene	13, 14, 15	5-phenylpropanol	13
β-myrcene	3, 4, 5, 8, 9, 13, 14, 16	**Aromatic aldehydes**	
γ-muurolene	13, 14	benzaldehyde	1, 3, 4, 7, 8, 10, 13, 14, 15, 16, 17
(*E*)-β-ocimene	11, 12, 13, 14, 15	m-hydroxybenzaldehyde	7
(*Z*)-β-ocimene	4, 6, 8, 9, 10, 12, 13, 17, 18	phenyl acetaldehyde	14
γ-patchoulene	14	3-phenyl-2-propenal	4
β-phellandrene	14, 15	vanillin	4
α-phellandrene	14, 15	**Aromatic ketones**	
2-pinene	14	acetophenone	4, 12, 15
α-pinene	11, 12, 14, 15, 16, 17	ρ-methoxyacetophenone	7
β-pinene	2, 5, 15, 17	ρ-methylacetophenone	7
3,7-(11)-selinadiene	14	methyl benzyl ketone	7

Table 3 (Cont.)

Compound	References	Compound	References
Aromatic esters		5-methyl-2-furfural	3
benzyl acetate	7, 16	2,5-dimethyl-4-methoxy-3-(2H)-furanone	4, 7,15
trans-chrysanthenyl acetate	14	5-ethyldihydro-2(5H)- furanone	13
ethyl phenyl acetate	4, 7, 16, 17	5-ethyl-2-(5H)-furanone	7, 8, 13
phenylethyl acetate	1, 3, 7, 14, 15, 16	4-hydroxy-5-methyl-3(2H)-furanone	4
3-phenylpropyl acetate	4, 6, 7, 8, 13, 14, 15, 17, 18	furfuryl hexyl ketone	7
3-phenylprop-2-enyl acetate	8	furfuryl pentyl ketone	7
benzyl benzoate	14	2-methyltetrahydrofuran-3-one	4
ethyl benzoate	4, 6, 7, 10, 11, 12, 11, 13, 14, 15, 16, 17	ethyl 2-furoate	4
(*Z*)-3-hexenyl benzoate	12	methyl 2-furoate	4
methyl benzoate	1, 4, 7, 16, 17, 18	acetylfuran	3
methyl (*E*)-cinnamate	1, 4	2-acetyl furan	7, 14
methyl (*Z*)-cinnamate	4	2-methyl-5-propyl furan	7
methyl nicotinoate	4	2-pentylfuran	4, 7, 17
ethyl phenyl propanoate	6, 7, 16	2-propionyl furan	7
2-phenylethyl propanoate	16	**Miscellaneous**	
ethyl 3-phenylprop-2-enoate	8	acetal	16, 17
diethyl phthalate	7	benzothiazole	4
Aromatic hydrocarbones		β-caryophyllene hydrate	14
benzene	8	diacetyl	15
isobutylbenzene	8	diethylene glycol	7
ethyl benzene	4, 7, 8, 9	5,6-dihydro-2H-pyran-2-carboxaldehyde	4
1,4-dimethylbenzene	12	2,4-dimethyl 1,3-dioxane	6
1,2-dimethoxybenzene	4	monobutyl ether	
1-methyl-2-ethylbenzene	4, 8	3,4-dihydro-8- hydroxy-3-methyl-2-benzo-1H-pyran-1-one	4
1-ethyl-4-methylbenzene	8	N,N-dimethyl formamide	7
1-methylpropylbenzene	8	dimethylene glycol monomethyl ether	7
propyl benzene	4	1-ethoxypropane	8
1,3, 5-trimethylbenzene	8	5-ethoxythiazole	4
vinyl benzene	4	(*E*)-3-hexenyl methyl ether	15
1-methoxycyclohexene	16	(*Z*)-3-hexenyl methyl ether	15
ρ-cymene	4, 8, 14, 15, 17	hexyl methyl ether	15
2,6-dimethyl-1-3-6-heptatriene	13	isopentana	15
2,5-dimethylstyrene	4	junipercamphor	15
styrene	12, 14	1-methyl-3-cyclohexen-I-carboxaldehyde	4
α,ρ-dimethylstyrene	15	methylpyrazine	4
toluene	3, 4, 7, 8, 9	N-methylpyrrolidone	7
m-xylene	7, 8, 9, 14, 15	octyl methyl ether	15
o-xylene	7, 9, 14, 15	(*Z*)-5-2-pentenylpentanlide-5,1	7
ρ-xylene	4, 7, 9, 14	pentyl methyl ether	15
Furan		1-phenoxybutane	4
furaneol	16	2,3,5-trimethylpyrazine	4
furfuryl alcohol	7		
furfural	7, 14, 15, 16		
2-furfural	3		
5-methylfurfural	7, 14		

References: 1) Stevens *et al.* 1970; 2) Wilson and Shaw 1978; 3) Macleod and Toconis 1982; 4) Idstein and Schreier 1985; 5) Hashinaga *et al.* 1987; 6) Chyau and Wu 1989; 7) Nishimura *et al.* 1989; 8) Vernin *et al.* 1991; 9) Ekundayo and Ajani 1991; 10) Yen *et al.* 1992; 11) Chyau *et al.* 1992; 12) Yen and Lin 1999; 13) Paniandy *et al.* 2000; 14) Pino *et al.* 2001; 15) Pino *et al.* 2002; 16) Jordan *et al.* 2003; 17) Chen *et al.* 2006; 18) Soares *et al.* 2007

hexenal, and (*E*)-3-hexenal. Ethyl hexanoate and (*Z*)-3-hexenyl acetate were the major volatile components of ripe fruit. Yen *et al*. (1992) studied of changes guava puree volatile flavor during processing and frozen storage, the pasteurized guava puree showed increases in aldehydes and hydrocarbons with decrease in esters when compared with unpasteurized puree. Yen *et al*. (1999) reported that pressure-treated guava juice showed increases in methanol, ethanol, and 2-ethylfuran with decreases in the other components during storage period. Pino *et al*. (2001) reported two hundred and four compounds were identified in the aroma concentrate of strawberry guava fruit, of which ethanol, α-pinene, (*Z*)-3-hexenol, (*E*)-β-caryophyllene, and hexadecanoic acid were found to be the major constituents. The presence of many aliphatic esters and terpenic compounds is thought to contribute to the unique flavor of the guava fruit. Pino *et al.* (2002) characterized the volatile of Costa Rican guava. They reported 173 components and sensorially characterized by sniffing-GC, major constituents were β-caryophyllene, α-terpineol, α-pinene, α-selinene, β-selinene, δ-cadinene, 4,11-selinadiene and α-copaene. The amounts of aliphatic esters and terpenic compounds were thought to contribute to the unique flavor of this fruit. Jordán *et al*. (2003) studied the aromatic profile in commercial guava reported that the principal components in guava essence and fresh fruit puree by GC-MS yieled a total of 51 components quantified. In the olfactometric analyses total of 43 and 48 aroma active components were detected by the panelists in commercial essence and fruit puree, respectively. Principal differences between the aroma of the commercial guava essence and the fresh fruit puree could be related to acetic acid, 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, α-copaene, and an unknown component. (*E*)-2-Hexenal seems to be more significant to the aroma of the commercial essence than of the fresh fruit puree. Chen *et al*. (2006) studied the characterization of volatiles in guava fruit from Taiwan. They reported that the principal components in guava fruit by GC-MS yielded a

total of 64 components. The major constituents identified in the guava fruit were: α-pinene, 1,8-cineole, β-caryophyllene, nerolidol, globule, C_6 aldehydes, alcohols and esters. The presence of C_6 aldehydes and esters, terpenes and 1,8-cineole is thought to contribute to the unique flavor of the guava fruit. Soares *et al.* (2007) using headspace technique and analyzed using GC/MS system. They reported the behavior of volatile compounds of fruits in the three stages of maturation was: in immature fruits and those in their inter mediate stage of maturation, were predominantly the aldehydes such as (*E*)-2-hexenal and (*Z*)-3-hexenal, in mature fruits, esters like (*Z*)-3-hexenyl acetate and (*E*)-3-hexenyl acetate and sesquiterpenes caryophyllene, α-humulene and β-bisabollene are present.

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