



ORIGINAL ARTICLE

Aroma Volatile Constituents of Brazilian Varieties of Mango Fruit

Eloisa Helena A. Andrade*, José Guilherme S. Maia† and Maria das Graças B. Zoghbi*,¹

*Departamento de Botânica, Museu Paraense Emílio Goeldi, CP 399, 66040-170 Belém, PA, Brazil and

†Departamento de Química, Universidade Federal do Pará, Campus Universitário do Guamá, 66075-900 Belém, PA, Brazil

Received March 5, 1999, and in revised form September 14, 1999

The aromas of 15 varieties of mango (*Mangifera indica* L.) cultivated in Brazil were obtained by simultaneous distillation–extraction and analyzed by GC/MS. The data analysis of volatile compounds has identified three distinguishable aroma groups. The first group, rich in α -terpinolene, was composed of the following varieties: Cheiro (66.1%), 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, rich in Δ^3 -carene, comprised the following varieties: Haden (71.4%), Tommy (64.5%) and Keith (57.4%). The third group, rich in myrcene, was dominated by the following varieties: Cavalo (57.1%), Rosa (52.4%), Espada (37.2%) and Paulista (30.3%). α -Terpinolene was the principal constituent of Willard, Parrot, Bowen and Kensington varieties. The first two occur in Sri Lanka, the Bowen fruit is indigenous of Australia and the Kensington mango is cultivated in Florida. The Δ^3 -carene is the major contributor to the aroma of mango fruit grown in Venezuela. Myrcene and (*Z*)- β -ocimene are characteristics of the Alphonso and Jaffna varieties from India and Sri Lanka, respectively.

© 2000 Academic Press

Key Words: *Mangifera indica*; Anacardiaceae; manga, mango varieties; aroma volatiles.

INTRODUCTION

The mango tree (*Mangifera indica* L.) is of great importance to inhabitants of the tropics. It is one of the oldest of cultivated fruits, having originated in southeastern Asia where it had been domesticated for centuries before spreading to other parts of the tropical world. In many parts of the tropics it now occurs in a semi-wild state, and grows well wherever fairly humid conditions prevail (Medina, 1981). In Brazil, the first country in America to introduce the species, the mango is cultivated on a large scale in the states of Southeast and Northeast. According to the data published by FAO, Brazil is the fifth largest producer of mangoes, although it represents just 2.7% of the total production of 15 million tons, coming after India (63.2%), Mexico (5.3%), Pakistan (4.2%) and China (3.0%). In Brazil, the demand for mangoes to the year 2020 will reach 900 thousand tons, equivalent to almost double the offer projected for that year, which can stimulate the rational increase of the mango production (Cunha *et al.*, 1994).

¹To whom correspondence and reprint requests should be addressed. Fax: (5591) 274-4025. E-mail: zoghbi@museu-goeldi.br.

The present work was undertaken to investigate the aroma constituents of mango varieties cultivated or growing wild in Brazil. Fourteen varieties of mango were obtained in the State of Pará (North Brazil). The 12 mango fruits collected in the local markets of the city of Belém were identified as Chana, Comum, Carlota, Rosa, Bacuri, Cheiro, Espada, Paulista, Tommy, Keith, Haden and Gojoba varieties. The two varieties collected in the localities of Salinópolis and Salvaterra were identified as Coquinho and Cametá varieties, respectively. The variety called Cavalo was collected in the city of Alagoas (Northeast Brazil). All 15 varieties are readily distinguishable by their external appearance, size and taste. The Comum mango is the principal variety eaten in the city of Belém, the greatest of the Amazon Region. Until recently, the variety Haden was predominant in the market and in the commercial plantations of Brazil. Now, for consumption *in natura*, it is being substituted by other varieties like Keith, Kent, Tommy Atkins and Van Dyke (Cunha *et al.*, 1994). The Carlota variety has been studied for the production of mango nectar (Bleinroth *et al.*, 1976).

The volatile components of mango have been extensively investigated. The results obtained by most authors show that there are considerable differences which occur between varieties grown in the same country to the same stage of ripeness. Most of the studies have been undertaken using mangoes cultivated in India, Africa, Venezuela, Australia, United States and Sri Lanka. The varieties in which the volatile compositions have been most extensively studied are Venezuelan, Alphonso, Bowen, African, Jaffna, Willard, Parrot, Kensington, Langra, Bombay and Desi (MacLeod and Triconis, 1982; MacLeod and Pieris, 1984; Sakho *et al.*, 1985; Idstein and Schreier, 1985; Bartley and Schwede, 1987; MacLeod *et al.*, 1988; Ansari *et al.*, 1999). No reports have appeared on the volatile components of the specimens or varieties cultivated in Brazil.

METHODS

Sample Collection and Preparation

Fresh ripe mangoes were obtained from local markets in the city of Belém (Pará State, Brazil) and the surrounding localities or collected in orchards belonging to edible fruit providers. The varieties of Chana, Comum, Carlota, Rosa, Bacuri, Cheiro, Espada, Paulista, Tommy, Keith, Haden and Gojoba were obtained from local markets; the varieties of Coquinho and Cametá were collected in the cities of Salinópolis and Salvaterra (Pará State), and the variety called Cavalo was collected in the city of Alagoas (Northeast Brazil). After removal of the skin and kernel, the freshly macerated pulp (100 g each) was mixed with water (20 mL) and submitted to simultaneous distillation-extraction for 3 h, using a Chrompack Micro-steam Distillation Extractor and pentane (2 mL) as organic mobile phase. Two extractions of each sample were performed and submitted to GC/MS analyses.

Sample Analyses

A Finnigan Mat INCOS XL instrument was used, linked on-line to a Data General data processing system, with the following conditions: a WCOT DB-5 (30 m × 0.25 mm i.d.; 0.25 m film thickness) fused silica capillary column; temperature programmed: 40–60°C (2°C/min), 60–260°C (4°C/min); injector temperature: 220°C; carrier gas: He, adjusted to a linear velocity of 32 cm/s (measured at 100°C); injection type: splitless (1 µL, of a 1:1000 hexane soln.); split flow was adjusted to give a 20:1;

septum sweep was a constant 10 mL/min; EIMS: electron energy, 70 Ev; ion source temperature and connection parts: 180°C.

RESULTS AND DISCUSSION

Individual components were identified by comparison of both mass spectra and GC retention data with those of authentic compounds previously analyzed and stored in the data system. Other identifications were made by comparison of mass spectra with those in the data system libraries and cited in the literature (Adams, 1995; Jennings and Shibamoto, 1980). The retention indices were calculated for all compounds using a homologous series of *n*-alkanes under the same operational conditions of analyses. The 81 volatile constituents identified in the 15 analyzed aromas are listed in Table 1. A number of significant differences can be observed and on the basis of these results the aromas can be split into three groups. The first group, rich in α -terpinolene, comprised eight varieties: Cheiro (66.1%), 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 was made up of three varieties rich in Δ^3 -carene: Haden (71.4%), Tommy (64.5%) and Keith (57.4%), originally from the United States. The third group, rich in myrcene, was composed of four varieties: Cavalo (57.1%), Rosa (52.4%), Espada (37.2%) and Paulista (30.3%). The compound Δ^3 -carene was the major contributor of the Venezuelan cultivar (MacLeod and Troconis, 1982) and the Indian Langra cultivar (Ansari *et al.*, 1999). The compound α -terpinolene was the principal constituent of Willard and Parrot (MacLeod and Pieris, 1984), Bowen (Bartley and Schwede, 1987) and Kensington (MacLeod *et al.*, 1988) varieties. The first two cultivars occur in Sri Lanka, the Bowen mango is indigenous to Australia and the Kensington variety, despite being cultivated in Florida is reported as originating from the Bowen mango (MacLeod *et al.*, 1988). Myrcene and (*Z*)- β -ocimene are characteristics of the Alphonso and Jaffna varieties from India and Sri Lanka, respectively (MacLeod and Pieris, 1984; Sakho *et al.*, 1985). Moreover, the Baladi variety is described as containing valuable amounts of myrcene, ocimene and α -pinene (Engel and Tressel, 1983).

The terpenes α -pinene, limonene, (*Z*)- β -ocimene and β -selinene were identified in considerable amounts in some Brazilian varieties: α -pinene: Keith (19.9%), Rosa (16.8%), Paulista (17.8%) and Espada (16.5%); limonene: Carlota (19.3%), Bacuri (14.0%), Rosa (9.7%), Paulista (7.9%) and Chana (6.8%); (*Z*)- β -ocimene: Espada (15.5%); β -selinene: Paulista (15.3%) and Cavalo (10.8%). On the other hand, α -pinene was found in appreciable amounts in the Venezuelan, Willard and Bombay varieties; (*Z*)- β -ocimene in the Jaffna and Alphonso varieties; and β -selinene in the Venezuelan, Willard and Parrot varieties. The compound Δ^2 -carene was identified in the Coquinho and Kensington varieties. Among the sesquiterpenoid compounds were found alloaromadendrene, α -gurjunene and β -gurjunene. These tricyclic sesquiterpenes may arise from bicyclogermacrene (Tressel *et al.*, 1983) and are possible precursors of the sesquiterpene alcohols viridiflorol, guaiol and bulnesol, all identified in some samples of mango fruits. The compound β -caryophyllene was found in all analyzed samples. It is present also in the Jaffna, Willard, Parrot, Kensington and Bowen varieties. We could not find in the analyzed samples the sesquiterpene eremophilene, the principal volatile component ascribed to the African mango (Sakho *et al.*, 1985).

Alcohols and C₆ aldehydes previously detected in the Alphonso variety were also present in aromas extracted from analyzed mango fruits. (*E*)-Hex-3-enol and (*Z*)-hex-3-enol were identified in the Coquinho and Gojoba varieties, respectively. Undec-10-enol was found in the sample of Cavalo mango fruit. Hexadecanol was identified in

1-Isopropyl-4-methylbenzene	1113					0.4			0.4								
<i>allo</i> -Ocimene	1130																0.1
3-Methylacetophenone	1176		0.4	0.8	0.6				1.3								
Terpinen-4-ol	1178																0.1
<i>p</i> -Cymen-8-ol	1183	4.3	1.2	3.0	1.8	3.5		0.2	1.5	2.6			0.3				1.0
<i>cis</i> -Hex-3-enyl butanoate	1184			0.1		0.9		0.4			0.4						
Butyl hexanoate	1189																0.3
α -Terpineol	1190											0.4		0.5			0.8
Ethyl octanoate	1195												0.2				
Dodecane	1201																0.3
Linalyl acetate	1246						0.1										
<i>Trans-p</i> -2, 8-Menthadien-1-ol	1248					0.8			0.7								
Safrole	1284	0.4	0.6	0.4	0.3	0.3	0.2		0.6	0.8							
(<i>E</i>)-Tridec-2-enal	1311	0.6															
α -Ylangene	1373													0.9			
α -Copaene	1377	0.2						0.9				0.5					0.3
(<i>E</i>)- β -Damascenone	1381													0.2			
Ethyl decanoate	1394												0.2				
α -Gurjunene	1408					0.3		0.2	0.5		2.3	0.1		0.1	0.5		
β -Caryophyllene	1420	3.0	3.2	4.5	0.8	3.4	6.3	1.5	7.3	1.1	4.3	1.4	0.1	3.0	4.6	1.8	
α -Guaiene	1438													1.0			
α -Humulene	1456	1.9	1.8	2.1	0.5	2.0	3.7	0.8	3.9	0.8	2.6	0.7		1.6	2.8	1.0	
<i>allo</i> -Aromadendrene	1461										0.2						
Drima-7,9(11)-diene	1468		0.8										0.4	0.2			0.4
γ -Gurjunene	1473										1.9			0.8			
β -Chamigrene	1475				0.4					0.6		0.2					
Germacrene D	1482												0.9				
β -Selinene	1485		10.8		3.8			0.5			15.3		4.5	1.8	1.1	4.4	
Valencene	1492		0.6		0.2			0.1			3.6	0.1		0.7			
α -Selinene	1494		0.7		0.3			0.1			0.5		0.8				0.4
Bicyclogermacrene	1496													0.7			
α -Bulnesene	1503		0.2											2.6			
7- <i>epi</i> - α -Selinene	1518												0.2	0.1			
δ -Cadinene	1524													0.6			
Cadina-1,4-diene	1531													0.1			
Viridiflorol	1590										0.5						
Ethyl dodecanoate	1595												0.5				
Guaiol	1596													0.1			
Dillapiole	1621																0.6

TABLE 1 (Continued)

Constituents	RI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>l-epi</i> -Cubenol	1626															0.1
Bulnesol	1666															0.1
Apiole	1682				0.1											
Ethyl tetradecanoate	1793												0.5	0.1		
Hexadecanol	1878	1.3	8.5										0.4	0.1		
Palmitic acid	1962		0.3								0.5		0.2			
Ethyl hexadecanote	1976		1.6										0.3			
Undec-10-enol	2064		0.3													

RI = Retention Index on DB-5; 1 = variety Chana, 2 = variety Cavalo, 3 = variety Coquinho, 4 = variety Comum, 5 = variety Carlota, 6 = variety Rosa, 7 = variety Keith, 8 = variety Bacuri, 9 = variety Cheiro, 10 = variety Paulista, 11 = variety Tommy, 12 = variety Cametá, 13 = variety Espada, 14 = variety Haden, 15 = variety Gojoba.

the Chana, Cametá and Cavalo varieties. On the other hand, it was found in the Parrot, Willard, and Jaffna varieties. Furfural, one of the main constituents of Venezuelan mango fruit, was found in the Coquinho, Espada and Cavalo aroma samples. Phenylacetaldehyde was found in the Coquinho mango and (*E*)-tridecen-2-al in the Chana variety. The unique ether identified was methyl butyl ether in the Coquinho and Cavalo varieties. The unique ketone was 2,3-dimethyl-cyclopent-2-en-1-one in the Coquinho variety. Hexadecanoic acid was found in the Paulista variety while palmitic acid was found in the Cametá and Cavalo mango samples.

Besides the terpenes, the major class was the esters, totalizing 10 compounds found in the Cametá, Espada, Coquinho, Cheiro, Carlota, Paulista, Cavalo and Haden varieties. Ethyl butanoate is one of the main components of the Kensington and Bowen mangoes. For the analyzed samples it was detected in minute quantities on Cametá and Espada varieties. Ethyl but-2-enoate found in the aroma of Kensington mango was also identified in the Cametá variety.

Probably, some of the identified compounds are formed or produced during crushing and extraction of most of the samples, specially alcohols, aldehydes, organic acids and furan derivatives.

ACKNOWLEDGEMENTS

The authors are grateful to the Pilot Program to Protect the Brazilian Rain Forest (PPG-7/World Bank) for financial support.

REFERENCES

- Adams, R. P. (1995). *Identification of Essential Oil Components by Gas Chromatography/Mass Spectroscopy*, Allured Publishing Corporation, IL, U.S.A.
- Ansari, S. H., Ali, M., Velasco-Negueruela, A., and Pérez-Alonso, M. J. (1999). Volatile constituents of the fruits of three mango cultivars, *Mangifera indica* L., *J. Essent. Oil Res.* **11**, 65–68.
- Bartley, J. P., and Schwede, A. (1987). Volatile flavour components in the headspace of the Australian or “Bowen” mango. *J. Food Sci.* **52**, 353–355.
- Bleinroth, E. W., Kato, K., Simão, S., de Martin, Z. J., Miya, E. E., Angelucci, E., Aloisio Sobrinho, J., de Carvalho, A. M., and Pompeo, R. M. (1976). *Caracterização de Variedades de Manga para Industrialização*. ITAL, Instruções Técnicas No. 13, São Paulo.
- Cunha, G. A. P. da, Sampaio, J. M. M., do Nascimento, A. S., Santos Filho, H. P., and Medina, V. M. (1994). *Manga para Exportação: Aspectos Técnicos da Produção*, Programa de Apoio à Produção e Exportação de Frutas, Hortaliças, Flores e Plantas Ornamentais — FRUPEX, EMBRAPA-SPI, Brasília.
- Engel, K. H., and Tressel, R. (1983). Studies on the Volatile Components of Two Mango Varieties. *J. Agric. Food Chem.* **31**, 796–799.
- Idstein, H., and Schreier, P. (1985). Volatile constituents of Alphonso mango (*Mangifera indica*). *Phyt.* **24**, 2313–2316.
- Jennings, W., and Shibamoto, T. (1980). *Qualitative Analysis of Flavor and Fragrance Volatiles by Glass Capillary Gas Chromatography*. Academic Press, New York.
- MacLeod, A. J., MacLeod, G., and Snyder, C. H. (1988). Volatile aroma constituents of mango (cv Kensington). *Phyt.* **27**, 2189–2193.
- MacLeod, A. J., and Pieris, N. M. (1984). Comparison of the volatile components of some mango cultivars. *Phyt.* **23**, 361–366.
- MacLeod, A. J., and Troconis, N. G. de (1982). Volatile flavour components of mango fruit. *Phyt.* **21**, 2523–2526.
- Medina, J. C. (1981). *Frutas Tropicais*. 8. *Manga*. ITAL, São Paulo.
- Sakho, M., Crouzet, J., and Seck, S. (1985). Volatile components of African mango. *J. Food Sci.* **50**, 548–550.
- Tressel, R., Engel, K. H., Kossa, M., Köpplu, H. (1983). Characterization of tricyclic sesquiterpenes in Hop (*Humulus lupulus*, var. Hersbrucker Spät). *J. Agric. Food Chem.* **31**, 892–895.