

Okai, 1985) the possible similarity among the bitter, sweet, and sour taste receptors and proposed that they might be contained within the same biological structure. The results obtained in this study appear to confirm this idea.

Ariyoshi et al. (1974) proposed the possibility that more than three affinity sites might be present on the sweet receptor since they had prepared several sweet di-, tri-, and tetrapeptides indicating that hydrogen bonding with several other sites on the receptor by the amide protons might lead to production of a sweet taste (Ariyoshi et al., 1974; Ariyoshi, 1976, 1980, 1984-1986). The sweet compounds reported here, however, have only *one* amide linkage, indicating that these extra bonds are not a requirement for sweetness.

Additionally, we point out that there is some interaction between the molecular functional groups (AH, B, X) and taste receptor sites (A', B', X'). We explained the tastelessness of dipeptide, *N*-L-aspartyl-1-aminocyclopropane-carboxylic acid benzyl ester (**2**) by assuming that the chain length of **2** was too great to interact with all three receptor sites (see Figure 1). We also prepared several aspartic acid amides and found that they were all sweet even though some had chain lengths longer than that of **2**. This phenomenon can be explained in Figure 3. Since **13** has about the same molecular size as the tasteless dipeptide **2**, **13** should also be tasteless. However, **13** has a floppy chain and there is apparently a strong affinity between its phenyl ring (the most hydrophobic part of the molecule) and the X' site on the receptor giving **13** a sweet taste.

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Volatile Aroma Components of *Curcuma amada* Roxb.

Alapati Srinivasa Rao, Bandaru Rajanikanth, and Ramachandran Seshadri*

The aroma concentrate of fresh rhizomes of *Curcuma amada* Roxb. was prepared by an efficient simultaneous steam distillation/solvent extraction. The qualitative analysis of these volatile aroma components was performed by using a gas chromatography/mass spectroscopy system aided by the computer library search. This led to the identification of 61 unreported compounds out of 68 compounds for which mass spectra have been recorded. Identification of the components has been confirmed by their Kovats retention indices. The aroma concentrate of mango ginger was comprised of a mixture of character impact compounds of both raw mango and turmeric.

Curcuma amada Roxb., popularly known as mango ginger, belongs to the family Zingiberaceae. The rhizomes of mango ginger are cultivated mostly in India and Malaysia where it is known as *Curcuma mangga* valet. The vegetative characteristics are similar to those of *Curcuma longa*. The rhizomes of mango ginger resemble those of true ginger and have mangolike flavor, but they have no pungency like ginger. In view of the exotic aroma it is commonly used in culinary preparations especially pickles, chutneys, etc. The rhizomes of mango ginger also find application therapeutically as a carminative and stomachic

as well as for its topical use over contusions and sprains.

The chemistry and technology of *C. amada* have been comprehensively reviewed as part of a review on turmeric (Govindarajan, 1980). Recently the botany, agronomy, technology, and chemical composition of mango ginger have also been reviewed (Shankaracharya, 1982). Ocimene has been reported as the major constituent of mango ginger besides linalool, linalyl acetate, and safrole (Dutt and Tayal, 1941). Curcumene, a sesquiterpene hydrocarbon present in turmeric, has also been reported as a major aroma component in mango ginger (Jain and Mishra, 1964; Ahuja and Nigam, 1971). The essential oil content of mango ginger has been determined by distillation-extraction and low-temperature high-vacuum distillation methods as 0.3% and 0.2%, respectively (Gholap and Bandyopadhyay, 1984). Car-3-ene and *cis*-ocimene, which are

*Organic Chemistry Section, Food Chemistry Department, Central Food Technological Research Institute, Mysore 570 013, India.

Table I. GC-MS Analysis of Volatile Flavor Components of Mango Ginger

Sl no.	compound name	ret time	Kovats index ^a	base peak	% ^b	MW
1	β -pinene	1.84	969.9	93.1	0.62	136
2	<i>cis</i> -dihydroocimene	2.56	998.6	41.0	14.22	138
3	myrcene	2.60	1000.2	41.0	14.90	136
4	<i>trans</i> -dihydroocimene	2.74	1005.8	41.0	15.94	138
5	α -phellandrene	2.82	1009.0	41.0	0.76	136
6	<i>p</i> -cymene	2.88	1011.4	41.0	1.76	134
7	carvomenthene	3.04	1017.7	41.0	0.53	136
8	<i>cis</i> -ocimene	3.14	1021.7	41.0	1.85	136
9	β -phellandrene	3.22	1024.9	41.0	0.32	136
10	1,8-cineole	3.30	1028.1	69.0	0.26	154
11	limonene	3.36	1030.5	41.0	0.29	136
12	<i>trans</i> -ocimene	3.42	1032.9	92.1	0.64	136
13	2,6-dimethylhept-5-en-1-al	3.54	1037.7	92.1	0.81	140
14	Δ -car-3-ene	3.62	1040.9	92.1	0.75	136
15	α -terpinene	3.72	1044.9	69.0	0.29	136
16	(ethoxymethyl)benzene	3.80	1047.9	92.1	0.59	136
17	γ -terpinene	3.98	1055.3	69.0	0.37	136
18	2-methylheptan-3-ol	4.12	1060.8	69.0	0.29	130
19	non-2-en-4-one	4.22	1064.8	69.0	0.34	140
20	dihydromyrcenol	4.28	1067.2	69.0	1.37	154
21	<i>p</i> -menth-4-en-9-ol	4.42	1072.8	78.0	0.37	154
22	<i>p</i> -menth-1-en-9-ol	4.52	1076.8	93.0	0.53	154
23	<i>p</i> -menth-1,8-dien-9-ol	4.58	1079.2	93.0	0.54	152
24	linalool	4.90	1092.0	93.0	13.37	154
25	nonan-2-one	5.08	1099.1	43.0	5.38	142
26	2-methyl-6-methyleneocta-1,7-dien-3-one	5.20	1103.9	41.0	2.93	150
27	nonan-2-ol	5.32	1108.7	45.0	1.51	144
28	morbornyl acetate	5.46	1114.3	41.0	0.33	196
29	citronellal	5.66	1122.3	41.0	1.93	154
30	<i>p</i> -cymen-8-ol	5.80	1127.9	43.0	0.26	150
31	2,6-dimethyleneoct-7-en-3-one	5.90	1131.9	53.0	0.21	150
32	camphor	6.16	1142.2	41.0	0.72	152
33	β -terpineol	6.48	1155.0	43.0	1.48	154
34	lavandulol	6.52	1156.6	41.0	0.53	154
35	α -terpineol	6.72	1164.6	43.0	1.38	154
36	citral	7.48	1194.9	41.1	0.09	152
37	neral	8.16	1222.0	41.1	0.11	152
38	hept-1-en-1-ol acetate	8.46	1234.0	43.0	0.22	156
39	undecan-2-one	9.02	1256.3	43.0	0.94	170
40	undecanal	9.66	1281.9	43.0	0.13	170
41	α -terpinyl acetate	10.34	1309.0	43.0	0.13	196
42	α -ionone	10.70	1323.4	41.1	0.14	192
43	δ -elemene	11.88	1370.5	41.1	0.29	204
44	β -elemene	12.74	1404.8	41.1	1.82	204
45	β -curcumene	13.04	1416.8	41.1	0.26	204
46	β -selinene	13.50	1435.1	93.0	0.24	204
47	β -copaene	13.80	1447.1	41.1	0.09	204
48	bisabolene	14.26	1465.4	41.1	0.11	204
49	α -zingiberene	14.42	1471.8	41.1	0.13	204
50	2-hydroxy-2'-methoxy diphenyl ether	14.64	1480.6	108.0	0.35	216
51	α -curcumene	16.96	1573.2	41.1	0.32	202
52	curzerenone	17.52	1595.5	122.0	0.80	230
53	epicurzerenone	17.68	1601.9	122.0	0.68	230
54	patchoulane	18.10	1618.6	41.1	0.27	206
55	hexadecane	18.54	1636.2	43.1	1.04	226
56	<i>cis</i> -farnesal	19.26	1664.9	41.1	0.38	220
57	germacrone	19.92	1691.3	107.1	0.10	218
58	<i>trans</i> -farnesal	21.08	1737.5	41.1	0.21	220
59	heptadecane	21.30	1746.3	43.1	0.30	240
60	<i>ar</i> -turmerone	22.72	1803.8	41.1	0.46	216
61	octadecane	24.0	1854.1	43.1	0.13	254
62	unknown	27.0	1976.2	149.0	0.40	
63		27.46	1992.1	41.1	0.41	
64		27.56	1996.6	43.0	0.14	
65		27.92	2010.5	41.0	0.10	
66		28.22	2022.4	41.1	0.17	
67		29.60	2077.5	41.1	0.11	
68		36.08	2336.10	41.1	0.54	

^aThe calculated Kovats retention indices and observed values (shown in parentheses) of authentic standards are as follows: tetradecane, 1396.8 (1400); pentadecane, 1518.9 (1500); hexadecane, 1638.6 (1600); myrcene, 993.8 (986); carvone, 1226.8 (1228). The extension of the calculation of Kovats indices developed by Vernin and Metzger (1984) to OV-101 was found to be accurate. ^bThe amount of each of the constituents present in the volatile aroma concentrate has been calculated by taking the mean of the two experimental determinations.

responsible for the mango flavor, have been identified along with α -pinene in the volatile oil of mango ginger by GLC analysis (Gholap and Bandyopadhyay, 1984). How-

ever, volatile aroma components of mango ginger have not been studied in detail. Hence, the principal objective of the present investigation was to reexamine the aroma

Table II. Eight Most Abundant m/z Ratios for Some of the Most Uncommon Aroma Components in Mango Ginger

compound	base peak	m/z (relative abundance, %)							
		69 (42)	93 (40)	91 (37)	79 (36)	55 (27)	133 (24)	67 (22)	
β -elemene	41	69 (42)	93 (40)	91 (37)	79 (36)	55 (27)	133 (24)	67 (22)	
β -curcumene	41	93 (72)	121 (71)	53 (56)	67 (54)	55 (43)	107 (41)	43 (38)	
α -curcumene	41	43 (64)	57 (40)	55 (38)	79 (27)	69 (26)	53 (23)	71 (22)	
curzerenone	122	94 (37)	65 (20)	66 (18)	41 (16)	91 (13)	77 (12)	230 (11)	
epicurzerenone	122	94 (34)	65 (20)	66 (19)	230 (12)	91 (10)	123 (8)	162 (8)	
<i>ar</i> -turmerone	93	41 (80)	108 (79)	91 (72)	107 (58)	105 (59)	53 (57)	77 (57)	

concentrate of mango ginger by Likens-Nickerson extraction method and subsequent analysis by GC and GC/MS techniques.

MATERIALS AND METHODS

Samples. Fresh rhizomes of *C. amada* were procured from a local market. The rhizomes selected were unaffected by rot and were free from any external damage. The rhizomes were peeled and sliced into small pieces.

Isolation Procedure. A simultaneous distillation-extraction (SDE) method was used for the isolation of the volatile from the *C. amada* rhizomes (Schultz et al., 1977). The cut pieces of rhizomes were placed in the sample flask containing distilled water (1:2, w/v). Pentane-ether (1:1, 50 mL, v/v) solvent mixture was placed in the solvent flask. The extraction of the volatiles was carried out for 3 h by circulating cold water in the condenser at 5–10 °C. After the extraction, pentane-diethyl ether solution was dried over anhydrous sodium sulfate and the solvent mixture was concentrated to about 1 mL on a Vigreux column. The concentrated extract was kept at 4 °C.

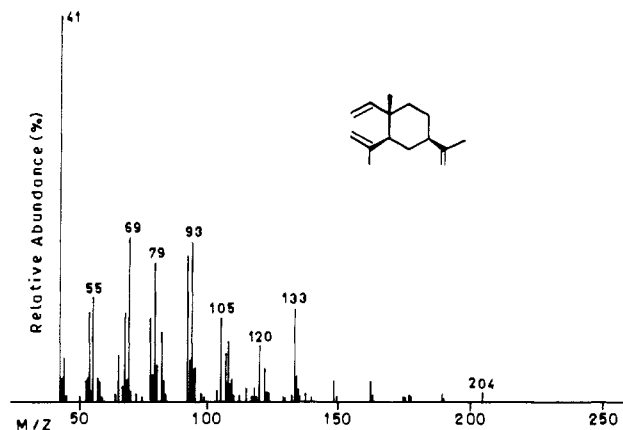
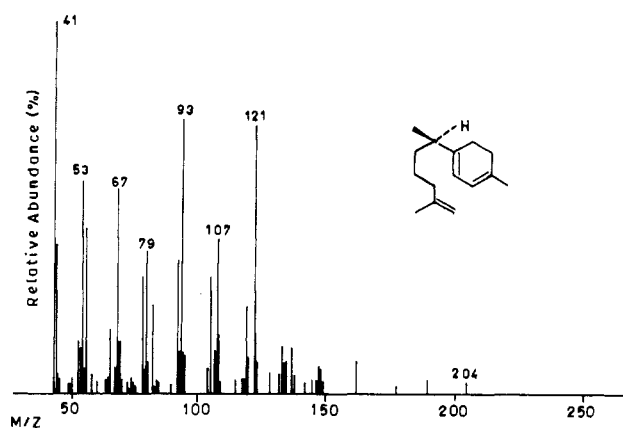
GC-MS Analysis. A Hewlett-Packard Model 5995B gas chromatography/mass spectrometer was used to record the mass spectra of the aroma components. The aroma concentrate (1 μ L) was injected into a 12 m \times 0.5 mm (i.d.) fused silica column coated with cross-linked methyl silicone with a splitless injection system. The flow rate of the carrier gas was 1 mL/min. The spectra were recorded at 70 eV. The temperature conditions were as follows: injector, 250 °C; ion source, 148 °C; analyzer, 180 °C; oven (initial), 70 °C programmed to 250 °C (15 min) at 4 °C/min. The mass range was monitored from 40 to 800 amu at two scans/s.

A Hewlett-Packard 9133 data system coupled to the GC-MS was used for mass spectral comparison, which allowed the identification of several components (flavour-fragrance entries, 1982). Spectra reported in the literature (ten Noever de Brauw et al., 1979; Stenhagen et al., 1974; Sukh Dev et al., 1982; Hikino et al., 1975; Gosselin et al., 1979) were used for the identification of the compounds that were not included in the above data system. Quantitative determinations of individual components (without considering response factor of detector, calibration $F = 1.00$ for all components) were carried out on a Hewlett-Packard 2671 G integrator on the same column. Mass spectral identifications were verified by comparison with Kovats retention indices of authentic reference standards (Jennings and Shibamoto, 1980). Kovats retention indices were calculated against *n*-paraffins (C_{14} , C_{15} , and C_{16} ; Hewlett-Packard) as references.

RESULTS AND DISCUSSION

The volatile aroma concentrate obtained by the SDE procedure closely resembled the aroma of the fresh rhizomes.

The results of the GC-MS analysis of the volatile flavor components are presented in Table I. As can be seen, 61 volatile components have been identified from the 68 components recorded by gas chromatography-mass spectrometry. Identification of these compounds has been accomplished by Kovats retention indices (Jennings and Shibamoto, 1980) and computer-aided search using the mass spectral data system; and in some of the cases the components were identified by comparing their mass spectra recorded with those reported in the literature. The concentrations of some of the individual components are very low. In the total volatile extract, the percentage contents of different groups of compounds were as follows: hydrocarbons, 55.80; alcohols, 22.38; aldehydes, 3.66; ke-

Figure 1. Electron impact mass spectrum of β -elemene.Figure 2. Electron impact mass spectrum of β -curcumene.

tones, 11.88; esters, 0.68; others, 5.60. The main compounds detected in the volatile oil are *cis*- and *trans*-dihydroocimene, ocimene, myrcene, linalool, nonan-2-one, citronellal, α -terpineol, β -terpineol, and β -elemene. The major sesquiterpene hydrocarbon fraction of *C. amada* volatile oil is composed of the following: β - and δ -elemenes, α - and β -curcumenes, β -selinene, β -copaene, bisabolene, α -zingiberene, and *ar*-turmerone. *ar*-Turmerone has been identified earlier as an important constituent of turmeric oil. Curzerenone and epicurzerenone reported in the present work have also been reported earlier to be present in *Curcuma zedoaria* Rosce (Hikino et al., 1975).

The m/z ratios and relative peak abundance for the most abundant peaks of distinct aroma components identified from *C. amada* are given in Table II. Structures of some of the most uncommon compounds along with their mass spectra have been given in Figures 1–6.

Recently, three character impact hydrocarbons, viz. *cis*-ocimene, α -pinene, and car-3-ene, have been tentatively identified during an analysis of mango ginger volatiles by comparing their gas chromatographic retention times with those of authentic samples (Gholap and Bandyopadhyay, 1984). While *cis*-ocimene has been reported to contribute to green mango aroma, α -pinene and car-3-ene have been reported to impart floral and leafy mango aromas, re-

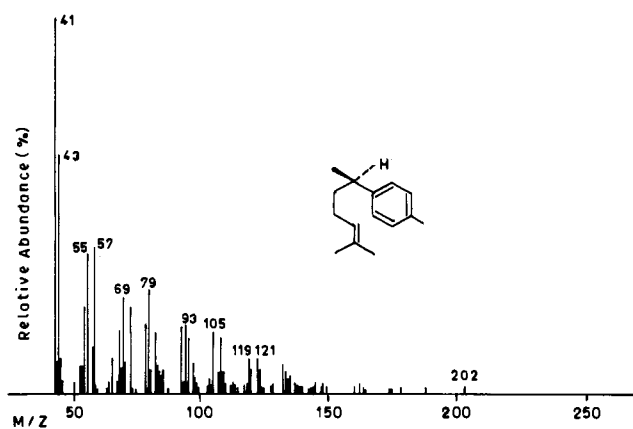


Figure 3. Electron impact mass spectrum of α -curcumene.

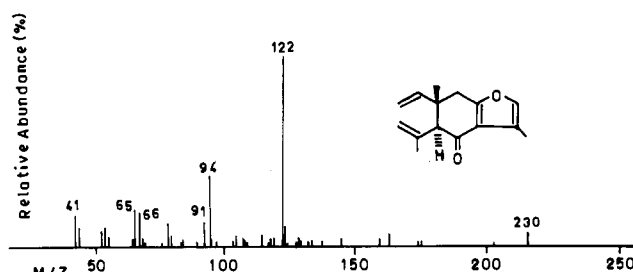


Figure 4. Electron impact mass spectrum of curzerenone.

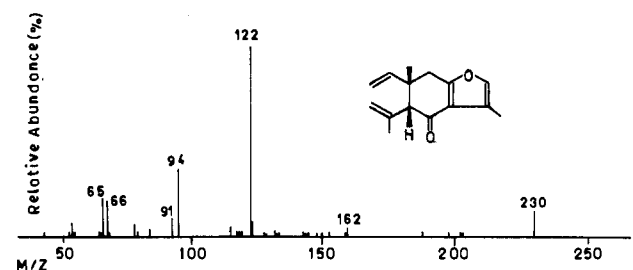


Figure 5. Electron impact mass spectrum of epicurzerenone.

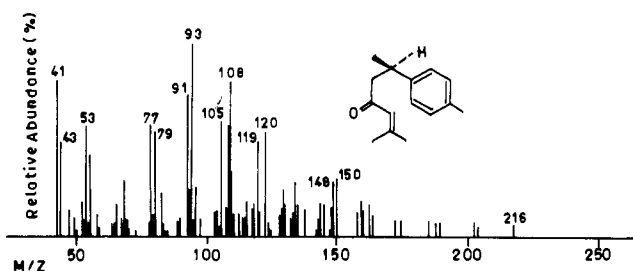


Figure 6. Electron impact mass spectrum of *ar*-turmerone.

spectively. In the present investigation *cis*- and *trans*-dihydroocimene, ocimene, and myrcene have been considered to be the major character impact compounds of *C. amada* volatile oil. Thus, the volatile aroma constituents of mango ginger constitute a mixture of character impact aroma components of raw mango (Ramteke et al., 1981) and turmeric (Govindarajan, 1980).

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Registry No. β -Pinene, 127-91-3; myrcene, 123-35-3; α -phellandrene, 99-83-2; *p*-cymene, 99-87-6; carvomenthene,

5502-88-5; *cis*-ocimene, 27400-71-1; β -phellandrene, 555-10-2; 1,8-cineole, 470-82-6; limonene, 138-86-3; *trans*-ocimene, 27400-72-2; 2,6-dimethylhept-5-en-1-al, 106-72-9; Δ -car-3-ene, 13466-78-9; α -terpinene, 99-86-5; (ethoxymethyl)benzene, 539-30-0; γ -terpinene, 99-85-4; 2-methylheptan-3-ol, 18720-62-2; non-2-en-4-one, 32064-72-5; dihydromyrcenol, 53219-21-9; *p*-menth-4-en-9-ol, 15714-10-0; *p*-menth-1-en-9-ol, 18479-68-0; *p*-menth-1,8-dien-9-ol, 1946-01-6; linalool, 78-70-6; nonan-2-one, 821-55-6; 2-methyl-6-methyleneocta-1,7-dien-3-one, 41702-60-7; nonan-2-ol, 628-99-9; norbornyl acetate, 34640-76-1; citronellal, 106-23-0; *p*-cymen-8-ol, 1197-01-9; camphor, 76-22-2; β -terpineol, 138-87-4; lavandulol, 498-16-8; α -terpineol, 98-55-5; citral, 5392-40-5; neral, 106-26-3; hept-1-en-1-ol acetate, 35468-97-4; undecan-2-one, 112-12-9; undecanal, 112-44-7; α -terpinyl acetate, 80-26-2; α -ionone, 127-41-3; δ -elemene, 20307-84-0; β -elemene, 33880-83-0; β -curcumene, 28976-67-2; β -selinene, 17066-67-0; β -copaene, 18252-44-3; bisabolene, 495-62-5; α -zingiberene, 495-60-3; 2-hydroxy-2'-methoxy diphenyl ether, 21905-60-2; α -curcumene, 644-30-4; curzerenone, 20493-56-5; epicurzerenone, 20085-85-2; patchoulane, 25491-20-7; hexadecane, 544-76-3; farnesal, 19317-11-4; germacrone, 6902-91-6; heptadecane, 629-78-7; *ar*-turmerone, 532-65-0; octadecane, 593-45-3.

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