Volatile Components of Two Cultivars of Mango from Florida

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Two cultivars of mango from Florida (Tommy Atkins and Keitt) were analyzed for their volatile aroma components. Seven new constituents were identified. Overall, the results for the two cultivars were very similar, and both possessed monoterpene hydrocarbons as their major group of volatiles (>90% w/w of the total volatiles) and both had car-3-ene as their most abundant component (>60%). However, comparison of these results with those previously reported for other cultivars of mango shows wide variation, especially with respect to the major monoterpene hydrocarbons. For one cultivar (Keitt), the volatiles of under- and overripe fruit were compared with those of the fully ripe fruit, and the effects on the volatiles of storage of the fruit at 10 °C and of storage when deep-frozen were also assessed.

Mango (*Mangifera indica* L.) is one of the most important and most popular of tropical fruits, mainly due to its extremely attractive flavor. However, there have been relatively few studies investigating its flavor composition. Early work was carried out mainly in India on Indian cultivars (Angelini et al., 1973; Gholap and Bandyopadhyay, 1975, 1976, 1977; Bandyopadhyay and Gholap, 1979), but in the last few years there have been reports of analyses of the aroma volatiles of mangoes from Venezuela (MacLeod and de Troconis, 1982) and from Sri Lanka (MacLeod and Pieris, 1984). Also, two of the most common Indian cultivars (Alphonso and Baladi), but grown in Egypt, have recently been studied in detail by Engel and Tressl (1983). However, there are many hundreds of mango cultivars, probably more than for any other fruit, and the relatively few above-mentioned investigations have shown interesting variations in aroma volatiles between cultivars (MacLeod and Pieris, 1984). At this time, no data have been reported regarding the aroma volatiles of the commercially important cultivars of mango grown in Florida. Thus, the main objective of this project was to analyze the volatiles of some Florida cultivars and to compare results with those already documented for other cultivars. A secondary objective was a brief survey of the effects of some different storage conditions on the aroma volatiles of fresh mango, associated with a consideration of how the volatiles varied with the ripeness of the fruit.

EXPERIMENTAL SECTION

Sample Preparation. All the mangoes used in this work were shipped by air freight to London from Miami, Florida. They were analyzed when fully ripe, except as described below. Aroma volatiles were extracted with a modified (MacLeod and Cave, 1975) Likens and Nickerson apparatus (Likens and Nickerson, 1964), basically as previously described for mango (MacLeod and de Troconis, 1982). 2-Methylbutane (50 mL) was used as solvent and extraction was carried out for 2 h. Extracts were subsequently concentrated as previously described (MacLeod and Cave, 1975).

Examination of Green, Overripe, and Stored Keitt Mangoes. (a) Green. These were analyzed about 9 days before they would have been fully ripe. Much foaming was encountered during the first hour of extraction. **(b) Overripe.** These fruit were kept at ambient temperature and were analyzed 12 days after having been fully ripe. **(c) Stored at 10 °C.** Three ripe mangoes were divided into

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thirds and one-third of each combined for a reference analysis of the ideal fully ripe fruit. Another one-third of each were combined and then sliced, wrapped in polythene film and stored for 13 days at 10 °C before extraction as before. **(d) Stored Frozen.** The final thirds of each of the three mangoes were again combined and sliced, but were then stored in the deep-freeze compartment of a refrigerator at about –15 °C for 15 days before extraction as previously described.

Gas Chromatography. Extracts were examined by gas chromatography with Pye-Unicam 204 and Philips PU 4500 instruments, both equipped with heated FID. Most work was done with 25 m × 0.2 mm id fused silica capillary columns containing PEG 20M or OV 101 or BP 20 bonded-phase (equivalent to PEG 20M) or BP1 bonded-phase (equivalent to OV 101). Hydrogen carrier gas was used (1.2 mL/min) and the temperature program was 70 °C for 5 min, followed by an increase of 3 °C/min to 180 °C for the remainder of the run. Detector and injection point heaters were 275 and 250 °C, respectively. Other columns used were 5.5 m × 4 mm id glass, packed with either 10% PEG 20M or 3% OV 101 coated on 100–120 BSS mesh acid-washed Diatomite C, using nitrogen (30 mL/min) as carrier gas and the same temperature program.

Gas Chromatography–Mass Spectrometry. Components in the concentrates were identified as far as possible by GC–MS with a Kratos MS 25 instrument linked on-line to a Kratos DS 50S data processing system. The same GC columns and conditions as described above were employed but with helium as carrier gas. A single-stage, all-glass jet separator was used at 250 °C. Significant operating parameters of the mass spectrometer: ionization voltage, 70 eV; ionization current, 100 μA; source temperature, 225 °C; accelerating voltage, 1.33 kV; resolution, 1500; scan speed, 1s/decade (repetitive throughout run).

Quantitative Assessment. Samples were prepared in such a manner that a known aliquot of the fruit sample was analyzed. Quantitative data were then derived both from the trace obtained from the TIC monitor during GC–MS and from the FID trace during routine GC. In the latter case a solution of ethyl acetate (0.050M) was used as a quantitative GC standard. Under reproducible and standardized GC conditions, the peak area due to the injection of an accurate volume of the ethyl acetate (four carbon atoms) was determined. Since the FID response for organic compounds is proportional to the number of carbon atoms present in a compound, peak areas of all constituents detected in this work (under the same GC conditions) were corrected and normalized by a variable factor relating their number of carbon atoms to that of the ethyl acetate standard. The corrected areas could then be more accurately related to the area provided by the

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known amount of the quantitative standard. An average carbon–number correction factor was applied to unidentified GC peaks. In this manner the absolute amounts of components comprising all GC peaks of a sample were assessed, and in total provided the total concentration of volatiles for the sample. Percentage data for individual components were then readily determined by relating their absolute amounts to the total concentration.

Odor Assessment. Aromas of the separated components of the samples were assessed at an odor part following GC with a Pye-Unicam 104 instrument. An outlet splitter set at 10:1 deverted the major fraction of the eluate through a heated line to the outside of the GC oven for aroma assessment by three subjects, all of whom were familiar with mango flavor but none was a trained perfumer.

RESULTS AND DISCUSSION

By far the most important cultivars of mango grown in Florida are Tommy Atkins and Keitt, so these were the ones studied in this work. Fresh fruit were transported by air freight from Florida to London, where valid aroma extracts were prepared by using well-established methods, which were basically the same as those previously used in this laboratory for mango (MacLeod and de Troconis, 1982). The extracts were concentrated as before (MacLeod and de Troconis, 1982), and the resultant essences were found, on appropriate redilution, to possess characteristic mango aroma. Samples were analyzed by GC and by GC–MS, and results are given in Table I. A number of GC columns were employed, including packed columns and fused silica capillary columns (both with PEG 20M or OV 101 stationary phases), and bonded-phase fused silica capillary columns containing either BP1 (equivalent to OV 101) or BP20 (equivalent to PEG 20M) stationary phase. The retention data given in Table I were obtained with a 25-m fused silica column coated with BP20. Kováts retention indices (Andersen and Falcone, 1969; Jennings and Shibamoto, 1980) of most components (on PEG 20M) are also included in the table, and they confirm the general elution sequence. The qualitative data in the table were mainly obtained with the bonded-phase fused silica columns. In all instances where positive identities are given, the mass spectra obtained on GC–MS agreed with those in the literature (e.g., Ryhage and von Sydow, 1963; Moshonas and Lund, 1970; Jennings and Shibamoto, 1980) and with those previously obtained for mango volatiles in this laboratory (MacLeod and de Troconis, 1982; MacLeod and Pieris, 1984). Where there is no entry for quantitative data in Table I, this means that the component was not detected in that particular sample. Odor qualities given in the table relate to descriptions of perceived aromas as the appropriate GC peaks due to the identified constituents emerged from the column.

The numbers of unidentified components not included in Table I and their total percentage contributions to the samples were 15 (4.2% w/w) for Tommy Atkins and 9 (3.5%) for Keitt (ripe). Similar data for the other Keitt samples—stored frozen, stored at 10 °C, overripe, and green—were 6 (4.4%), 13 (0.4%), 8 (3.6%), and 4 (0.9%), respectively. The majority of the unidentified components were present in such small amounts that mass spectra would not be obtained even with packed GC columns and high sample loadings.

Seven volatile components were identified in this work which have not previously been reported as mango consistuents, namely ethylcyclohexane, ethanol, α-fenchene, camphene, sabinene, and the less positively identified 1,1-diethoxyethane and sabinyl acetate. However, of these,

ethanol was not detected in the main samples and it was found only in fruit which had been stored or was overripe, so it is not a genuine aroma component of fresh, ripe mango.

Comparing the results for the Tommy Atkins and Keitt (ripe) cultivars of mango, it can be seen from Table I that they are quite similar, particularly taking into account the previously observed differences between cultivars, even when grown in the same region (MacLeod and Pieris, 1984). Thus, for example, both Tommy Atkins and Keitt gave a similar total concentration of volatiles (about 72 μg/g and 54 μg/g, respectively), both gave a very surprisingly high predominance of one class of compounds (monoterpene hydrocarbons, greater than 90% w/w of the total volatiles) and both had the same constituent, car-3-ene, as their most abundant volatile, present in very high relative concentration. However, Keitt did yield rather more car-3-ene (76.4% w/w) than did Tommy Atkins (60.2%), but the latter gave a much greater amount of α-pinene (22.2% as against 1.3% for Keitt). These were the only "major" differences between the aroma volatiles of the two Florida cultivars, and it is doubtful that alone they would cause much noticeable difference in flavor. On odor assessment, the GC peak due to car-3-ene was one of the very few which was described as having a specific mango quality (see Table I), so the presence of relatively large amounts of this compound in both Florida cultivars can be considered a desirable feature.

The remarkable similarity in the aroma volatiles of Tommy Atkins and Keitt is put more into perspective when these data are compared with those previously reported for other mango cultivars (MacLeod and de Troconis, 1982; Engel and Tressl, 1983; MacLeod and Pieris, 1984). Some representative figures, relevant to the ensuing discussion, are summarized in Table II. Although monoterpene hydrocarbons were by far the major group of volatiles for all the mango cultivars listed in the table, the Florida cultivars together afford the extreme. It follows that their relative abundances of other groups of compounds are likely to be lower than for other cultivars, as seen for the sesquiterpene hydrocarbons. However, some classes of compounds found for other cultivars were not even detected at all in the Florida mangoes (e.g., ketones). Other types of compounds, generally found in appreciable amounts in most other cultivars, were produced by only one of the Florida cultivars, and then only in very low relative abundance (e.g., alcohols, aldehydes, and esters). It would be expected that these gross differences would contribute appreciably to the different flavors of these cultivars, but that the two Florida mangoes would constitute a pair having similar flavor. This deduction is further supported by consideration of individual aroma volatiles, where some interesting results are also observed.

With regard to the major aroma volatile of the mango cultivars included in Table II, it has already been mentioned that this was car-3-ene for the Florida cultivars. That compound was also the major volatile of the Venezuelan mango studied (unknown cultivar), but it was present there in much lesser amount (26.0%). Two of the Sri Lankan cultivars investigated (Willard and Parrot) contained reasonable amounts of car-3-ene, but the compound was not detected at all in the third (Jaffna) nor in either of the Indian cultivars (Alphonso and Baladi) grown in Egypt. This latter agrees with earlier work in which again car-3-ene was not detected in Indian cultivars, for which either *cis*-β-ocimene or myrcene were generally the major components (Gholap and Bandyopadhyay, 1977; Bandyopadhyay and Gholap, 1979). Engel and Tressl

Table I. Volatile Constituents of Two Cultivars of Mango from Florida

component	t_R, min	Kováts index (lit.)	Tommy Atkins % rel abund	Tommy Atkins μg/g	Keitt – ripe % rel abund	ripe μg/g	stored frozen % rel abund	stored frozen μg/g	stored at 10 °C % rel abund	stored at 10 °C μg/g	overripe % rel abund	overripe μg/g	green % rel abund	green μg/g	odor quality
cyclohexane		765													
methylcyclohexane		800													
a branched chain C8 hydrocarbon	1.9–2.2		1.7	1.3											fruity, sweaty, buttery
a dimethylcyclohexane															
ethylcyclohexane															
? 1,1-diethoxyethane	2.2	880			0.5	0.3	0.2	0.1	1.5	16.0	2.4	1.2	0.3	0.2	sickly
ethanol	2.3	900	22.2	16.6	1.3	0.7	2.5	0.8	90.7	970.0	47.5	23.1	0.2	0.1	sweet, yeasty
α-pinene	2.6	1039							0.4	4.4	0.4	0.2			pine, cedar wood
2-methylpropan-1-ol	3.4	1054	1.2	0.9	1.5	0.8	1.2	0.4	0.7	7.7	1.1	0.5			pungent
toluene	3.4	1055			0.7	0.4	0.7	0.2			0.6	0.3	1.1	0.6	caramel, solvent
α-fenchene	3.6	1070											0.7	0.4	fruity
camphene	3.8	1083	0.4	0.3											camphor, moth balls
hexanal		1084			tr[b]	tr									green grass, hexanal
an ethyl butenoate	a				0.4	0.2	0.3	0.1							estery, acidic
butan-1-ol	4.6	1113			0.5	0.2	0.2	0.1	0.1	0.5	1.1	0.5			sweet, sickly
β-pinene	4.9	1124	2.0	1.5							0.2	0.1			polish, varnish
sabinene	5.1	1130	0.2	0.1											floral, fragrant
p-xylene	5.2	1140	tr	tr											cold meat fat
m-xylene	5.3	1147	tr	tr											
car-3-ene	5.5	1165	60.2	45.2	76.4	41.1	76.2	23.7	3.7	39.4	35.1	17.1	82.9	46.1	green, pungent, mango leaves
myrcene	5.7	1173	1.3	1.0	3.2	1.7	1.6	0.5	0.1	0.9	0.7	0.3	1.7	0.9	fresh, green grass
α-phellandrene	5.9	1177	0.2	0.1	0.4	0.2			tr	0.1	0.1	tr	0.3	0.2	estery
3-methylbutan-1-ol	6.4	1184							2.1	22.3	2.1	1.0			sweaty, valeric
limonene	6.5	1206	1.7	1.3	2.4	1.3	3.3	1.0					2.1	1.2	lemon-like
β-phellandrene	7.0	1216	0.5	0.4	0.8	0.4	0.5	0.2					0.6	0.3	fatty, oily
? γ-terpinene	7.3	1251					tr	tr							flat, dull
p-cymene	8.9	1272	0.1	0.1	tr	tr	0.2	0.1	tr	tr	tr	tr			herbal, minty
α-terpinolene	9.4	1287	1.5	1.1	3.5	1.9	2.7	0.9	0.1	1.3	1.0	0.5	2.8	1.5	floral, fragrant
cis-hex-3-en-1-ol	9.8	1351			tr	tr			tr	tr					green grass, fruity, hexenol
2-furfural	14.3	1449			0.3	0.1	tr	tr	tr	0.4	0.4	0.2	0.4	0.2	cold meat, gravy
ethyl octanoate	17.2	1457			0.2	0.1	0.5	0.2	tr	0.2					slightly nutty, coconut
α-copaene	17.3	1520	0.8	0.6					tr	0.2	1.5	0.7	0.3	0.2	earthy, mango
β-caryophyllene	19.5	1618	1.2	0.9	3.0	1.6	3.8	1.2	0.2	1.7	1.5	0.8	3.7	2.1	sickly sweet, wallflowers
ethyl decanoate	22.3	1624							tr	0.4					floral, fragrant
? sabinyl acetate	24.2	1651	tr	tr	tr		tr								none detected
α-humulene	24.7	1682	0.6	0.5	1.4	0.8	1.7	0.5	0.1	1.0	0.7	0.4	2.0	1.1	fresh green, floral
ethyl dodecanoate	25.2	1826							tr	0.4					slight mango

[a] Detected in BP1 run only. [b] tr = trace (<0.1).

Table II. Relative Percentage Abundances of Some Classes of Aroma Compounds and of Some Specific Important Volatile Constituents of Eight Mango Cultivars

compd	Tommy Atkins	Keitt	Venezuelan[a]	Alphonso[b]	Baladi[b]	Jaffna[c]	Willard[c]	Parrot[c]
monoterpene hydrocarbons	90.3	92.5	55.0	69.8	71.7	49.6	51.1	63.0
sesquiterpene hydrocarbons	2.6	4.9	13.9	5.4	8.0	14.3	13.6	18.9
non-terpenoid hydrocarbons	2.9	1.5	9.3	2.6	2.0	3.3	18.7	4.2
alcohols	d	0.5	d	12.8	3.3	8.1	5.7	7.6
aldehydes	d	0.3	16.9	3.3	0.4	4.4	d	d
ketones	d	d	3.1	0.7	0.3	0.7	2.2	0.7
esters	d	0.4	d	3.4	13.3	15.9	6.2	1.7
car-3-ene	60.2	76.4	26.0	d	d	d	2.7	11.7
cis-β-ocimene	d	d	2.6	18.1	5.6	37.9	1.0	1.9
myrcene	1.3	3.2	d	45.9	18.9	4.3	1.4	2.2
limonene	1.7	2.4	6.0	0.7	44.6	2.6	3.8	3.1
α-terpinolene	1.5	3.5	d	tr[e]	tr	tr	32.1	35.0
α-pinene	22.2	1.3	8.2	2.2	0.9	0.7	6.6	1.6
β-pinene	2.0	d	d	0.5	0.1	2.9	2.1	2.7
β-selinene	d	d	8.7	d	d	d	7.7	14.1
dimethyl disulfide	d	d	tr	d	d	d	1.9	4.4
hexadecan-1-ol	d	d	d	1.2	0.6	3.8	3.9	4.3

[a] MacLeod and de Troconis, 1982. [b] Calculated from data in Engel and Tressl, 1983. [c] MacLeod and Pieris, 1984. [d] Compound not detected. [e] tr = trace (<0.1).

Table III. Relative Percentage Abundances of Some Classes of Aroma Compounds and of Some Specific Important Volatile Constituents of Mango cv. Keitt

compd	green (underripe)	ripe	overripe	sliced fruit stored at 10 °C	sliced fruit stored frozen
monoterpene hydrocarbons	91.3	92.5	38.4	4.3	87.7
sesquiterpene hydrocarbons	6.0	4.9	3.7	0.3	6.0
non-terpenoid hydrocarbons	1.1	1.5	0.6	a	1.2
alcohols	0.3	0.5	49.8	93.6	0.2
esters	a	0.4	1.1	tr[b]	0.3
ethanol	0.3	a	47.5	90.7	a
2-methylpropan-1-ol	a	a	1.1	0.7	a
3-methylbutan-1-ol	a	a	1.0	2.1	a
car-3-ene	82.9	76.4	35.1	3.7	76.2
limonene	2.1	2.4	0.7	a	3.3
α-terpinolene	2.8	3.5	1.0	0.1	2.7
β-caryophyllene	3.7	3.0	1.5	0.2	3.8
approx total concn of volatiles, μg/g	56	54	49	1069	31

[a] Compound not detected. [b] tr = trace (<0.1).

(1983) did identify cis-β-ocimene in their study of Indian cultivars, but they found myrcene to be the major constituent of Alphonso, and, rather surprisingly, limonene to be the most abundant for Baladi. However, limonene is one of the few volatiles common to all cultivars listed in Table II. cis-β-Ocimene was not detected at all in the Florida cultivars, but it was the major volatile of Jaffna, the one Sri Lankan cultivar of those studied which is grown in the north of the island, nearest to India. The two other Sri Lankan cultivars showed some similarities and they both contained similar amounts of α-terpinolene as their major volatile constituent.

Thus, the eight mango cultivars under consideration exhibited five different compounds as their most abundant volatile, such constituents sometimes being completely absent from other cultivars. It may be that an abundance of car-3-ene is a characteristic of New World cultivars (hybrids developed from Old World stock), whilst cis-β-ocimene, myrcene, or α-terpinolene could be dominant characteristics of the many Old World cultivars, although clearly it is dangerous to make generalizations on the basis of such a limited survey. Graduated trends are also observed and these might be expected depending on the origins and interrelationships of the cultivars. For example, it is noticeable that both Florida cultivars contained reasonable quantities of α-terpinolene, which was dominant in Willard and Parrot but produced in only trace amounts by other Old World cultivars.

Similar differences between constituents other than the five major volatiles are also evident from Table II (e.g., α-pinene and hexadecan-1-ol, the latter found only in the Old World cultivars), but the many cultivars of mango possess an unusually wide range of flavor, so perhaps it is not so surprising that overall such a considerable variation in aroma volatiles is observed, even on such a small sample. However, it follows that for mango, unlike most other fruits, there can be no typical aroma component listing nor typical aroma formulation.

Table III summarizes the important results, extracted from Table I, with regard to the variations in the aroma volatiles of mango (Keitt) with the ripeness of the fruit. Despite many individual differences, it is interesting that the total concentration of volatiles for the three samples (green, or underripe, ripe, and overripe) were about the same (56 μg/g, 54 μg/g, and 49 μg/g, respectively). Some progressive changes are evident in certain groups of compounds during ripening. Thus, the concentration of sesquiterpene hydrocarbons (especially β-caryophyllene) decreased regularly, whilst the concentration of esters increased over the range. However, the most important feature of these results is the considerable difference (qualitative as well as quantitative) between the aroma volatiles of the overripe fruit and those of the much more alike ripe and green mango. The "new" components detected only in the overripe fruit were all alcohols, namely ethanol (47.5% w/w of the volatiles), 2-methylpropan-1-ol

(1.1%), and 3-methylbutan-1-ol (1.0%), and these can be reasonably considered as indicators that the fruit is "going off". As such alcohols became the dominant group of volatiles in the overripe mango, the relative concentrations of other groups of compounds were, of course, correspondingly reduced. In particular, monoterpene hydrocarbons were much diminished, from over 90% w/w of the volatiles to less than 40%. The amount of the important car-3-ene was more than halved, but other terpenes, such as limonene, were reduced by even greater proportions. A few (e.g., α-fenchene) could no longer even be detected. It follows from the foregoing that such overripe mango would have inferior flavor.

Results for the effects of different storage conditions on the aroma volatiles of fresh ripe mango (Keitt) are also summarized in Table III. Fruits were sliced and wrapped in polythene film before being stored at reduced temperature. It can be seen from the table that storage at 10 °C was totally ineffective in arresting deterioration. The results show much similarity with those just discussed for the overripe fruit, particularly with regard to the production of the same new volatiles (the alcohols), although some additional new components (some esters) were also formed (Table I). The fruit was stored at 10 °C for only one day longer than the overripe sample, but it can be seen from Table III that there was considerable progression beyond the already inferior set of volatiles obtained from the overripe fruit, presumably caused by the fact that the fruit was stored sliced whereas overripe fruit had, of course, been kept whole. Thus, even lower relative percentage abundances of monoterpene hydrocarbons (only 3.7% car-3-ene) and of sesquiterpene hydrocarbons were produced, whilst alcohols were formed in even greater concentration, and ethanol constituted over 90% w/w of the total volatiles. In addition, since the concentration of total volatiles also increased considerably (to about 1069 µg/g), the increase in the absolute concentration of ethanol was even more extreme and the compound reached a very high level of about 1 mg/g. There is little doubt that mangoes with such a composition of aroma volatiles would be expected to have very poor flavor, and the ones analyzed in this survey possessed a sharp yeasty odor and a yeasty taste (these characteristics obviously being endowed mainly by the excess ethanol—note the described odor quality, Table I). The fruit had virtually no typical mango flavor.

On the other hand, when sliced mangoes were stored frozen (at about −15 °C in the deep-freeze compartment of a refrigerator) the results were much better, as would be expected, and the fruit, which was slightly softer in texture than before storage, was described as "fresh tasting, sweet, and delicious, with typical mango flavor". Indeed, as can be seen from Table III, results for the volatiles of mango stored in this manner (for 15 days in this instance) provided very close agreement with those for the ideal, ripe

mango. In particular, the levels of monoterpene hydrocarbons as a group and of car-3-ene were maintained near perfectly, and none of the undesirable alcohols was detected. Although this experiment was not pursued for a very long time, the results indicated that such storage may well provide an acceptable method for maintaining the volatile aroma composition of stored sliced mangoes.

LITERATURE CITED

Andersen, N. H.; Falcone, M. S. J. Chromatogr. 1969, 44, 52.
Angelini, P.; Bandyopadhyay, C.; Rao, B. Y. K.; Gholap, A. S.; Bazinet, M. L. "33rd Annual Meeting of the Institute of Food Technologists", Miami Beach, FA, 1973; Paper no. 366.
Bandyopadhyay, C.; Gholap, A. S. "Proceedings of the First Indian Convention of Food Scientists and Technologists"; 1979; p 4.
Engel, K.-H.; Tressl, R. J. Agric. Food Chem. 1983, 31, 796.
Gholap, A. S.; Bandyopadhyay, C. J. Food Sci. Technol. 1975, 12, 262.
Gholap, A. S.; Bandyopadhyay, C. Indian Food Packer 1976, 30, 63.
Gholap, A. S.; Bandyopadhyay, C. J. Sci. Food Agric. 1977, 28, 885.
Jennings, W.; Shibamoto, T. "Qualitative Analysis of Flavor and Fragrance Volatiles by Glass Capillary Gas Chromatography"; Academic Press: New York, 1980.
Likens, S. T.; Nickerson, G. B. Proc. Am. Soc. Brew. Chem. 1964, 5.
MacLeod, A. J.; Cave, S. J. J. Sci. Food Agric. 1975, 26, 351.
MacLeod, A. J.; Pieris, N. M. Phytochemistry 1984, 23, 361.
MacLeod, A. J.; de Troconis, N. G. Phytochemistry 1982, 21, 2523.
Moshonas, M. G.; Lund, E. D. Flavour Ind. 1970, 1, 375.
Ryhage, R.; von Sydow, E. Acta Chem. Scand. 1963, 17, 2025.