Volatile Flavor Constituents of *Monstera deliciosa*

Terry L. Peppard

Givaudan Corporation, 125 Delawanna Avenue, Clifton, New Jersey 07015

The volatile flavor components of *Monstera deliciosa* have been isolated using two different procedures. There was evidence of thermally induced artifacts in the extract obtained using a Likens–Nickerson device; a more representative extract was obtained, however, using a direct, cold homogenization/extraction technique employing solid carbon dioxide and dichloromethane. The latter was followed by fractionation of the extract using adsorption chromatography on silica gel, employing solvent mixtures of gradually increasing polarity. Approximately 400 components were detected in these fractions by a combination of GC–MS and GC with simultaneous detection by FID, sulfur-specific FPD, and nitrogen-specific NPD. Components most responsible for the characteristic flavor of *M. deliciosa* were found, using GC with odor port evaluation, to be a variety of esters and lactones.

INTRODUCTION

There presently exists in the flavor industry a tremendous interest in "exotic" fruits of various types, mostly originating from tropical and subtropical regions of the globe (Engel et al., 1990; Shibamoto and Tang, 1990; Young and Paterson, 1990). The kiwi is a notable example of such an exotic fruit, which has in recent years become a commercial success and about which much flavor data (both sensory and compositional) have already been published. A great deal of information has also been uncovered concerning the flavor chemistry of certain other exotic fruits, e.g., passion fruit, guava, and papaya, while yet others have hardly been investigated at all. The work described herein represents part of an ongoing program aimed at characterizing flavor components of exotic fruits, with a view to evaluating them as potential sources of novel flavors and flavor constituents.

During the course of a number of flavor evaluation sessions, 15 types of exotic fruit were assessed for aroma, taste, and texture/mouthfeel by a panel of experienced judges. On the basis of the results obtained, *Monstera deliciosa* was selected for further investigation, as panelists showed significant interest in the flavor characteristics of this fruit, while very little is apparently known of its flavor chemistry.

M. deliciosa Liebm., also known as ceriman (Trinidad) or piñanona (Mexico), is a climbing vine (growing to a height of 30 ft or more) which belongs to the family Araceae (*Hortus Third*, 1976). It is native to the tropics of America, although it has also been grown in Florida, Portugal, Algeria, and Australia. As well as being grown for its fruit, when limited in size, it is also well-known as a foliage house plant (Mexican breadfruit, Swiss-cheese plant, etc.). The monstera fruit is green in color, shaped like an elongated pine cone (up to 10 in. in length), and covered in small tile-like platelets. These gradually fall away as the fruit ripens, and a pervasive though delicate aroma develops, somewhat reminiscent of pineapple and banana fruits. The fruit is also extremely sweet-tasting, although before fully mature it imparts to the mouth an intensely irritating sensation supposedly caused by needle-like crystals of calcium oxalate.

Stahl (1935) published brief compositional data for the ripe fruit pulp of monstera; Peters and Lee (1977) more recently studied the composition and physiology of *M. deliciosa* fruit and juice. They indicated that addition of 8–15% of monstera juice to other fruit juices, such as those of apple and pineapple, produced an attractively flavored product. However, little information is currently available regarding the underlying flavor chemistry.

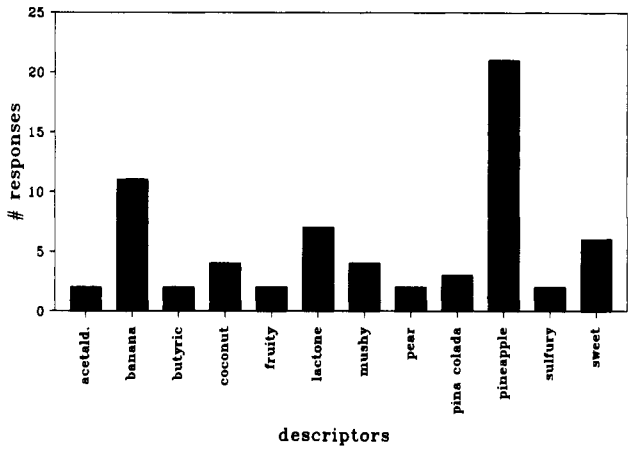

Figure 1. Flavor assessment of *M. deliciosa*.

MATERIALS AND METHODS

Materials. Monstera fruits were purchased from a local delicatessen/supermarket. Silica gel (70–230 mesh, 60 Å) was of chromatography grade, obtained from Aldrich Chemical Co. (Milwaukee, WI). Solvents were as follows: dichloromethane, OmniSolv HR-GC grade (EM Science, Gibbstown, NJ); diethyl ether, absolute/ACS reagent grade (Aldrich); methanol, HPLC reagent grade (J. T. Baker, Phillipsburg, NJ); and *n*-pentane, OmniSolv Spec/Chrom grade (EM Science). Except in the case of methanol, all solvents were redistilled in glass prior to use. Authentic flavor compounds were obtained from various suppliers and were used without further purification; *n*-alkane hydrocarbon standards were obtained from Alltech Associates (Deerfield, IL).

Preparation and Storage of *M. deliciosa* Fruit Pulp. Six monstera fruits, ranging in weight from approximately 360 to 440 g, were allowed to ripen at room temperature during the course of 11 days. From these, after removal of the outer skin and woody interior, a combined mass of ca. 1.6 kg of fruit pulp was obtained. This was frozen in liquid nitrogen immediately, to arrest additional enzymic changes, and stored thereafter at −30 °C until required for further processing.

Isolation of Flavor Volatiles from *M. deliciosa* by Likens–Nickerson Extraction of Fruit Pulp with Dichloromethane. Monstera fruit pulp (ca. 460 g) was mixed with distilled water (980 mL) containing a few drops of antifoam emulsion and extracted with dichloromethane (100 mL) for 5 h in a Likens–Nickerson apparatus. The dichloromethane extract was stored

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Table I. Flavor Constituents of *M. deliciosa*: Preliminary Study[a]

compound	area % Likens–Nickerson extract	area % homogenization extract	compound	area % Likens–Nickerson extract	area % homogenization extract
1-butanol	1.3	ND[b]	*cis*-linalool oxide*	0.5	ND
acetoin	23.1	ND	*trans*-linalool oxide*	0.4	ND
ethyl propanoate	1.2	ND	linalool*	2.4	0.8
propyl acetate		ND	benzyl cyanide*	0.1	ND
methyl butanoate*	0.4	ND	ethyl 3-hydroxyhexanoate*	0.4	0.1
3-penten-2-one	0.1	ND	ethyl benzoate*	0.6	0.5
isoamyl alcohol*	0.4	ND	ethyl octanoate*	0.1	0.3
2-methylbutanol	0.5	ND	ethyl phenylacetate*	0.2	ND
ethyl 2-methylpropanoate*	0.6	NQ[c]	δ-octalactone*	0.4	0.6
2,3-butanediol, isomer 1	ND	2.4	4-vinylguaiacol	NQ	ND
2,3-butanediol, isomer 2	ND	1.8	*n*-tridecane*	NQ	ND
ethyl butanoate*	18.4	63.3	ethyl decanoate*	0.3	0.1
furfural*	0.9	ND	*n*-tetradecane*	0.1	ND
ethyl crotonate*	0.3	0.4	*n*-pentadecane*	0.2	ND
2-hexenal*	1.6	ND	3,4-dihydro-8-hydroxy-3-methyl-1*H*-2-benzopyran-1-one	0.2	ND
2-furylmethanol	0.2	ND	ethyl dodecanoate*	0.5	0.3
ethyl 2-methylbutanoate or 3-methylbutanoate	3.6	4.7	*n*-hexadecane*	0.3	ND
4-hexen-1-ol	0.3	ND	*n*-heptadecane*	0.8	ND
2-methylbutyl or 3-methylbutyl acetate	0.1	ND	ethyl tetradecanoate*	0.2	NQ
			n-octadecane*	1.1	ND
propyl butanoate*	0.2	0.3	*n*-nonadecane*	1.6	ND
ethyl pentanoate*	0.1	0.4	ethyl hexadecanoate*	0.4	0.1
ethyl 3-hydroxybutanoate*	5.9	8.0	*n*-eicosane*	1.6	ND
ethyl hexenoate isomer?	0.6	0.4	*n*-heneicosane*	8.1	ND
ethyl hexanoate*	3.9	8.5			
ethyl 3-hexenoate*	0.2	0.1			
γ-hexalactone*	ND	0.4	% of peak area total accounted for by listed components	84.6	93.5
phenylacetaldehyde	0.2	ND			

[a] An asterisk indicates peak identity supported by GC retention index data; identifications based on mass spectral data alone are designated "tentative". [b] ND, not detected. [c] NQ, not quantified.

Table II. Organoleptic Evaluation of Monstera Extract, Fractions I–VII

fraction	approx % of extract	comments
whole extract	100%	initially fruity, then lactone-like, and finally cinnamon; acidic background
I	<1%	weak ripe pear-like; weak terpene hydrocarbon character
II	50%	strong fruity/estery aroma, somewhat pineapple/banana-like; very pleasant; geranyl acetate-like note
III	3%	woody, waxy, paraffin-like; not fruity or pleasant; linalool-like note
IV	40%	strong lactone/coconut character
V	3%	very weak aroma; rubbery/sulfury
VI	4%	weak, faintly rubbery, faintly fruity
VII	ND[a]	very little odor

[a] ND, not determined.

overnight at −30 °C to freeze out water crystals before being filtered directly from the freezer and concentrated. The concentration procedure was carried out in two stages: (i) gentle distillation in a Kuderna-Danish apparatus and (ii) slow evaporation to ca. 0.8 mL at room temperature. The extract was stored at −30 °C until required for analysis.

Residual aqueous phase from the Likens–Nickerson apparatus was then extracted for a further 5.5 h with a 2:1 mixture of *n*-pentane and diethyl ether (100 mL). The organic extract was concentrated to ca. 0.2 mL as described above and was likewise stored at −30 °C prior to analysis.

Extraction and concentration of flavor volatiles as carried out, and described above, undoubtedly involve significant losses of some components, and the same applies to the direct homogenization/extraction method outlined below.

Isolation of Flavor Volatiles from *M. deliciosa* by Direct Homogenization/Dichloromethane Extraction of Fruit Pulp. Monstera fruit pulp (ca. 800 g) was homogenized for several minutes with solid carbon dioxide and dichloromethane (1000 mL) in a Waring CB6 SB Explosion Resistant Blendor operated at the low-speed setting. The mixture was transferred to a large beaker and the blender rinsed with a further portion of dichloromethane (800 mL), which was subsequently transferred to a second large beaker. Both mixtures were allowed to warm to room temperature during the course of several hours before being filtered under gravity through (i) two layers of cheesecloth and (ii) Whatman No. 4 filter paper. The combined product (ca. 750 mL) was stored overnight at −30 °C to freeze out water crystals before being filtered directly from the freezer and concentrated. Tbe latter was achieved by gentle distillation in two stages using (i) a round-bottom flask equipped with a Vigreux column and (ii) a Kuderna-Danish apparatus. The resulting extract (ca. 5 mL) was filtered through a Pasteur pipet containing a small glass wool plug and finally allowed to concentrate to ca. 0.5 mL by gradual evaporation at room temperature. The extract was stored at −30 °C prior to analysis.

Fractionation of Monstera Flavor Extract by Adsorption Chromatography on Silica Gel. The homogenization/dichloromethane extract from above was concentrated to ca. 0.35 mL by slow evaporation at room temperature and then applied to the top of a water-cooled column of silica gel (250 mm × 14 mm). The sample was rinsed on with several small portions of pentane

Table III. Flavor Constituents of *M. deliciosa*: Components Detected in Adsorption Chromatography Fractions[a]

component	RI (DB-1) unk peak	RI (DB-1) auth compd	rel peak area (% of largest peak in fraction)
fraction I			
n-nonane	900	900	NQ[b]
β-myrcene	983	986	28.37
n-decane	1000	1000	23.91
limonene	1023	1030	49.51
β-phellandrene	1038	1025	NQ
decahydronaphthalene	1054		NQ
n-undecane	1099	1100	14.12
methyldecahydro-naphthalene	1111		NQ
n-dodecane	1200	1200	NQ
n-tridecane	1300	1300	NQ
n-tetradecane	1400	1400	18.75
calarene	1442		NQ
germacrene D	1485	1490	12.46
n-pentadecane	1500	1500	46.01
n-hexadecane	1600	1600	83.73
n-heptadecane	1701	1700	100.00
n-octadecane	1800	1800	67.49
n-nonadecane	1900	1900	45.89
n-eicosane	2001	2000	32.38
n-heneicosane	2100	2100	35.80
fraction II			
ethyl propanoate	<700	691	3.27
propyl acetate	<700	694	NQ
methyl butanoate	705	705	1.54
ethyl 2-methylpropanoate	741	746	2.26
2-methylpropyl acetate	754	758	NQ
methyl 2-methylbutanoate	759	765	NQ
or 3-methylbutanoate		764	
ethyl butanoate	791	782	100.00
butyl acetate	798	793	NQ
ethyl crotonate	822	823	1.13
ethyl 2-methylbutanoate	835	837	13.73
or 3-methylbutanoate		840	
isoamyl acetate	857	860	NQ
2-methylbutyl	861		NQ
or 3-methylbutyl acetate			
propyl butanoate	880	881	2.09
ethyl pentanoate	882	884	2.27
methyl hexanoate	906	906	NQ
ethyl tiglate	919	920	NQ
ethyl hexenoate isomer?	966		2.80
butyl butanoate	978	979	NQ
ethyl hexanoate	984	980	30.42
ethyl 3-hexenoate	987	986	NQ
ethyl hexenoate isomer?	989		1.36
ethyl hexadienoate isomer?	1001		NQ
ethyl 2-hexenoate	1020		NQ
ethyl sorbate	1067	1075	NQ
methyl benzoate	1070	1078	NQ
ethyl 4-heptenoate isomer?	1073		NQ
propyl hexanoate	1077	1079	NQ
ethyl heptanoate	1080	1082	NQ
methyl octanoate	1107	1107	NQ
methyl phenylacetate	1133	1154	NQ
ethyl benzoate	1147	1154	3.84
ethyl 4,7-octadienoate	1159		1.81
ethyl 4-octenoate	1170	1176	NQ
or *cis*-3-octenoate		1178	
butyl hexanoate	1173	1177	NQ
ethyl octanoate	1179	1179	3.60
ethyl phenylacetate	1214	1219	NQ
propyl octanoate	1274	1277	NQ
ethyl nonanoate	1279	1280	NQ
ethyl decanoate	1379	1378	3.31
ethyl undecanoate	1477	1479	NQ
ethyl dodecanoate	1579	1578	6.94
ethyl tridecanoate	1677	1677	NQ
2-pentadecanone	1681		NQ
ethyl tetradecanoate	1778	1777	2.18
ethyl pentadecanoate	1877	1877	NQ
methyl hexadecanoate	1908	1911	NQ
ethyl 9-hexadecenoate	1955		NQ
ethyl hexadecanoate	1978	1977	3.34
methyl linolenate	>2100		1.09
ethyl oleate	>2100		1.19
butyl hexadecanoate	>2100		NQ
ethyl octadecanoate	>2100		NQ
fraction III			
2-pentanone	<700		1.71
or 3-methyl-2-butanone			
ethyl propanoate	<700	691	1.51
propyl acetate	<700	694	3.92
ethyl butanoate	781	782	3.10
butyl acetate	795	793	1.17
ethyl crotonate	821	823	9.69
2-hexenal	824	824	NQ
2-heptanone	867	867	NQ
ethyl 2-methyl-2-hydroxybutanoate	902		1.05
ethyl 3-oxobutanoate	907		1.80
ethyl sorbate	1067	1075	NQ
ethyl 3-(methylthio)propanoate	1070	1070	NQ
ethyl sorbate isomer?	1072		NQ
linalool	1085	1092	100.00
methyl phenylacetate	1133	1154	NQ
ethyl phenylacetate	1214	1219	1.49
phenyl ethyl acetate	1226	1233	NQ
3,4-dihydro-8-hydroxy-3-methyl-1*H*-2-benzopyran-1-one	1506		7.63
fraction IV			
butanol	<700		NQ
acetoin	<700		100.00
isoamyl alcohol	716	719	NQ
2-methylbutanol	720		NQ
methyl hexanoate isomer?	840		NQ
γ-butyrolactone	854	854	1.83
ethyl hydroxybutanoate isomer?	902		9.74
ethyl 3-hydroxybutanoate	912	908	82.88
γ-hexalactone	1005	1005	7.42
ethyl 3-hydroxypentanoate	1007		7.42
δ-hexalactone	1042		2.92
cis-linalool oxide	1060	1068	NQ
phenylethanol	1085	1104	1.85
ethyl hydroxyhexanoate isomer?	1087		NQ
ethyl 3-hydroxyhexanoate	1104		3.06
γ-lactone (branched)?	1145		NQ
γ-octalactone	1213	1215	NQ
δ-octalactone	1241	1252	10.41
4-methoxy-6-methyl-2*H*-pyran-2-one	1297		NQ
vanillin	1355	1392	NQ
γ-decalactone	1429	1429	NQ
δ-decalactone	1455	1463	1.55
δ-undecalactone	1539	1535	NQ
6,10,14-trimethyl-2-pentadecanone	1833		1.90
fraction V			
2-pentanone	<700		NQ
acetoin	<700		4.81
4-methoxy-6-methyl-2*H*-pyran-2-one	1298		16.11
1-phenyl-1,2-ethanediol	1384		2.61
(4-hydroxy-3-methoxyphenyl) methyl acetate	1677		2.67
1*H*-indolyl-3-ethanol	1707		22.65
fraction VI			
2,3-butanediol	750		13.55

[a] Where identifications are based on mass spectral data alone due to the nonavailability of reference standards or GC retention index data therefrom, such identifications are designated "tentative". [b] NQ, not quantified.

and subsequently eluted using the following solvent mixtures: I, 100% pentane (100 mL); II, 2:1 pentane/dichloromethane (100 mL); III, 9:1 pentane/diethyl ether (100 mL); IV, 1:1 pentane/diethyl ether (125 mL); V, 1:1 pentane/diethyl ether (100 mL); VI, 100% diethyl ether (125 mL); VII, 100% methanol (100 mL). Fractions were concentrated to small volume (ca. 0.1–2.0 mL)

using the two-stage procedure described above, the final volume chosen for a particular fraction depending upon the amount of material apparently present in the fraction. Extracts were stored at −30 °C until required for analysis.

Instrumental Analysis. Extracts were analyzed by gas chromatography employing various methods of detection: (i) mass spectrometry; (ii) simultaneous flame ionization detection (FID), sulfur-specific flame photometric detection (FPD), and nitrogen/phosphorus detection (NPD) operating in the nitrogen-specific mode; and (iii) simultaneous FID and odor port evaluation by trained odor assessors.

Gas Chromatography–Mass Spectrometry. GC–MS was carried out on an IBM 9630 gas chromatograph coupled to a Hewlett-Packard 5970A mass-selective detector linked to an RTE-6 data system. Separations were performed using a 30-m × 0.25-mm (i.d.) capillary column, chemically bonded with a 1-μm film of DB-1 stationary phase (J&W Scientific, Folsom, CA), connected to a 2.5-m × 0.53-mm (i.d.) deactivated fused silica retention gap via a Direct-Connect capillary connector (Alltech Associates). The carrier gas was helium, with a column head pressure of 10 psig, and the oven temperature program employed was 40–250 °C at 3 °C/min, with a final temperature hold period of 30 min. Injections were made, in most cases, in split-stream mode, with injection volume ranging from 0.5 to 5.0 μL, depending on sample. The mass spectrometer was operated at 70 eV and was scanned from m/z 39 to 350 every 1.6 s.

Acquired mass spectral data were computer-searched against both commercial and proprietary mass spectral databases, and identifications were confirmed, where possible, by comparison of gas chromatographic retention indices with published values (Jennings and Shibamoto, 1980; Peppard and Ramus, 1988).

Gas Chromatography FID/FPD/NPD. GC with simultaneous flame ionization, sulfur-specific flame photometric, and nitrogen-specific detection was carried out using a Perkin-Elmer Sigma 2000 gas chromatograph. Separations were performed using a 30-m × 0.53-mm (i.d.) Megabore capillary column, chemically bonded with a 1.5-μm film of DB-1 stationary phase (J&W Scientific). The column was connected to the three detectors via a 1:1:1 outlet splitter and a makeup gas flow of 55 mL/min. The carrier gas was helium, at a flow rate of 7.2 mL/min, and the oven temperature program employed was 50–280 °C at 3 °C/min, with a final temperature hold period of 30 min. The injector temperature was 220 °C, and the detector temperature was 280 °C. Injections were made in splitless mode, with injection volume ranging from 0.5 to 1.0 μL, depending on sample. Electrometer range/attenuation settings were as follows: FID 100/1; FPD 100/8; NPD 1/1.

Gas Chromatography FID/Odor Port Evaluation. GC with simultaneous flame ionization detection and odor port evaluation was carried out using an IBM 9630 gas chromatograph. Separations were performed using a 30-m × 0.53-mm (i.d.) Megabore capillary column, chemically bonded with a 3-μm film of DB-1 stationary phase (J&W Scientific). The carrier gas was helium, flowing at 7.6 mL/min; the outlet splitter (1:1 nominal split ratio) resulted in 3.4 mL/min going to the FID (makeup 10.8 mL/min) and 4.2 mL/min going to the odor port (makeup 13.4 mL/min). The oven temperature program employed was 50–260 °C at 5 °C/min, with a final temperature hold period of 30 min. The injector temperature was 220 °C, and the detector temperature was 280 °C. Injections were made in splitless mode, with injection volume ranging from 0.5 to 1.0 μL, depending on sample. Odor port evaluation was carried out using a modified nose-piece comprising a glass powder funnel fitted over the end of the heated capillary column outlet. Odor evaluators' comments were recorded with a small cassette tape recorder and transcribed onto gas chromatograms.

Sensory Analysis of Fruits. *M. deliciosa* and the other fruits investigated were evaluated for aroma, taste, and texture/mouthfeel by a panel of 12–15 experienced flavorists during the course of two sessions. Fruits were cut into pieces immediately prior to evaluation by panelists.

RESULTS AND DISCUSSION

The most significant organoleptic characteristics of the fruit of *M. deliciosa*, according to the results of the flavor evaluation panel, were pineapple- and banana-like notes, with sweet, lactone, and coconut overtones (Figure 1). This combination of flavor characteristics led to a number of judges describing the fruit as having an aroma somewhat reminiscent of piña colada.

Flavor constituents were isolated from *M. deliciosa* pulp using the two different procedures described above and resulting extracts analyzed by capillary GC–MS. Table I lists the flavor constituents identified, together with comparative levels of components in the two dichloromethane extracts. It should be noted that the composition of the Likens–Nickerson extract was elucidated in somewhat more detail than was that of the direct homogenization extract; the latter contained a fairly high proportion of involatile material, and it was considered advisable to inject only a relatively small sample onto the capillary column.

From examination of the compounds listed in Table I, it is clear that the majority of flavor constituents identified in *M. deliciosa* are esters. The largest proportion of these was found to comprise ethyl esters, mostly even-carbon number, straight-chain compounds, although hydroxy esters and several other classes of ester were also found. The only terpene characterized was linalool. However, fatty acids, alcohols, and a series of normal hydrocarbons were found, together with some evidence of lipid breakdown products (e.g., 2-hexenal).

Significant differences were found in both the qualitative and quantitative composition of extracts obtained by the Likens–Nickerson and direct homogenization/extraction procedures. This was undoubtedly due, at least in part, to differing efficiencies of extraction of flavor constituents from, in one case, the fruit pulp directly vs, in the other, a largely aqueous medium coupled with the process of steam distillation. Thus, different extraction efficiencies between procedures probably resulted in the Likens–Nickerson extract containing approximately 18% ethyl butanoate, while the figure for this compound was much higher (ca. 63%) in the direct homogenization extract. Similarly, two butanediols comprised 4.2% of the latter, while neither isomer was detected in the former. The Likens–Nickerson extraction technique additionally involves the possibility of forming thermally induced artifacts. Consequently, the Likens–Nickerson extract contained, for example, detectable levels of furfural and the two furanoid isomers of linalool oxide, neither of which was readily apparent in the homogenization extract. The formation of thermally induced artifacts was even more apparent in the Likens–Nickerson pentane/diethyl ether extract which involved an additional 5.5-h period of heating; in this case furfural accounted for greater than 4% of the total peak area in the extract, cf. less than 1% in the Likens–Nickerson dichloromethane extract.

In view of the indications of thermally induced artifacts in the case of the Likens–Nickerson extracts, it was decided to proceed with further chemical characterization of *M. deliciosa* volatiles using the extract obtained by the direct cold homogenization/extraction procedure. The material prepared in this way was therefore next separated into seven fractions using adsorption chromatography on silica gel with solvents and solvent mixtures of gradually increasing polarity (see Materials and Methods). These fractions were evaluated organoleptically and then concentrated to small volume and analyzed by some or all of the following: (i) GC–MS; (ii) GC with simultaneous detection by FID, NPD, and FPD; and (iii) GC with simultaneous FID and odor port evaluation.

Organoleptic evaluation of the seven monstera silica gel

fractions, prior to concentration, gave rise to the comments cited in Table II. Fractions II and IV were noted to be of particular sensory interest, as their odors were reminiscent of the original monstera fruit. They were therefore the main focus of attention in the chemical characterization studies described below, while fraction VII was not investigated further.

Approximately 400 peaks were detected in the six monstera fractions analyzed by GC–MS, although this figure includes a number of components that were found in more than one of the fractions. Of the 400 peaks detected, ca. 150 were either partly or fully characterized, and these are listed in Table III. Fraction I (which represented an extremely small proportion of the total quantity of volatile flavor components isolated) comprised, as expected, hydrocarbons and included a number of mono- and sesquiterpenes. Fraction II comprised almost entirely (saturated and unsaturated, branched and straight chain) esters, most of which are well-known to occur widely in fruits. Fraction III also consisted largely of esters but with a few additional compounds including several ketones and aldehydes, linalool (the most prominent terpenoid constituent found in any of the six fractions investigated), and a compound tentatively identified as a substituted dihydrobenzopyranone. Fraction IV was found to contain a variety of functionalities, including alcohols, ketones, fatty acids, a series of ethyl 3-hydroxyalkanoate esters, and, most notably, numerous γ- and δ-lactones, some of which are significant contributors to the flavor of coconut (Lin and Wilkens, 1970). Few compounds were positively identified in fraction V or VI, but relatively little attention was given to these fractions, in view of their low sensory impact.

Relatively few sulfur- and/or nitrogen-containing components were detected in the six fractions analyzed using simultaneous FPD and NPD; the only component positively identified (occurring in fraction III) was ethyl 3-(methylthio)propanoate, a contributor to the flavor of pineapple (Engel et al., 1990). Since occurrence of the remaining, unidentified components generally spanned fractions of dissimilar sensory properties (some interesting, some not), it was concluded that they were probably not of major flavor significance and were therefore not investigated further.

Fractions II, IV, and, to a lesser extent, III were thought to be of most interest from the sensory viewpoint and so were analyzed by GC using FID coupled with odor port evaluation in the hope that peaks from the most odor-active substances characteristic of monstera flavor could be pinpointed in the gas chromatogram. These fractions were evaluated on several occasions, by more than one experienced assessor. Fraction II was separated into numerous components having intense estery/fruity-type odors, many of which were somewhat reminiscent of the original monstera fruit. However, most of the compounds responsible were identified as well-known esters, such as ethyl butanoate (see Table III). In contrast, fraction III was separated into relatively few odor-active components. A wide range of aromas was again noted in the case of fraction IV; of particular interest were several components having intense lactone- and coconut-like character. A number of these were identified as lactones (see Table III).

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Registry No. *n*-Nonane, 111-84-2; β-myrcene, 123-35-3; *n*-decane, 124-18-5; limonene, 138-86-3; β-phellandrene, 555-10-2; decahydronaphthalene, 91-17-8; *n*-undecane, 1120-21-4; *n*-dodecane, 112-40-3; *n*-tridecane, 629-50-5; *n*-tetradecane, 629-59-4; calarene, 17334-55-3; germacrene D, 23986-74-5; *n*-pentadecane, 629-62-9; *n*-hexadecane, 544-76-3; *n*-heptadecane, 629-78-7; *n*-octadecane, 593-45-3; *n*-nonadecane, 629-92-5; *n*-eicosane, 112-95-8; *n*-heneicosane, 629-94-7; ethylpropanoate, 105-37-3; propyl acetate, 109-60-4; methyl butanoate, 623-42-7; ethyl 2-methylpropanoate, 97-62-1; 2-methylpropyl acetate, 110-19-0; methyl 2-methylbutanoate, 868-57-5; methyl 3-methylbutanoate, 556-24-1; ethyl butanoate, 105-54-4; butyl acetate, 123-86-4; ethyl crotonate, 10544-63-5; ethyl 2-methylbutanoate, 7452-79-1; ethyl 3-methylbutanoate, 108-64-5; isoamyl acetate, 123-92-2; 2-methylbutyl acetate, 624-41-9; propyl butanoate, 105-66-8; ethyl pentanoate, 539-82-2; methyl hexanoate, 106-70-7; ethyl tiglate, 5837-78-5; butyl butanoate, 109-21-7; ethyl hexanoate, 123-66-0; ethyl 3-hexenoate, 2396-83-0; ethyl 2-hexenoate, 1552-67-6; ethyl sorbate, 2396-84-1; methyl benzoate, 93-58-3; propyl hexanoate, 626-77-7; ethyl heptanoate, 106-30-9; methyl octanoate, 111-11-5; methyl phenylacetate, 101-41-7; ethyl benzoate, 93-89-0; ethyl 4,7-octadienoate, 72276-09-6; ethyl *cis*-3-octenoate, 69668-87-7; butyl hexanoate, 626-82-4; ethyl octanoate, 106-32-1; ethyl phenylacetate, 101-97-3; propyl octanoate, 624-13-5; ethyl nonanoate, 123-29-5; ethyl decanoate, 110-38-3; ethyl undecanoate, 627-90-7; ethyl dodecanoate, 106-33-2; ethyl tridecanoate, 28267-29-0; 2-pentadecanone, 2345-28-0; ethyl tetradecanoate, 124-06-1; ethyl pentadecanoate, 41114-00-5; methyl hexadecanoate, 112-39-0; ethyl 9-hexadecenoate, 54546-22-4; ethyl hexadecanoate, 628-97-7; methyl linolenate, 301-00-8; ethyl oleate, 111-62-6; butyl hexadecanoate, 111-06-8; ethyl octadecanoate, 111-61-5; 2-pentanone, 107-87-9; 3-methyl-2-butanone, 563-80-4; ethyl propanoate, 105-37-3; propyl acetate, 109-60-4; ethyl butanoate, 105-54-4; 2-hexenal, 505-57-7; 2-heptanone, 110-43-0; ethyl 3-oxobutanoate, 141-97-9; ethyl 3-(methylthio)propanoate, 13327-56-5; linalool, 78-70-6; phenyl ethylacetate, 103-45-7; butanol, 71-36-3; acetoin, 513-86-0; isoamyl alcohol, 123-51-3; 2-meth-

ylbutanol, 137-32-6; γ-butyrolactone, 96-48-0; ethyl 3-hydroxybutanoate, 5405-41-4; γ-hexalactone, 695-06-7; δ-hexalactone, 823-22-3; ethyl 3-hydroxyhexanoate, 2305-25-1; γ-octalactone, 104-50-7; δ-octalactone, 698-76-0; 4-methoxy-6-methyl-2*H*-pyran-2-one, 672-89-9; vanillin, 121-33-5; γ-decalactone, 706-14-9; δ-decalactone, 705-86-2; 6,10,14-trimethyl-2-pentadecanone, 502-69-2; 1-phenyl-1,2-ethanediol, 93-56-1; 1*H*-indole-3-ethanol, 526-55-6; 2,3-butanediol, 513-85-9; 3-penten-2-one, 625-33-2; furfural, 98-01-1; 2-furanmethanol, 98-00-0; 4-hexen-1-ol, 6126-50-7; phenylacetaldehyde, 122-78-1; benzyl cyanide, 140-29-4; 4-vinylguaiacol, 7786-61-0; methyldecahydronaphthalene, 28258-89-1; ethyl hexenoate, 35724-13-1; ethyl hexadienoate, 138234-62-5; ethyl 4-heptenoate, 138234-60-3; ethyl 4-octenoate, 138234-61-4; ethyl 2-methyl-2-hydroxybutanoate, 77-70-3; 3,4-dihydro-8-hydroxy-3-methyl-1*H*-2-benzopyran-1-one, 1642-85-9; ethyl hydroxybutanoate, 131831-55-5; ethyl 3-hydroxypentanoate, 54074-85-0; phenylethanol, 1321-27-3; *cis*-linalool oxide, 5989-33-3; ethyl hydroxyhexanoate, 138234-63-6; δ-undecalactone, 710-04-3; (4-hydroxy-3-methoxyphenyl)methyl acetate, 15964-80-4; *trans*-linalool oxide, 34995-77-2.