Aroma Compounds of Mango and Papaya from Cameroon

Solid phase microextraction analyses of these important fruits—*Mangifera indica* L. and *Carica papaya* L.

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Mangos (*Magnifera indica* L., Anacardiaceae) and papayas (*Carica papaya* L., Caricaceae) are exotic fruits with increasing importance for the crop trade.[7,8,10,11,14,38,39] With a worldwide production of 25.1 million metric tons in the year 2001, mangos are in second place in the FAO statistics of exotic fruits (behind bananas, which boast a production volume of about 58 million metric tons in 2001).[14] *M. indica* and *C. papaya* find wide use in the flavoring of foodstuffs, in addition to distribution as fruit, juice and further aromatic-fruity food products, like ice-cream, sweets and tea. In perfumery applications, the characteris– tic, pleasant exotic-fruity aroma of mangos (apple, pineapple, banana and peach notes) and papayas (faint-tropic, banana- and pumpkin-like notes) is part of many applications in perfumery (e.g. perfumes) and cosmetics (e.g. lotions, shower-gels, deodorants and soaps). Many analyses of the aroma com– pounds of *M. indica* and *C. papaya* fruits and their different extracts have been performed in the past to identify these volatiles, responsible for the characteristic aroma. About 300 odor compounds for mangos and papayas, respectively, have been identified, with the dominating impact compounds being monoterpenes and short-chain alcohols, acids, esters and lactones.[2,4,5,12,13,15,16,30-32,37,40,45]

For many researchers in this field, the preferred methods of analysis for the aroma compositions of mango and papaya samples are dynamic headspace and solvent extraction.[12,13,15,16,30-32,37,40,45] However, to the best of our knowledge, no comparative studies on headspace-volatiles of ripe and unripe fruits of *M. indica* and *C. papaya* from Cameroon, trapped by solid-phase-microextraction (SPME), separated using achiral- (polar and apolar) and chiral-phase gas chromatography and single compounds detected as well as identified by flame-ionization and mass spectroscopy, are available until now. Therefore, the objective of this work was to identify the fragrance compounds of this exotic Cameroonian fruits by the above mentioned gas chromatographic-spectroscopic and olfactoric methods (GC-sniffing-technique and olfactoric correlations) to find out the importance of each single constituent with their specific odor attributes, responsible for the characteristic and pleasant fruit aroma of mangos and papayas for the first time.

Results and Discussion

The pulp samples of ripe and unripe *Mangifera indica* L. and *Carica papaya* L. from Cameroon were olfactorically evaluated by perfumers as follows: ripe mango: exotic fruity (mango) with ethyl acetate and spicy side-notes; unripe mango: exotic fruity (mango) with spicy and mango-leaves-like side-notes; ripe papaya: exotic fruity (papaya, apricot, banana and pineapple notes) with floral side-notes; unripe papaya: exotic fruity (papaya, apricot, banana and pineapple) some weaker than ripe pulp sample, floral and green side-notes, in the background pungent-sour aroma. Additionally, a high olfactoric quality for all four samples was certified by the perfumers in general.

For the trapping of the volatiles in the headspace of the four mango and papaya pulp samples, solid-phase-microextraction (SPME) was used, which is a very effective state-of-art-method to concentrate odor-active constituents of complex aroma samples before identification by means of hyphenated systems.[18,19,21-26,35,41]

As a result of GC-FID and GC-MS analyses (using two achiral phase columns of different polarity) more than 120 volatiles were detected, and more than 100 of them identified in all of the mango and papaya SPME-headspace samples. Main compounds (con– centration higher than 3.0 percent, calculated as percentage-peak area of GC-FID analysis using a polar (Carbowax) column were found to be in the SPME-headspace of the pulp of the ripe mango: δ-3-carene (28.90 percent), *cis*-3-hexenyl butanoate (12.92 percent), α-pinene (8.08 percent), *cis*-3-hexenyl acetate (5.60 percent), ethyl acetate (4.51 percent), ethyl hexanoate (3.54 percent), ethyl butanoate (3.48 percent), *trans*-β-ocimene (3.16 percent) and β-myrcene; of the unripe mango: δ-3-carene (67.40 percent), β-myrcene (9.40 percent) and α-pinene (8.82 percent); of the ripe papaya: linalool (68.96 percent), isoamyl butanoate (15.60 percent) and decanal (3.55 percent) as well as of the unripe papaya: linalool (47.57 percent), benzyl isothiocyanate (11.11 percent), isoamyl butanoate (5.01 percent), 2-pentanol (4.81 percent) and *trans*-1-hexen-3-ol (4.50 percent). Further constituents, especially ethyl-, propyl-, butyl-, amyl-, pentyl- and hexyl-esters, short-chain alcohols and acids, and monoterpenes were identified in concentrations from traces (< 0.01 percent) up to 2.75 percent in the investigated samples (see T-1). The compositions of the *M. indica* and *C. papaya* samples are therefore characterized by a high content of the monoterpenes δ-3-carene (mango) and linalool (papaya) with significant amounts of *cis*-3-hexenyl butanoate (mango) and isoamyl butanoate (papaya), which are compounds, found also in other samples of *M. indica* and *C. papaya*, but in lower concentrations.[4,5] The high content of benzyl isothiocyanate in the SPME-headspace of unripe papaya is remarkable, but has been identified in some *C. papaya* samples of different geographic origin in concentrations up to 18 percent.[5,12]

As generally known, the stereoselectivity of volatile enantiomers is of essential importance for the aroma impression of the compound and plays an elemental role for the characteristic total-odor of a complex odor system.[20,26,29,33,34,44] Therefore, chiral-phase gas chromatography (coupled with flame-ionization and mass spectroscopic detection) was used to get information on the enantiomeric properties of optical active main compounds (concentrations > 1.0 percent) of the pulp samples of mango and papaya. For the *M. indica* headspace constituents a high (-)-optical purity was found for α-pinene, β-pinene and δ-3-carene, and a high (+)-optical purity for 2-methyl butanoic acid, α-terpineol, γ-jasmin lactone and δ-jasmin lactone (see T-2). Linalool and 2-methyl butanoic acid as dominating compounds of the papaya pulp show a significant (+)-optical rotation.

This result is also in accordance with investigations of aroma compounds of *M. indica* and *C. papaya* from other geographic

SPME-headspace aroma compounds of ripe and unripe mangos (rmango and urmango) and papayas (rpapaya and urpapaya) from Cameroon in order of their Kovats indices (KI, using a polar Carbowax column) and concentrations in percent (calculated as percent-peak area of GC-FID analysis)

T-1

compound	rmango	urmango	rpapaya	urpapaya	KI
ethyl acetate	4.51	0.38	0.14	0.60	872
ethanol	0.14	0.02	0.11	0.01	900
ethyl butanoate	3.48	0.01	nd[a]	nd	912
ethyl hexanoate	3.54	0.02	nd	nd	917
pentanal	nd	0.02	nd	nd	941
2-pentanone	nd	nd	t[b]	0.16	958
2-butanol	0.01	0.01	t	t	998
α-pinene	8.08	8.82	0.12	0.38	1037
ethyl isovalerate	1.10	0.06	nd	nd	1058
camphene	0.22	0.13	tr	0.35	1071
3-methoxy propanol	nd	nd	nd	0.52	1081
2-pentanol	nd	nd	0.04	4.81	1091
propyl butanoate	0.15	t	nd	nd	1110
isoamyl acetate	0.06	t	0.06	0.64	1113
β-pinene	1.56	1.34	t	0.71	1124
cis-2-pentenyl acetate	0.03	nd	nd	nd	1126
2-methyl-2-pentenal	0.08	0.57	0.01	0.02	1140
isobutyl butanoate	0.65	0.06	1.15	1.18	1152
δ-3-carene	28.90	67.40	nd	nd	1154
amyl acetate	t	0.02	0.16	1.12	1161
3-methyl butanol	t	nd	t	0.86	1166
β-myrcene	3.11	9.40	0.07	0.84	1168
α-terpinene	0.06	0.09	0.06	t	1189
limonene	1.88	1.67	t	0.59	1206
cis-β-ocimene	0.17	0.09	t	0.99	1230
3-octanone	nd	nd	t	0.53	1242
γ-terpinene	0.04	0.18	0.12	t	1246
cis-3-hexenol	0.57	0.06	t	t	1248
trans-β-ocimene	3.16	2.75	t	0.01	1251
isoamyl butanoate	0.05	t	15.60	5.01	1259
2-methyl hexanoic acid	t	t	0.24	0.11	1262
p-cymene	0.13	0.09	t	t	1271
octanal	nd	nd	t	nd	1278
2-heptanol	nd	nd	t	0.42	1282
terpinolene	0.15	0.04	t	t	1285
cis-3-hexenyl acetate	5.60	0.72	nd	t	1300
trans-1-hexen-3-ol	0.01	0.53	0.02	4.50	1302
amyl butanoate	0.62	0.07	0.07	0.09	1305
hexyl acetate	2.71	0.09	nd	t	1307
trans-2-hexenyl acetate	0.07	t	nd	t	1315
cis-2-pentenyl butanoate	0.39	t	nd	nd	1317
hexanol	0.12	0.09	t	2.33	1329
isobutyl hexanoate	nd	nd	t	0.44	1350
cis-3-hexenyl propionate	0.55	0.04	nd	t	1371
nonanal	0.03	0.04	nd	t	1382
3-octanol	nd	nd	nd	t	1388
acetic acid	0.04	t	0.04	0.19	1410
butyl tiglate	0.22	t	nd	nd	1417
heptanol	nd	nd	t	1.05	1419
1-octen-3-ol	nd	nd	t	0.58	1422
ethyl octanoate	0.21	t	t	t	1424
cis-linalool oxide (furanoid)	nd	nd	0.92	0.73	1427
cis-3-hexenyl butanoate	12.92	0.13	nd	0.15	1449
isoamyl hexanoate	nd	nd	t	1.34	1451
trans-linalool oxide (furanoid)	nd	nd	0.45	0.12	1453

T-1 **SPME-headspace aroma compounds of ripe and unripe mangos (rmango and urmango) and papayas (rpapaya and urpapaya) from Cameroon in order of their Kovats indices (KI, using a polar Carbowax column) and concentrations in percent (calculated as percent-peak area of GC-FID analysis) (continued)**

compound	rmango	urmango	rpapaya	urpapaya	KI
trans-2-hexenyl butanoate	0.14	0.13	nd	t	1461
cis-3-hexenyl isovalerate	2.41	0.09	nd	t	1480
decanal	nd	nd	3.55	0.41	1485
amyl hexanoate	nd	nd	nd	0.15	1499
linalool	0.08	0.01	68.96	47.57	1502
benzaldehyde	nd	nd	t	0.53	1504
octanol	nd	nd	t	t	1519
linalyl acetate	nd	nd	t	0.46	1537
cis-3-hexenyl tiglate	0.12	0.03	nd	nd	1577
cis-3-hexenyl valerate	0.32	t	nd	nd	1584
butanoic acid	t	nd	0.05	t	1588
hexyl hexanoate	0.04	t	nd	nd	1599
methyl benzoate	nd	nd	t	0.38	1602
terpinen-4-ol	0.08	0.07	0.11	0.02	1608
benzyl isocyanate	nd	nd	t	0.23	1613
β-caryophyllene	0.29	0.28	t	0.09	1617
nonanol	0.29	0.33	1.64	0.68	1624
3-methyl butanoic acid	t	t	t	t	1630
2-methyl butanoic acid	1.11	0.44	1.19	0.32	1641
aromadendrene	0.10	0.08	nd	nd	1650
α-terpineol	1.04	1.13	1.05	0.77	1657
α-humulene	0.14	0.06	nd	0.02	1681
decanol	t	t	1.07	t	1723
verbenone	0.12	nd	nd	nd	1730
geranyl acetate	0.01	t	t	0.10	1735
methyl salicylate	nd	nd	t	0.07	1754
trans-carveyl acetate	t	0.01	nd	nd	1758
isobutyl benzoate	nd	nd	t	1.18	1771
trans-carveol	t	nd	nd	nd	1789
cis-carvyl acetate	0.10	0.02	nd	nd	1794
hexanoic acid	nd	0.05	0.06	t	1799
cis-carveol	t	t	nd	nd	1819
geraniol	0.07	0.04	t	0.08	1822
benzyl alkohol	nd	nd	t	0.47	1824
butyl benzoate	nd	nd	t	0.73	1841
cymen-8-ol	0.03	0.02	0.01	0.05	1846
benzyl butanoate	nd	nd	t	0.24	1854
benzyl thioisocyanate	nd	nd	2.31	11.11	1872
isobutyl salicylate	nd	nd	t	0.46	1891
isoamyl benzoate	nd	nd	t	0.01	1894
2,5-dimethyl-4-hydroxy-3(2H)-furanone (“furaneol”)	0.47	0.12	t	nd	1903
β-ionone	0.21	0.11	t	t	1908
amyl benzoate	nd	nd	t	1.89	1940
isoamyl salicylate	nd	nd	t	0.30	2021
benzyl hexanoate	0.30	nd	nd	nd	2057
amyl salicylate	nd	nd	nd	0.02	2077
eugenol	0.14	t	nd	nd	2103
γ-jasmin lactone	1.08	0.66	nd	nd	2157
δ-jasmin lactone	1.21	1.02	0.10	t	2171

[a]not detected

[b]trace compound (less than 0.01 percent)

T-2

Optical purity of target compounds (concentration higher than 1.0 percent) of mango and papaya SPME headspace samples by means GC-FID and GC-MS with chiral phase columns[10,13,27,30]

mango compounds	(+)	(-)
α-pinene	4.3	95.7
β-pinene	1.8	98.2
δ-3-carene	0.1	99.9
limonene	68.9	31.1
2-methyl butanoic acid	100.0	0.0
α-terpineol	72.2	37.8
γ-jasmin lactone	94.1	5.9
δ-jasmin lactone	83.6	16.4
papaya compounds		
linalool	93.8	6.2
2-methyl butanoic acid	100.0	0.0

origins, published elsewhere.[29,44] For a comparison of the odor impression of each single identified compound of pulp samples of ripe and unripe mango and papaya from Cameroon to the above-described overall aroma, a GC-sniffing-technique was used. The obtained data of this analysis were correlated with published aroma attributes for each identified constituent, published elsewhere.[3,6,12,36,42] As result of these combined data interpretation we state the following (see T-3): the characteristic aroma of ripe and unripe *M. indica* can be attributed to δ-3-carene, *cis*-β-ocimene, ethyl-, butyl-, amyl- and hexyl-derivatives (especially esters), partly "furaneol" and β-ionone, for the exotic fruity, to ethyl aceate (ripe mango) for the ethyl acetate and to the monoterpenes α-pinene, β-pinene, β-myrcene as well as *trans*-β-ocimene for the spicy odor impressions, while δ-3-carene in such a high content in the unripe *M. indica* SPME-headspace is known for its mango-leaf aroma. The aroma of ripe and unripe *C. papaya* SPME-headspace samples is the result of a totally high concentration of linalool and short-chain alcohols and esters (exotic fruity; floral odor is additionally known from linalool and its derivatives) and some hexene-derivatives in medium (e.g. *trans*-1-hexen-3-ol) or lower amounts (green-notes of unripe papaya), while a pungent-sour odor impression, found in the sample of unripe *C. papaya* pulp, is known from benzyl isothiocyanate ("mustard-oil-aroma") in a higher concentration (the aroma of diluted benzyl isothiocyante is described as fruity and papaya-like). [12]

To summarize this aroma compound analysis of SPME-headspace samples of ripe and unripe mangos and papayas from Cameroon, we can state that the characteristic odor impressions for such exotic fruits were also found. The compositions of the *M. indica* and *C. papaya* SPME-headspace are significantly different in correlations to mango and papaya samples from other geographic origins. Using achiral and chiral-phase gas chromatography (FID and MS detection) mainly monoterpenes [especially (-)-δ-3-carene in mango and (+)-linalool in papaya] and short-chain alcohols, acids [e.g. (+)-methyl butanoic acid], esters and lactones [e.g. (+)-γ-jasmin lactone and (+)-δ-jasmin lactone] were found to be dominating aroma compounds, responsible also for the characteristic odor impressions of these exotic fruits. The identification of benzyl isothiocyante in the SPME-headspace sample of unripe *C. papaya* from Cameroon in a concentration of 11.11 percent is remarkable (pungent-sour odor in this concentration, but fruity and papaya-like on dilution).

Experimental

Sample preparation: Ripe and unripe fruits of mango and papaya were collected at a local market in Ngaoundere (Western Cameroon) in August 2002. One ripe (weight of 422 g) and one unripe (weight

SPME-headspace aroma compounds of ripe/unripe mangos and ripe/unripe papayas from Cameroon and their corresponding aroma impressions in accordance to published data and obtained by the use of a GC-sniffing-technique (polar Carbowax column)[3,6,12,36,42]

compound	aroma impressions	GCST*
ethyl acetate	pineapple-like, ethereal	ethereal
ethanol	alcohol-like	ethanol
ethyl butanoate	fruity, banana- and pineapple-like	fruity
ethyl hexanoate	fruity, wine- and apple-like, brandy-like	fruity
pentanal	woody, vanilla, fruity, nutty on dilution	warm
2-pentanone	sweet-fruity, ethereal	ethereal
2-butanol	medicinal, ethereal	ethereal
α-pinene	woody, pine-like	piney
ethyl isovalerate	fruity, apple-like	fruity
camphene	camphoraceous, fresh	fresh
3-methoxy propanol	sweet, ethereal	-
2-pentanol	green, fusel-like	green
propyl butanoate	sharp, sweet, pungent, rancid	pungent
isoamyl acetate	fruity, banana-like, sweet	fruity
β-pinene	woody, pine-like	piney
cis-2-pentenyl acetate	green-sweet, fruity	-
2-methyl-2-pentenal	green-grassy, fruity	green
isobutyl butanoate	fruity, ethereal	ethereal
δ-3-carene	sweet, refined limonene-note, penetrating	sweet
amyl acetate	fruity, banana-like, ethereal	fruity
isoamyl alcohol	whiskey- and fusel-like	-
β-myrcene	sweet-balsamic, spicy	sweet
α-terpinene	spicy, citrus-note	spicy
α-phellandrene	minty, herbaceous	herbal
limonene	fresh, citrus-, lemon- and orange-note	citrus-like
cis-β-ocimene	mango-skin-note, estragon- and basil-notes	spicy
3-octanone	herbal-spicy, buttery	-
γ-terpinene	herbaceous, citrus-like	citrus-like
cis-3-hexenol	green (“leaf alcohol”), fresh-grass-like	green
trans-β-ocimene	spicy (estragon- and basil-notes)	spicy
isoamyl butanoate	fruity, apricot-, banana and pineapple-like	fruity
2-methyl hexanoic acid	ethereal-fruity, green	-

T-3

compound	aroma impressions	GCST*
p-cymene	weak citrus-note	citrus-like
octanal	fatty, citrus- and honey-notes	fatty
2-heptanol	earthy, oily	fatty
terpinolene	sweet-piney, slightly sweet-anisic	terpenic
cis-3-hexenyl acetate	green, fruity	green
trans-1-hexen-3-ol	intense green with bitter and fatty notes	green
amyl butanoate	strong, fruity, banana- and pineapple-like	fruity
hexyl acetate	floral, apple-, cherry and pear-like	fruity
trans-2-hexenyl acetate	green, fruity	-
cis-2-pentenyl butanoate	fatty, green, fruity	-
hexanol	alcoholic, ethereal, medicinal	alcoholic
isobutyl hexanoate	apple-like	fruity
cis-3-hexenyl propionate	fruity, green	-
nonanal	floral-fatty, citrus, orange- and rose-notes	fatty
3-octanol	oily, nutty, melon- and citrus-note	oily
acetic acid	pungent	pungent
butyl tiglate	fruity, ethereal	-
heptanol	woody-oily	oily
1-octen-3-ol	mushroom-like	earthy
ethyl octanoate	fruity, banana- and pineapple-like, floral	fruity
cis-linalool oxide (furanoid)	floral	floral
cis-3-hexenyl butanoate	brandy-, cognac- and wine-like, green	alcoholic
isoamyl hexanoate	fruity, apple- and pineapple-like	fruity
trans-linalool oxide (furanoid)	floral, fresh	floral
trans-2-hexenyl butanoate	alcoholic, green	-
decanal	sweet-waxy, floral, citrus-notes	waxy
amyl hexanoate	pineapple-like	fruity
linalool	floral	floral
benzaldehyde	clean-floral, citrus-lemon-orange notes	floral
octanol	fatty-waxy, citrus-note	fatty
linalyl acetate	floral, fresh, lavender-like	floral
cis-3-hexenyl tiglate	fruity, green	-

SPME-headspace aroma compounds of ripe/unripe mangos and ripe/unripe papayas from Cameroon and their corresponding aroma impressions in accordance to published data and obtained by the use of a GC-sniffing-technique (polar Carbowax column)[3,6,12,36,42] (continued) **T-3**

compound	aroma impressions	GCST*
cis-3-hexenyl-valerate	green, fatty	-
butanoic acid	sharp, cheesy, sour, rancid	sharp
hexyl hexanoate	fruity, vegetable-like	fruity
methyl benzoate	fruity	fruity
terpinen-4-ol	spicy, woody, nutmeg- and lilac-notes	terpenic
benzyl isocyanate	mustard- and broccoli-like	pungent
β-caryophyllene	terpene-odor, woody, spicy	terpenic
nonanol	fatty-waxy, citrus-note	fatty
3-methyl butanoic acid	rancid, cheesy, sweet	rancid
2-methyl butanoic acid	fruity-sour, cheesy	fruity
aromadendrene	herbal, woody	-
α-terpineol	lilac odor, floral, fruity	fruity
α-humulene	weak woody	woody
decanol	floral, fruity, fatty-waxy	fatty
verbenone	spicy, minty, camphoraceous	spicy
geranyl acetate	rose- and lavender-like, sweet-fruity	sweet
methyl salicylate	minty, spicy, wintergreen-note	spicy
trans-carveyl acetate	green, spearmint, fresh	fresh
isobutyl benzoate	fruity, ethereal	fruity
trans-carveol	spearmint, caraway	spearmint
cis-carveyl acetate	spearmint, fresh, green	fresh
hexanoic acid	pungent, sweet, rancid, sour, fatty	pungent
cis-carveol	spearmint, caraway	spearmint
geraniol	rose-like, sweet-floral, fruity, mild	rose
benzyl alcohol	floral, rose-note	floral
butyl benzoate	floral-balsamic, woody-spicy	balsamic
cymen-8-ol	spicy, vegetable-note	-
benzyl butanoate	fruity, floral, plum-note	fruity
benzyl thioisocyanate	sharp, mustard-oil-like	pungent
isobutyl salicylate	orchid- and wintergreen-like	floral
isoamyl benzoate	sweet-balsamic	balsamic
2,5-dimethyl-4-hydroxy-3(2H)-furanone	fruity, sweet, caramel-like	fruity

SPME-headspace aroma compounds of ripe/unripe mangos and ripe/unripe papayas from Cameroon and their corresponding aroma impressions in accordance to published data and obtained by the use of a GC-sniffing-technique (polar Carbowax column)[3,6,12,36,42] (continued)		T-3
compound	**aroma impressions**	**GCST***
β-ionone	floral, violet-like	floral
amyl benzoate	floral, cherry- and berry-like	-
isoamyl salicylate	sweet-floral, herbaceous-green	sweet
benzyl hexanoate	green-fruity, herbaceous	-
amyl salicylate	sweet-herbaceous, green-fruity	herbaceous
eugenol	spicy, cinnamon- and clove-like	spicy
γ-jasmine lactone	floral, jasmine-like, fruity, warm, spicy	floral
δ-jasmine lactone	floral, jasmin-like, fruity, pleasant	floral

*Odor impressions given by professional perfumers by means of GC-sniffing-technique analyses of the SPME-headspace samples of ripe/unripe mango and papaya pulp

of 408 g) mango were peeled and the fruit pulp extracted from the stones. Yellow pulp (232 g) from the ripe, and 219 g pale yellow-green pulp from the unripe mango were obtained and cut into small pieces before headspace analysis. One ripe mango (weight of 441 g) and one unripe (weight of 407 g) papaya were peeled and the seeds eliminated. Orange pulp (215 g) of ripe papaya and 202 g of orange-green unripe papaya were cut into small pieces and used for aroma investigations. Each of the four pulp samples were placed in dark-brown (light-tight) 240 ml flasks (Supelco 23235) and closed using septa (Supelco 23245-U) and hole-caps (Supelco 23237), after olfactoric evaluations by perfumers.

Olfactive evaluations: The four pulp samples of the *M. indica* and *C. papaya* in the flasks were olfactorically evaluated by perfumers at Dragoco, Vienna, Austria, and significant odor-descriptions given.

Solid phase micro-extraction sampling: The *M. indica* and *C. papaya* pulp samples in a closed dark-brown 240 ml flask were extracted with a 2 cm-50/30 µm DVB/Carboxen/ PDMS/StableFlex coated glass fiber (Supelco, USA, Cat-No. 5-7348) for 30 min at room-temperature each. Immediately afterwards, the trapped volatiles on the fiber were directly analyzed by GC-FID and GC-MS, using a method developed for previous investigations on various aroma systems.[18,19,21-26,35,41]

GC/FID: GC/FID analyses were carried out using a GC-14A with SPME sleeve adapted to injector, FID and C-R6A-Chromatopac integrator (Shimadzu, Japan), a GC-3700 with FID (Varian, Germany) and C-R1B-Chromatopac integrator (Shimadzu). The carrier gas was hydrogen; injector temperature, 250°C; detector temperature, 320°C. The temperature programme was: 40°C/5 min to 280°C/5 min, with a heating rate of 6°C/min. The columns were 30 m x 0.32 mm bonded FSOT-RSL-200 fused silica, with a film thickness of 0.25 µm (Biorad, Germany) and 30 m x 0.32 mm bonded Stabilwax, with a film thickness of 0.50 µm (Restek, USA) as well as for chiral separations 25 m x 0.25 mm FS-HYDRODEX-β-PM fused silica (film thickness, 0.25 µm, Restek, USA). Quantification was achieved using peak area calculations, and compound identification was partly carried out using correlations between retention times.[1,9,17,27,28,43]

GC/MS: For GC/MS measurements a GC-17A with QP5000 (Shimadzu), SPME sleeve adapted to injector and Compaq-ProLinea data system (class5k-software), a GC-HP5890 with HP5970-MSD (Hewlett-Packard, USA) and ChemStation software on a Pentium PC (Böhm, Austria), a GCQ (Finnigan-Spectronex, Germany-USA) and a Gateway-2000-PS75 data system (Siemens-Nixdorf, Germany, GCQ-software) were used. The carrier gas was helium; injector temperature, 250°C; interface-heating at 300°C, ion-source-heating at 200°C, EI-mode was 70 eV, and the scan-range was 41-450 amu. For other parameters, see description of GC/FID, above. Mass spectra correlations were done using Wiley, NBS, NIST and our own library as well as published data.[1,17,27]

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References

1. Adams, R.P. 2001 *Identification of Essential Oil Components by Gas chromatography/Quadrupole Mass spectroscopy.* Allured Publishing Co., Carol Stream.

2. Ansari, S.H., Ali, M., Velasco-Negueruela, A., Perez-Alonsos, M.J. 1999 Volatile constituents of the fruits of three mango cultivars, Mangifera indica L.J.Essent.Oil Res.11:65-68.

3. Arctander, St. 1969 *Perfume and Flavor Chemicals*, Published by the editor, Montclair.

4. BACIS-*Boelens Aroma Chemical Information Service* 1999 - *Volatile Compounds in Food Database*, Mango fresh (*Mangifera indica* L.), TNO Nutrition and Food Research, Zeist, The Netherlands.

5. BACIS-*Boelens Aroma Chemical Information Service 1999 – Volatile Compounds in Food Database*, Papaya (*Carica papaya* L.), TNO Nutrition and Food Research, Zeist, The Netherlands.

6. Bauer, K., Garbe, D., Surburg, H. 1997 *Common Fragrance and Flavor Materials*, 3rd Ed., VCH-Verlagsgesellschaft GmbH, Weinheim.

7. Brücher, H. 1977 *Tropische Nutzpflanzen*, Mangifera indica L. (2n=40), Springer-Verlag, Berlin-Heidelberg-New York, 316-321.

8. Brücher, H. 1977 *Tropische Nutzpflanzen*, Carica papaya L. (2n=18), Springer-Verlag, Berlin-Heidelberg-New York, 325-330.

9. Davis, N.W. 1990 *Gas chromatographic retention indices of monoterpenes and sesquiterpenes on methyl silicone and Carbowax 20M phases* J.Chromatogr. 503: 1-24.

10. Eiseman, F., Eiseman, M. 1988 *Fruits of Bali*, Mango, Periplus Editions, Berkeley, 32-33.

11. Eiseman, F., Eiseman, M. 1988 *Fruits of Bali*, Papaya, Periplus Editions, Berkeley, 40.

12. Fischer, N., 1996 *Flavour components in selected exotic fruits* Dragoco Reports: Flavoring Information Service 4: 137-140, 142-145, 147.

13. Flath, R.A., Light, D.M., Jang, E.B., Mon, T.R., John, J.O. 1990 *Headspace Examination of Volatile Emissions from Ripening Papaya (Carica papaya L., Solo Variety)* J.Agric. Food Chem. 38: 1060-1063.

14. Galan Sauco, V. 2002 *Mango: Emerging Tropical Export Crop*, Chronica Horticulturae 42:14-17.

15. Idstein, H., Schreier, P. 1985 *Volatile Constituents of Alphonso mango (Mangifera indica)* Phytochemistry 24: 2313-2316.

16. Idstein, H., Bauer, C., Schreier, P. 1985 *Flüchtige Säuren in Tropenfrüchten: Cherimoya (Annona cherimolia, Mill.), Guava (Psidium guajava, L.), Mango (Mangifera indica, L., var. Alphonso), Papaya (Caria papaya, L.)* Z.Lebensm.Unters.Forsch. 180: 394-397.

17. Jennings, W., Shibamoto, T. 1980 *Qualitative Analysis of Flavour and Fragrance Volatiles by Glass Capillary Gas Chromatography*. Academic Press, New York.

18. Jirovetz, L., Buchbauer, G., Ngassoum, M.B. 1999 *Analysis of the aroma compounds of "Baton," the fermented root-crop Cassava from Cameroon, using SPME* Ernährung/Nutrition 23: 461-464.

19. Jirovetz, L., Buchbauer, G., Ngassoum, M.B. 2000 *Analysis of the aroma compounds of the pulp of Borassus aethiopum L. (Palmaceae) from Cameroon using GC-MS, SPME-GCMS and Olfactometry* Ernährung/Nutrition 24: 159-161.

20. Jirovetz, L., Buchbauer, G., Stoyanova, A., Balinova, A. 2001 *Analysis, Chemotype and Quality Control of the Essential Oil of a New Cultivated Basil (Ocimum basilicum L.) Plant from Bulgaria* Sci.Pharm. 69: 85-89.

21. Jirovetz, L., Buchbauer, G., Ngassoum, M.B. 2001 *Analysis of the Aroma Compounds of Two Different Palm Wine Species ("Matango" and""Raffia") from Cameroon Using SPME-GC-FID, SPME-GC-MS and Olfactometry* Ernährung/Nutrition 25: 67-71.

22. Jirovetz, L., Buchbauer, G., Ngassoum, M.B. 2001 *Analysis of the Aroma Compounds of the Seeds of the Cameroonian "Garlic Tree" Scorodophloeus zenkeri Harms. Using GC-MS, SPME-GC-MS and Olfactometry* Ernährung/Nutrition 25: 354-356.

23. Jirovetz, L., Leitner, E., Buchbauer, G. 2001 *Applications of solid phase micro extraction [SPME] in aroma compound analysis of agriculturare and food products* Rec. Res. Develop. Agric. Food Chem., Vol. 5, 143-166.

24. Jirovetz, L., Buchbauer, G., Ngassoum, M.B., Geissler, M. 2002 *Analysis of the headspace aroma compounds of the seeds of the Cameroonian "garlic plant" Hua gabonii using SPME/GC/FID, SPME/GC/MS and olfactometry* Eur.Food Res.Technol. 214: 212-215.

25. Jirovetz, L., Smith, D., Buchbauer, G. 2002 *Aroma Compound Analysis of Eruca sativa (Brassicaceae) SPME Headspace Leaf Samples Using GC, GC-MS and Olfactometry* J.Agric.Food Chem. 50: 4643-4646.

26. Jirovetz, L., Buchbauer, G., Shahabi, M., Ngassoum, M.B. 2002 *Comparative Investigations of the Essential Oil and Volatiles of Spearmint* Perfumer & Flavorist 27: 16-22.

27. Joulain, D., König, W.A. 1998 *The Atlas of Spectral Data of Sesquiterpene Hydrocarbons*, E.B.-Verlag, Hamburg.

28. Kondioya, N. and Berdaque, J.-L. 1996 *A Compilation of Relative Retention Indices for the Analysis of Aromatic Compounds*, Edition du Laboratoire Flaveur, Saint Genes Champelle.

29. König, W.A. 1992 *Gas Chromatographic Enantiomer Separation with Modified Cyclodextrins*, Hüthig Buch Verlag GmbH, Heidelberg.

30. MacLeod, A.J., Gonzales de Troconis, N. 1982 *Volatile flavor components of mango fruit* Phytochemistry 21: 2523-2526.

31. MacLeod, A.J., Pieris, N.M. 1984 *Comparison of the volatile components of some mango cultivars* Phytochemistry 23: 361-366.

32. MacLeod, A.J., MacLeod, G., Snyder, C.H. 1988 Volatile aroma constituents of mango (cv Kensington) Phytochemistry 27: 2189-2193.

33. Mosandl, A. 1992 Capillary gas chromatography in quality assessment of flavours and fragrances Phytochemistry 624: 267-292.

34. Näf, F., Näf, R., Uhde, G. 1990 Synthesis of nature-identical flavour chemicals, Flavour science and technology, John Wiley & Sons Ltd., Chichester, 3-20.

35. Ngassoum, M.B., Jirovetz, L., Buchbauer, G. 2001 *SPME/GC/MS analysis of headspace aroma compounds of the Cameroonian fruit Tetrapleura tetraptera (Thonn.) Taub.* Eur. Food Res. Technol. 213: 18-21.

36. Ohloff, G. 1994 *Scent and Fragrances*, Springer-Verlag, Berlin.

37. Olle, D., Baumes, R.L., Bayonove, C.L., Lozano, Y.F., Sznaper, C., Brillouet, J.-M. 1998 *Comparison of Free and Glycosidically Linked Volatile Components from Polyembryonic and Monoembryonic Mango (Mangifera indica L.) Cultivars* J.Agric. Food Chem. 46:1094-1100.

38. Samson, J.A. 1986 *Tropical fruits*, 2nd Ed., Mango, Longman Inc., New York, 216-234.

39. Samson, J.A. 1986 *Tropical fruits*, 2nd Ed., Papaya, Longman Inc., New York, 256-269.

40. Schreier, P., Lehr, M., Heidlas, J., Idstein, H. 1985 *Über das Aroma der Papaya-Frucht (Caria papaya, L.): Hinweise auf Vorstufen flüchtiger Terpenverbindungen* Z.Lebensm. Unters.Forsch. 180: 297-302.

41. Sigma-Aldrich 1998 *Solid Phase Microextraction: Solventless Sample Preparation for Monitoring Flavor Compounds by Capillary Gas Chromatography* Supelco Bulletin 869A, Bellefont.

42. Sigma-Aldrich 2002 *Flavors & Fragrances – The Essence of Excellence*, Milwaukee.

43. Tudor, E. 1997 *Temperature dependence of the retention index for perfumery compounds on a SE-30 glass capillary column, I. Linear equations* J.Chromatogr. A 779: 287-297.

44. Werkhoff, P., Brennecke, St., Bretschneider, W., Günter, M., Hopp, R., Surburg, H. 1993 *Chirospecific analysis in essential oil, fragrance and flavor research* Z. Lebensm. Unters. Forsch. 196: 307-328.

45. Wong, K.C., Ong, C.H. 1993 *Volatile components of the fruits of Bachang (Mangifera foetida Lour.) and Kuini (Mangifera odorata Griff.)* Flavour Fragr. J. 8: 147-151. ■