

Comparison of the volatile compositions and flavour properties of cantaloupe, Galia and honeydew muskmelons

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Abstract

Aroma compounds were extracted from three cultivars of muskmelon (*Cucumis melo* L.) by solid-phase microextraction and analysed by gas chromatography–mass spectrometry. Sulfur-containing esters and compounds containing a straight six-carbon chain were present at high concentrations in cantaloupe melons. Compounds containing a straight nine-carbon chain were at high concentrations in honeydew melons. Methyl esters were present at the highest levels in Galia melons. The sensory properties of the three melons were also compared. Cantaloupe melons were associated with sweet, floral and fruity aromas and a persistent aftertaste. Galia melons possessed the strongest cucumber-like flavours, while cucumber aroma and sweet flavour scored highly in honeydew melons.

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1. Introduction

The volatile components of muskmelon (*Cucumis melo* L.) have been analysed by a number of authors (Beaulieu & Grimm, 2001), and approximately 240 compounds have been identified. Over half of these compounds are esters, of which some contain sulfur. Most of the remaining compounds are aldehydes and alcohols (Nijssen et al., 1996).

Esters, alcohols and aldehydes containing a nine-carbon straight chain have been shown to be important in muskmelon aroma (Buttery et al., 1982; Kemp, Knavel, & Stoltz, 1971; Kemp, Knavel, & Stoltz, 1972; Kemp, Stoltz, & Knavel, 1972; Kemp, Knavel, & Stoltz, 1973; Kemp, Knavel, Stoltz, & Lundin, 1974). Kemp et al. (1974) identified (*Z,Z*)-3,6-nonadien-1-ol in *reticulatus* melons (cv. Supermarket). The aroma of this compound

was described as muskmelon-like or musky and had a flavour threshold concentration in water of 10 µg per kg. Kemp et al. (1972) identified (*Z*)-6-nonenal as a key odorant of the same melon cultivar. Its flavour threshold in water was 20 ng per kg. Buttery et al. (1982) reported the odour threshold of this compound in water to be 5 ng per kg, and they also identified (*Z*)-6-nonen-1-ol, (*Z*)-6-nonenyl acetate and (*Z,Z*)-3,6-nonadienyl acetate in honeydew melon, reporting odour thresholds in water for these compounds of 1 µg per kg, 2 µg per kg and 15 µg per kg, respectively. (*Z*)-6-Nonenyl acetate possessed a pleasant honeydew melon-like aroma.

Wyllie, Leach, Wang, and Shewfelt (1994) stated that ethyl butanoate, methyl 2-methylbutanoate and ethyl 2-methylpropanoate were important contributors to muskmelon aroma. They also identified ethyl 2-methylbutanoate, 2,3-butanediol diacetate and the sulfur-containing compounds *S*-methyl thiobutanoate, 3-(methylthio)propanal, 3-(methylthio)propyl acetate

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and dimethyl tetrasulfide as character impact components of muskmelon (cv. Makdimon). Schieberle, Ofner, and Grosch (1990) identified methyl 2-methylbutanoate, (*Z*)-3-hexenal, (*E*)-2-hexenal and ethyl 2-methylpropanoate as the primary odorants of Israeli muskmelons, using aroma extract dilution analysis. Hayata et al. (2003) found 46 odorant compounds in Miyabi muskmelon, using gas chromatography-olfactometry. The highest odour dilution values were obtained for ethyl butanoate (grape-like), ethyl (methylthio)acetate (cucumber-like), (*E,Z*)-2,6-nonadienal (cucumber-like), (*Z*)-6-nonen-1-ol (sweet, green), (*Z,Z*)-3,6-nonadien-1-ol (grassy boiled leaf-like), 2,5-dimethyl-4-hydroxy-3(2*H*)-furanone (caramel-like) and an unknown with a *yakitori*-like aroma.

In this paper, we report the use of solid-phase microextraction (SPME), to compare the volatile components of three different varieties of muskmelon: Galia (*C. melo* var. *reticulatus* Naud.), orange-fleshed cantaloupe (*C. melo* var. *cantalupensis* Naud.) and honeydew (*C. melo* var. *inodorus* Naud.). Sensory profiling of the three melon varieties was also performed, to determine how sensory differences between the three varieties of melons could be related to the aroma volatile composition.

2. Materials and methods

2.1. Melons

Eight melons of three different cultivars – orange-fleshed cantaloupe, Galia and honeydew – were purchased from a local supermarket in July 2002. All three cultivars were grown in Spain. Melons were stored at 10 °C before analysis and all analyses were performed within 7 days of purchase.

2.2. Chemicals

Dithiothreitol (99%) and isobutyryl chloride (98%) were purchased from Acros Organics (Loughborough, UK); isopropenyl acetate (99%) and (*Z*)-6-nonen-1-ol (98%) were purchased from Lancaster (Morecambe, UK); 2-methylbutyryl chloride (97%), *p*-toluenesulfonic acid monohydrate (98.5%) and pyridinium chlorochromate (98%) were purchased from Sigma–Aldrich Company Ltd. (Gillingham, UK).

2.3. Solid-phase microextraction (SPME)

A 50/30 µm divinylbenzene/Carboxen™ on polydimethylsiloxane fibre (Supelco, Bellefonte, PA) was used, which was conditioned at 250 °C for 30 min before use. For each melon studied, plugs (1 cm diameter, 2 cm long) were removed from its equator, using a steel cork borer. The peel was removed from the plugs with a

sharp knife, and the plugs (~30 g) were weighed into a 100 ml glass bottle, fitted with a screw cap, pre-drilled with a single hole and a PTFE-lined septum (Elmore, Mottram, & Hierro, 2001). The stainless steel needle, housing the SPME fibre, was placed through the hole and penetrated the liner. After equilibration at 37 °C for 5 min, the fibre was exposed to the headspace above the sample for 30 min. Three melons of each cultivar were analysed, with one analysis per melon.

2.4. Gas chromatography-mass spectrometry (GC–MS)

After extraction, the SPME device was inserted into the injection port of an HP5972 GC–MS system (Agilent, Palo Alto, CA). The contents of the SPME fibre were desorbed for 3 min in a split/splitless injection port, held in splitless mode at 250 °C, onto a non-polar deactivated fused silica retention gap (5 m × 0.25 mm i.d.; Varian Chrompack International B.V., Middelburg, The Netherlands). The retention gap contained 5 small loops in a coil, which were cooled in solid carbon dioxide, contained within a 250 ml beaker. The retention gap was attached to a CP-Wax 52 CB fused silica capillary column (60 m × 0.25 mm × 0.25 µm film thickness; Varian Chrompack). Immediately before desorption of the fibre, 0.1 µl of a standard (1000 ng µl⁻¹ 1,2-dichlorobenzene in methanol) were injected in splitless mode onto the GC column.

During desorption, the oven was held at 40 °C. After desorption, the solid carbon dioxide was removed from the oven. The oven was maintained at 40 °C for a further 2 min and then the temperature was raised at 4 °C min⁻¹ to 250 °C. Helium at 16 psi was used as the carrier gas, resulting in a flow of 1.0 ml min⁻¹ at 40 °C. *n*-Alkanes (C₅–C₂₅) were analysed under the same conditions to obtain linear retention index (LRI) values for the components.

The mass spectrometer, which was operated in electron impact mode, scanned from *m/z* 29 to *m/z* 400 at 1.9 scans/s. Compounds were identified by first comparing their mass spectra with those contained in the NIST/EPA/NIH Mass Spectral Database (MS Windows version 2.0a, 2002) or in previously published literature, followed by comparing mass spectra and LRI values with those of authentic standards. Approximate quantities of the volatiles were estimated by comparison of their peak areas with that of the 1,2-dichlorobenzene standard, obtained from the total ion chromatograms, using a response factor of 1. Authentic standards were run under the same conditions, except that the mass spectrometer scanned from *m/z* 10 to *m/z* 400 at 1.9 scans/s.

2.5. Synthesis of esters and (*Z*)-6-nonenal

Standard compounds for confirmation of identifications obtained by GC–MS were purchased, where

available. Unsaturated and sulfur-containing acetate esters were synthesised according to the method of Hagemeyer and Hull (1949). Appropriate alcohols were heated with excess isopropenyl acetate in the presence of catalytic amounts of *p*-toluenesulfonic acid. As acetone formed it was distilled off, allowing the desired product to be formed. After completion, the product was neutralised with 0.01 M sodium bicarbonate and the organic layer removed and dried with anhydrous sodium sulfate. Saturated esters were prepared by conventional refluxing of excess alcohol and acid under acidic conditions.

S-Methyl 2-methylpropanethioate and *S*-methyl 2-methylbutanethioate were prepared by reacting methanethiol and the appropriate acid chloride at $-10\text{ }^{\circ}\text{C}$ (Rylander & Tarbell, 1950). The acid chloride (5 mmol) was dissolved in 5 ml of chloroform containing 5 mmol of pyridine in a 20 ml vial with screw top and septum. Methanethiol (10 mmol, 0.48 g) was prepared in a 40 ml vial with screw top and septum (Qm_x, Thaxted, Essex, UK) from the action of Cleland's reagent on dimethyl disulfide in water at $50\text{ }^{\circ}\text{C}$. A fused silica capillary inserted through the two septa allowed the methanethiol to bubble into the acid chloride. When no more bubbles of methanethiol were observed, the capillary was removed and the reaction mixture was allowed to reach room temperature. The products were washed with 0.01 M sodium bicarbonate solution and the organic layer was separated and dried with anhydrous sodium sulfate.

(*Z*)-6-Nonenal was prepared by refluxing (*Z*)-6-nonen-1-ol with pyridinium chlorochromate in dichloromethane (Corey & Suggs, 1975). After completion, the product was dissolved in diethyl ether, washed with 0.01 M sodium bicarbonate and saturated salt solution. The organic layer was removed and dried with anhydrous sodium sulfate.

2.6. Sensory analysis of melons

A panel of 15 people developed a consensus list of 14 terms to describe the aroma and taste attributes of musk melons. They then used these terms to assess the flavour and aroma properties of the three cultivars, using 10-cm continuous line scales to score the intensities of each attribute. Assessors sat in individual booths and were asked to score the sensory properties of the melons, using the 14 terms. Four melons of each cultivar were peeled and seeds were removed before slicing into 2-cm thick pieces. A slice of each of the three types of melon was presented separately to the assessors in a randomly numbered Petri dish, in random order, under artificial light. The assessments were performed twice by each panellist in two sessions, one day apart. Panellists had not analysed melons before but were familiar with using a continuous line scale for intensity measurement.

2.7. Statistical analysis

The quantitative data for each compound identified in the GC–MS analyses were compared for the three melons using analysis of variance (ANOVA). The sensory data for each of the attributes scored for the melons were also examined using ANOVA. For those compounds exhibiting significant difference in the ANOVA, Fisher's least significant difference test was applied to determine which sample means differed significantly ($p < 0.05$).

3. Results

3.1. Gas chromatography–mass spectrometry

Eighty-four compounds were present at levels above 2 ng per 100 g of sample in the SPME extracts of at least one cultivar (Table 1), of which 35 varied significantly with cultivar.

S-Methyl 2-methylpropanethioate and *S*-methyl 2-methylbutanethioate have not been reported as components of melon aroma before, although their analogues, *S*-methyl butanethioate (Wyllie et al., 1994), *S*-methyl 3-methylbutanethioate (Beaulieu & Grimm, 2001) and *S*-methyl pentanethioate (Wyllie et al., 1994) have. It is possible that these three compounds have been incorrectly identified. A reference sample of *S*-methyl butanethioate analysed by us had a similar mass spectrum to *S*-methyl 2-methylpropanethioate, but its LRI value was 1205, whereas that for *S*-methyl 2-methylpropanethioate was only 1141. The mass spectrum of *S*-methyl 2-methylbutanethioate has not been previously reported in the literature. It is: $m/z(\%)$ 57(100), 41(49), 85(46), 29(30), 27(14), 75(13), 56(12), 47(10), 39(11), 45(7), 55(7), 117(6), 132 (M^+ ; 5), 58(4). Its spectrum is very similar to that of *S*-methyl 3-methylbutanethioate (NIST/NIH/EPA database), the major difference being that the mass spectrum of *S*-methyl 3-methylbutanethioate contains a major ion at m/z 43 (approximately 25%), whereas there the relative intensity of m/z 43 in *S*-methyl 2-methylbutanethioate is less than 1%. Furthermore, no compounds containing the 3-methylbutyl group were identified in any of the melons in this study, whereas 8 other compounds in Table 1 contain the 2-methylbutyl group. The mass spectra and linear retention indices for these 8 compounds were compared with analogous reference compounds possessing 2- or 3-methylbutyl groups, in order to confirm that the correct identifications had been made.

(*Z*)-4-Hepten-1-yl acetate was synthesised from isopropenyl acetate and (*Z*)-4-hepten-1-ol. Its mass spectrum, which has not been reported previously, is: $m/z(\%)$ 81(100), 43(73), 67(31), 54(30), 41(28), 96(27), 68(24), 55(21), 39(18), 27(11), 79(10), 53(9), 29(9),

Table 1
Aroma compounds in the headspace of three varieties of muskmelon

LRI ^a	No.	Compound	Relative amount in headspace ^b			LSD ^c	<i>P</i> ^d	Identification ^e
			Cantaloupe	Galia	Honeydew			
826	1	Methyl acetate	61b	54b	8a	46	*	MS + LRI
889	2	Ethyl acetate	86	133	54	220	NS	MS + LRI
908	3	Methyl propanoate	9a	18b	3a	7.6	**	MS + LRI
924	4	Methyl 2-methylpropanoate	4	13	tr			MS + LRI
934	5	Ethanol	5	10	9	6.1	NS	MS + LRI
953	6	Ethyl propanoate	9	12	8	11	NS	MS + LRI
962	7	Ethyl 2-methylpropanoate	4	4	3	6.9	NS	MS + LRI
969	8	Propyl acetate	27b	9a	11a	16	*	MS + LRI
980	9	Methyl butanoate	17a	50b	4a	16	***	MS + LRI
1014	10	Methyl 2-methylbutanoate	63	214	66	193	NS	MS + LRI
1017	11	Isobutyl acetate	615b	189a	126a	315	**	MS + LRI
1039	12	Ethyl butanoate	14	55	49	91	NS	MS + LRI
1043	13	Isopropyl butanoate	3	4	3	5.1	NS	MS + LRI
1047	14	Propyl propanoate	4	2	3	3.5	NS	MS + LRI
1052	15	<i>S</i> -Methyl ethanethioate	9b	1a	1a	2.6	***	MS + LRI
1055	16	Ethyl 2-methylbutanoate	17	13	21	33	NS	MS + LRI
1075	17	Butyl acetate	232b	42a	74a	127	**	MS + LRI
1083	18	Isobutyl propanoate	31	12	11	20	NS	MS + LRI
1087	19	Hexanal	–	7	5			MS + LRI
1089	20	Methyl pentanoate	1	6	tr			MS + LRI
1094	21	Isobutyl 2-methylpropanoate	25b	5a	6a	16	*	MS + LRI
1125	24	2-Methylbutyl acetate	1578	822	485	1260	NS	MS + LRI
1126	25	Propyl butanoate	4	1	4	4.9	NS	MS + LRI
1138	26	Ethyl pentanoate	3	2	9	15	NS	MS + LRI
1141	27	<i>S</i> -Methyl 2-methylpropanethioate	16b	2a	2a	5.5	***	MS + LRI
1143	28	Butyl propanoate	12b	4a	4a	8.1	*	MS + LRI
1162	29	Isobutyl butanoate	34b	4a	7a	17	**	MS + LRI
1176	30	Pentyl acetate	46	20	37	56	NS	MS + LRI
1180	31	Isobutyl 2-methylbutanoate	23b	5a	4a	11	**	MS + LRI
1190	32	Methyl hexanoate	10a	33b	2a	23	*	MS + LRI
1192	33	2-Methylbutyl propanoate	22	11	9	17	NS	MS + LRI
1199	34	2-Methylbutyl 2-methylpropanoate	14b	4a	4a	7.3	*	MS + LRI
1205	35	<i>D</i> -Limonene	11b	3a	2a	4.7	**	MS + LRI
1215	36	1,8-Cineole (eucalyptol)	16	3	tr			MS + LRI
1221	37	Butyl butanoate	4	–	2			MS + LRI
1225	38	<i>S</i> -Methyl 2-methylbutanethioate	75b	5a	6a	17	***	MS + LRI
1232	39	A 6-carbon alcohol acetate	5	2	tr	2.6		se
1236	40	Ethyl hexanoate	24	10	45	85	NS	MS + LRI
1250	41	2-Methyl-2-butenyl acetate	8	11	2	12	NS	ms ^f
1269	42	2-Methylbutyl butanoate	14b	2a	2a	8.4	**	MS + LRI
1275	43	Hexyl acetate	1465b	232a	208a	497	***	MS + LRI
1279	44	<i>p</i> -Cymene	3	1	4	5.7	NS	MS + LRI
1285	45	2-Methylbutyl 2-methylbutanoate	8b	2a	1a	4.4	*	MS + LRI
1291	46	Methyl heptanoate	8	13	3	13	NS	MS + LRI
1310	47	(<i>E</i>)-3-Hexen-1-yl acetate	25b	1a	1a	4.8	***	MS + LRI
1320	48	(<i>Z</i>)-3-Hexen-1-yl acetate	583b	32a	36a	131	***	MS + LRI
1336	49	Ethyl heptanoate	8	2	10	14	NS	MS + LRI
1342	50	Hexyl propanoate	5	2	tr			MS + LRI
1348	51	1-Hexanol	6b	3a	2a	2.3	*	MS + LRI
1356	52	Isobutyl hexanoate	4	–	–			MS + LRI
1377	53	Heptyl acetate	64	51	36	72	NS	MS + LRI
1379	54	1-Octen-3-yl acetate	28b	9a	4a	13	**	MS + LRI
1382	55	Ethyl (<i>E</i> or <i>Z</i>)-4-heptenoate	2	tr	22			ms
1387	56	2-Ethylhexyl acetate	6b	8b	3a	3.2	*	MS + LRI
1393	57	Methyl octanoate	6	8	1	6.3	NS	MS + LRI
1401	58	Nonanal	5a	26a	133b	62	**	MS + LRI
1415	59	(<i>Z</i>)-3-Hepten-1-yl acetate	4	3	8	8.4	NS	MS + LRI
1419	60	(<i>Z</i>)-4-Hepten-1-yl acetate	13	7	86	152	NS	MS + LRI
1438	61	A heptadienyl acetate	7	–	–	2.7		se
1445	62	1-Octen-3-ol	4	5	5	3.4	NS	MS + LRI
1459	63	(<i>Z</i>)-6-Nonenal	1a	4a	127b	79	**	MS + LRI
1478	64	Octyl acetate	33	21	9	31	NS	MS + LRI

Table 1 (continued)

LRI ^a	No.	Compound	Relative amount in headspace ^b			LSD ^c	P ^d	Identification ^e
			Cantaloupe	Galia	Honeydew			
1487	65	2,3-Butanediol diacetate (enantiomer)	7	21	–		MS + LRI	
1502	66	2-(Methylthio)ethyl acetate	5	–	–		MS + LRI	
1513	67	(Z)-3-Octen-1-yl acetate	12b	2a	3a	7.3	*	MS + LRI
1531	68	(Z)-5-Octen-1-yl acetate	3	1	4	5.1	NS	MS + LRI
1541	69	Benzaldehyde	9	3	10	9.2	NS	MS + LRI
1548	70	(E)-2-Nonenal	3a	10ab	14b	7.7	*	MS + LRI
1552	71	1-Octanol	2	4	3	3.2	NS	MS + LRI
1581	72	Nonyl acetate	14	15	28	57	NS	MS + LRI
1598	73	(E,Z)-2,6-Nonadienal	1	5	17	17	NS	MS + LRI
1610	74	(Z)-3-Nonen-1-yl acetate	200	146	60	230	NS	MS + LRI
1634	75	(Z)-6-Nonen-1-yl acetate	7	7	141	217	NS	MS + LRI
1639	76	3-(Methylthio)propyl acetate	29	–	–			MS + LRI
1654	77	1-Nonanol	4a	19a	48b	24	**	MS + LRI
1671	78	(Z,Z)-3,6-Nonadienyl acetate	118	85	76	158	NS	ms ^g
1682	79	(Z)-3-Nonen-1-ol	24a	78b	31a	41	*	MS + LRI
1711	80	(Z)-6-Nonen-1-ol	2a	3a	57b	33	**	MS + LRI
1711	81	α -Terpinyl acetate	6	tr	–			MS + LRI
1741	82	Phenylmethyl acetate	336	79	78	287	NS	MS + LRI
1749	83	(Z,Z)-3,6-Nonadien-1-ol	9	29	28	21	NS	ms ^h
1829	84	2-Phenylethyl acetate	72b	11a	2a	39	**	MS + LRI
Total volatiles in headspace			6381	2894	3111			

^a Linear retention index on a CP-Wax 52CB column.

^b Relative to 1,2-dichlorobenzene (100 ng) injected onto GC column. Means labelled with different letters are significantly different ($P < 0.05$); means are from three replicate samples; tr, <1.0; –, not detected (limit of detection 0.5).

^c Least significant difference at $P = 0.05$.

^d Probability that there is a difference between means; NS, no significant difference between means ($P > 0.05$); * significant at the 5% level; ** significant at the 1% level; *** significant at the 0.1% level.

^e MS + LRI, mass spectrum and LRI agree with those of authentic compound; ms, mass spectrum agrees with spectrum in NIST/EPA/NIH Mass Spectral Database or with other literature spectrum: se, tentative identification from structure elucidation of mass spectrum.

^f Rowan et al. (1996).

^g Buttery et al. (1982).

^h Kemp et al. (1974).

82(7) 156 (M^+ , 0). Compound 39 was tentatively identified as a 6-carbon alcohol acetate, although reference compounds showed that it was not hexyl acetate, nor 3-methyl-1-pentyl acetate. Its mass spectrum is: m/z (%) 43(100), 56(54), 41(32), 69(29), 61(26), 84(14), 101(12), 29(8). Compound 61 was tentatively identified as a heptadienyl acetate. Its mass spectrum is: m/z (%) 43(100), 80(65), 79(58), 41(13), 39(13), 67(8), 65(6), 40(6).

Several of the compounds considered to be important contributors towards melon flavour varied significantly between cultivars. For instance (Z)-6-nonenal and (Z)-6-nonen-1-ol were strongly associated with honeydew melon. Sulfur-containing esters, which may contribute to the musky notes in melon aroma (Bauchot, Mottram, Dodson, & John, 1999) were significantly higher in cantaloupes. These compounds are likely to be derived from methionine (Wang, Wyllie, & Leach, 1996).

Other compounds present at significantly higher levels in cantaloupes were acetate esters, as well as esters derived from 1-butanol, 2-methyl-1-propanol and alcohols containing six carbon atoms. Alanine, γ -aminobutyric acid and valine are likely precursors of acetates, butyl esters and 2-methylpropyl esters, respectively

(Wang et al., 1996). Bauchot et al. (1999) suggested that ethyl esters were important contributors to cantaloupe aroma, although levels of these compounds were not significantly higher in cantaloupe, compared with the other varieties. Levels of aldehydes were significantly higher in honeydew melons; alcohols were present at lower levels in cantaloupes, compared with Galia and honeydew melons. Several methyl esters were at higher levels in Galia melons than in the other two cultivars.

Elmore, Toji, and Mottram (2003), using a 75 μ m CarboxenTM/polydimethylsiloxane fibre, showed that Galia melons also contained higher levels of several acetate esters, including isobutyl, butyl, 2-methylbutyl and hexyl acetate, than cantaloupe or honeydew. Fallick et al. (2001) reported high levels of these four compounds in the SPME extracts of Galia melons, using a 100 μ m polydimethylsiloxane fibre.

Principal component analysis was used to visualise the differences between the three types of melon (Fig. 1). The first two principal components accounted for all of the variation in the data; principal component 1 (PC 1) displayed 60.2% of the variation and principal

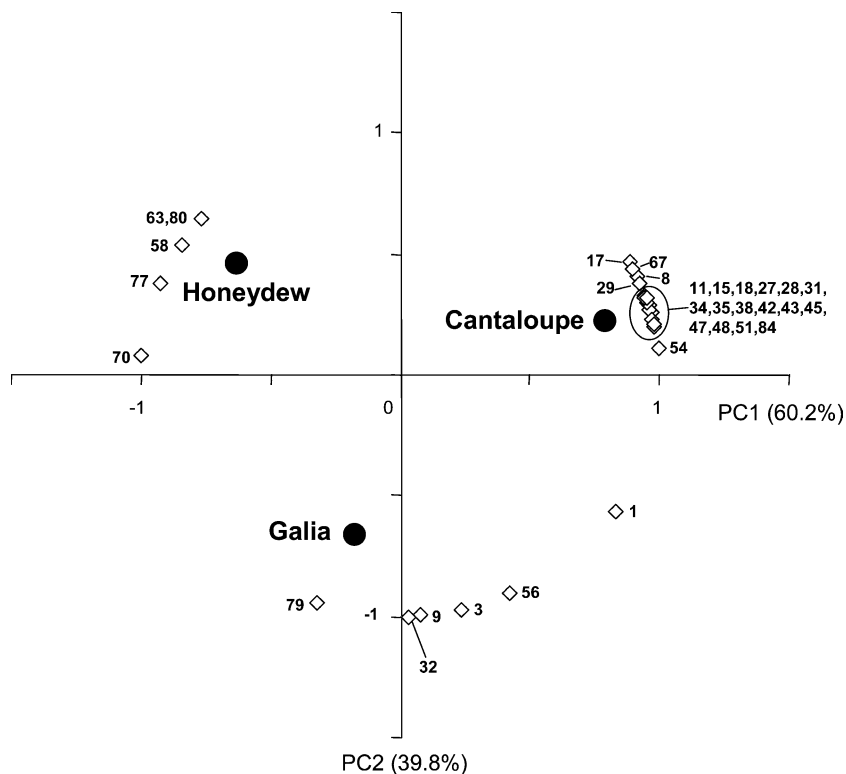


Fig. 1. Principal component plot (PC1 versus PC2) of three melon cultivars, showing correlations with statistically significant aroma volatiles (Numbers on plot refer to compound numbers in Table 1).

component 2 (PC 2) displayed 39.8%. Cantaloupes were separated from Galia and honeydew melons across PC 1. The volatile compounds associated with cantaloupe included sulfur-containing esters, branched esters and six-carbon alcohol-derived esters. Galia melons were separated from honeydew melons across PC 2. Methyl esters were correlated with Galia melons, whereas 9-carbon aldehydes and alcohols were associated with honeydew melons.

3.2. Sensory analysis of melons

Eight aroma attributes and six flavour/taste attributes were used to describe the sensory properties of the three muskmelons (Table 2). Two fruity aromas were defined; one was a fruitiness typically associated with melon, although different from characteristic melon aroma; the other was a fruitiness more typical of fruit sweets and candy. Floral aroma, fruity (not melon) aroma, sweet aroma and persistence of aftertaste were all significantly higher in cantaloupe than Galia and honeydew melons. Melon-like aroma and fruity (melon) aroma were significantly lower in Galia compared with the other two melons. Similar scores for both of these attributes may mean that the assessors could not distinguish these terms. Honeydew scored highest for cucumber aroma but Galia scored highest for cucumber flavour, as well as scoring higher than honeydew for green flavour.

Honeydew tasted sweetest, then cantaloupe, then Galia. No significant differences were observed for green aroma, fatty/dairy aroma, bitter taste or acid taste.

Table 2
Mean scores for sensory attributes of three varieties of muskmelon

Sensory attribute	Score (0–100) ^a			LSD ^b	<i>P</i> ^c
	Cantaloupe	Galia	Honeydew		
<i>Aroma</i>					
Green	37.8	41.0	52.2	16.2	ns
Floral	52.9 ^b	21.2 ^a	27.1 ^a	13.3	***
Melon-like	52.4 ^b	30.1 ^a	57.1 ^b	17.0	**
Fruity (melon)	51.5 ^b	28.9 ^a	50.1 ^b	17.0	*
Fruity (other)	45.9 ^b	18.2 ^a	18.4 ^a	11.9	***
Cucumber	19.1 ^a	35.6 ^b	49.4 ^c	13.9	***
Sweet	52.3 ^c	19.8 ^a	36.9 ^b	13.1	***
Fatty/dairy	12.6	15.1	20.4	12.1	ns
<i>Flavour</i>					
Green	40.4 ^{ab}	45.2 ^b	30.7 ^a	11.1	*
Cucumber	21.4 ^a	45.2 ^b	31.2 ^a	12.9	**
Acid	26.8	23.4	22.1	11.9	ns
Bitter	26.0	18.3	13.2	12.1	ns
Sweet	50.7 ^b	44.5 ^b	63.5 ^a	10.0	**
Aftertaste	50.9 ^b	25.7 ^a	35.1 ^a	16.8	*

^a Means labelled with different letters are significantly different ($P < 0.05$); means are from 15 assessors, two replicate analyses for each assessor.

^b Least significant difference at $P = 0.05$.

^c Probability that there is a difference between means; NS, no significant difference between means ($P > 0.05$); * significant at the 5% level; ** significant at the 1% level; *** significant at the 0.1% level.

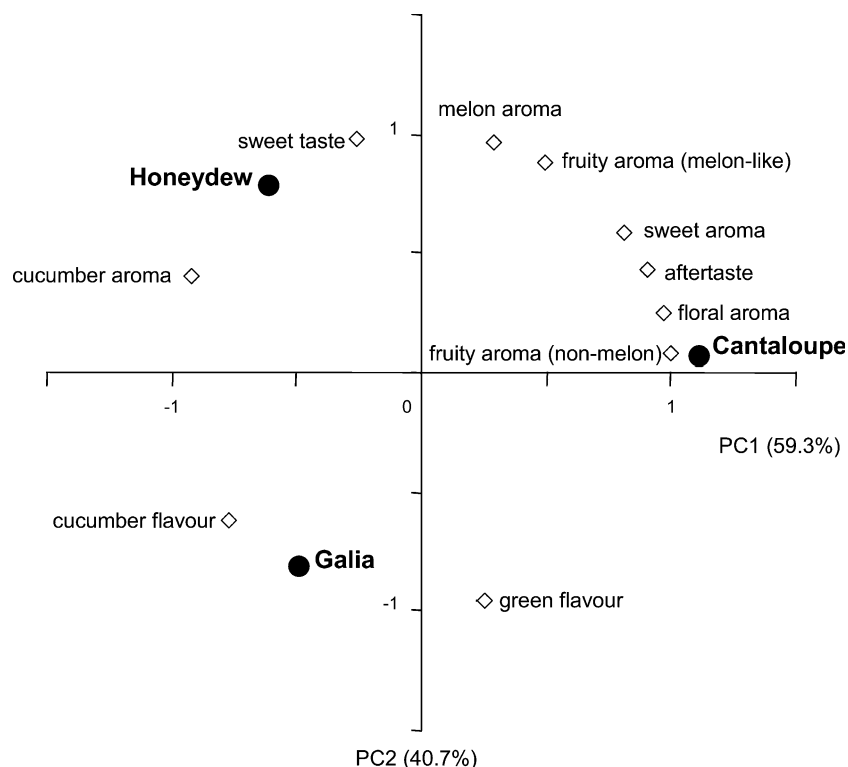


Fig. 2. Principal component plot (PC1 versus PC2) of three melon cultivars, showing correlations with sensory attributes.

Principal component analysis was also carried out on the correlation matrix of all samples and all attributes (Fig. 2). Again, all of the variation in the data was explained by two principal components. PC 1 displayed 59.3% of the variation and PC 2 displayed 40.7%. In a similar way to the volatiles data, cantaloupes were separated from Galia and honeydew melons across PC 1. The attributes positively associated with cantaloupe were sweet aroma, floral aroma, fruity aroma (non-melon), acid taste, bitter taste and aftertaste. Galia melons were separated from honeydew melons across PC 2. Sweet flavour and melon-like aroma were associated with honeydew melon, while green flavour was associated with Galia melons.

3.3. Comparison of sensory and analytical data

Comparison of the volatile and sensory PC plots suggests that the cucumber-like aroma of honeydew melons may be due to 9-carbon aldehydes and alcohols. (*E*)-2-Nonenal and (*E,Z*)-2,6-nonadienal have been reported as possessing green, cucumber-like aromas and have been shown to contribute towards muskmelon aroma (Schieberle et al., 1990). The acetate of (*Z*)-6-nonen-1-ol was reported by Buttery et al. (1982) as having a typical honeydew melon aroma. This compound was found at much higher levels in honeydew melons, compared to the other two cultivars but because of its high variability within the three replicates, the

difference was not statistically significant. It is more difficult to relate typical cantaloupe aroma and flavour to specific compounds, although it is clear that esters, in particular sulfur-containing esters, are important.

The larger pore size of the divinylbenzene/Carboxen™ on polydimethylsiloxane fibre (Shirey, 2000) proved to be more effective than the smaller pores of the Carboxen™/polydimethylsiloxane fibre for the adsorption of those compounds reported as being important in melon aroma. Results also compared favourably with those obtained using a 100 µm polydimethylsiloxane fibre (Beaulieu & Grimm, 2001).

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