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SHORT REPORTS

AROMA VOLATILES OF AUBERGINE (*SOLANUM MELONGENA*)

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Key Word Index—*Solanum melongena*; Solanaceae; aubergine; aroma volatiles.

Abstract—Samples of the aroma volatiles of aubergine were obtained by well-established methods and were analysed by routine GC and GC/MS. Hydrocarbons comprised over 70 % of the samples and included 20 acyclic alkanes. A very low concentration of total volatiles (*ca* 2.4 μg/kg) was produced.

INTRODUCTION

Aubergine or 'egg-plant' (*Solanum melongena*) is widely grown in tropical, subtropical and warm temperate regions for its fruit, which is eaten as a cooked vegetable. The glossy, firm-fleshed fruit can be up to 30 cm in length, and although common varieties are the well-known deep purple colour, others are white. Cooked aubergine (usually broiled or fried) is widely consumed for its characteristic attractive flavour. As the demand for a more varied and sophisticated diet has increased in recent years, so too has the consumption of aubergine, and this report describes the first investigation of its volatile flavour constituents.

RESULTS AND DISCUSSION

Extracts of the aroma volatiles of cooked aubergine were obtained using a modified Likens and Nickerson apparatus [1, 2]. Due to the very delicate flavour of aubergine it was necessary to pool the products from four such extractions, using a total of over 2 kg of the fruit. Extracts were concentrated by low temperature-high vacuum distillation [2] and the resultant essence, on appropriate re-dilution, possessed an aroma characteristic of cooked aubergine. Essences were examined by conventional GC and constituents were identified as far as possible by high sensitivity GC/MS, using both EI and CI techniques. Odour qualities of the separated components were assessed by three people using an odour port at the exit of the GC column.

Table 1 lists the volatile components of cooked aubergine, together with GC retentions, quantitative data and odour qualities, and is an amalgam of the results obtained in three separate analyses, the degree of reproducibility of quantitative data generally being *ca* ± 5 %. In all instances where positive identities are given, mass spectra of sample components agreed with those in the literature [3–5], within instrumental variability. Literature [3, 6] Kováts retention indices are given for some important components and these serve as limited further supportive evidence of identity, confirming the general elution sequence. Where no odour quality is given in Table 1 this means that none could be detected at the GC odour port during elution of that particular peak.

Table 1 shows that 60 main components were detected in the essences, of which 37 (comprising *ca* 67 % w/w of the sample) were positively identified and a further 18 (*ca* 32 % w/w) were partially or tentatively characterized. Most of the compounds in the latter group (*ca* 30 % w/w of the sample) were alkanes or cycloalkanes, for which the only uncertainties were the structure and/or orientation of alkyl substituents.

Hydrocarbons comprised over 70 % w/w of the aroma volatiles of aubergine and included 20 acyclic alkanes (*ca* 52 % w/w of the sample) ranging from heptane to eicosane. Most were straight chain, but the series was not complete and C_9–C_{12} inclusive were not detected. From their mass spectra, the majority of the partially characterized branched chain alkanes (seven) were probably 2-methylalkanes. Alkanes are, of course, common amongst food aroma volatiles, but it is unusual for them to reach dominance, particularly in vegetables, as in this instance. Indeed, of the five compounds produced in the samples in amounts greater than 5 %, three were alkanes (a branched C_8, *ca* 21.5 %; C_8, *ca* 5.3 %; C_7, *ca* 5.1 %), one was an aromatic hydrocarbon (toluene, *ca* 5.6 %), and only one was not a hydrocarbon (hexan-1-ol, *ca* 8.5 %). A range of six cycloalkanes (*ca* 2.7 %) was also recognized in the essences and these are less common aroma volatiles than acyclic alkanes. Other hydrocarbons from aubergine include three sesquiterpenes (*ca* 1.1 %) and one monoterpene, car-3-ene, produced in relatively large amount (*ca* 3.5 %).

Seven aldehydes (*ca* 8.4 %) but only three alcohols (*ca* 10.6 %) were detected in the samples. Three chlorine-containing compounds (*ca* 2.4 %, 0.06 μg/kg) were identified, and these are assumed to be pesticide residues. Similarly, the fungicide biphenyl (*ca* 1.8 %, 0.04 μg/kg) was probably a residue originating from surface treatment of the fruit. However, the skins of the aubergines were

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Table 1. Volatile flavour components of aubergine (*Solanum melongena*)

Peak No.	Component	Retention time (min)	Kováts index (lit.)*	% relative abundance†	µg/kg edible part	Odour quality
1	Branched C_7 hydrocarbon	3.5	—	tr	tr	—
2	Heptane	3.8	700	5.1	0.12	—
3	Branched C_8 hydrocarbon	4.1	—	0.7	0.02	—
4	Dimethyl sulphide	4.3	—	4.6	0.11	sulphurous, cabbage-like
5	Branched C_8 hydrocarbon	4.8	—	21.5	0.52	—
6	Methylcyclohexane	5.0	—	tr	tr	—
7	Octane	5.3	800	5.3	0.13	—
8	A dimethylcyclohexane	5.8	—	0.9	0.02	—
9	A dimethylcyclohexane	6.1	—	0.7	0.02	—
10	A dimethylcyclohexane	6.9	—	0.5	0.01	—
11	Ethylcyclohexane	7.8	—	0.5	0.01	—
12	Dichloromethane	8.4	—	1.4	0.03	green, stale
13	A C_2 alkylfuran‡ plus benzene	9.1	*ca* 951 971	0.1	tr	—
14	Branched C_{10} hydrocarbon	10.5	—	0.6	0.01	—
15	Pentan-3-one plus pentanal	11.6	980 1002	0.5	0.01	horseradish, slightly pungent
16	Toluene	12.9	1056	5.6	0.14	sweet, buttery
17	Hexanal	13.7	1084	1.4	0.03	green
18	Unknown	14.2	—	tr	tr	—
19	*m*- and/or *p*-Xylene	15.1	1145	0.4	0.01	solvent
20	Car-3-ene	15.8	1165	3.5	0.08	aubergine
21	Heptanal	16.3	1186	3.3	0.08	nutty, hazelnuts
22	*o*-Xylene	16.6	1191	1.0	0.02	slightly estery
23	Unknown	17.1	—	tr	tr	—
24	Pentylfuran	17.3	1229	2.1	0.05	oily, flat, dull
25	Unknown	17.5	—	tr	tr	—
26	Tridecane	18.8	1300	0.5	0.01	slightly fragrant
27	Hexan-1-ol plus a C_3 alkylbenzene‡	19.4	1316	10.5	0.25	almonds
28	*cis*-Hex-3-en-1-ol	20.4	1351	0.8	0.02	estery, fragrant
29	Tetradecane	20.9	1400	tr	tr	—
30	An alkylcyclohexane	21.4	—	tr	tr	—
31	Unknown	21.9	—	0.6	0.01	dandelions
32	Furfural plus *o*-dichlorobenzene	22.6	1449	0.3	0.01	oil, fatty, stale
33	Pentadecane	23.5	1500	0.3	0.01	—
34	*m*-Dichlorobenzene	24.0	—	0.8	0.02	floral, fragrant
35	Benzaldehyde plus linalool	24.8	1502 1506	2.6	0.06	musty, mouldy
36	Hexadecane	26.5	1600	0.8	0.02	raw nuts
37	A hexadecene	27.3	—	0.1	tr	—
38	Unknown	28.0	—	tr	tr	slightly roasted
39	Acetophenone plus phenylacetaldehyde	28.8	1627 1646	2.1	0.05	floral, fragrant, wallflowers
40	Branched C_{17} hydrocarbon	29.3	—	1.3	0.03	roasted cereal
41	Bergamotene	30.0	—	0.2	tr	floral
42	? α-Humulene	30.3	1682	0.2	tr	putty
43	Heptadecane	31.0	1700	0.8	0.02	oily, fatty
44	Methylthiophencarboxaldehyde	32.9	—	0.9	0.02	dry hay
45	Bisabolene	34.0	1730	0.7	0.02	slight dandelion
46	Branched C_{18} hydrocarbon	34.3	—	0.5	0.01	hay
47	Octadecane	36.5	1800	2.6	0.06	sweet, floral, wet hay
48	Branched C_{19} hydrocarbon	40.5	—	1.9	0.05	cereal, grain-like
49	Nonadecane	44.1	1900	4.5	0.11	herbal, sickly
50	Biphenyl	46.0	—	1.8	0.4	floral, fragrant
51	Hydrocarbon	47.3	—	0.2	tr	hay
52	Hydrocarbon	50.0	—	1.0	0.02	fruity
53	Eicosane	54.4	2000	4.1	0.10	—
54	Hydrocarbon	56.3	—	tr	tr	—

*Lit. refers to refs. [3, 6].

†tr, Trace.

‡C_2 and C_3 signify the total number of carbon atoms in one or more substitutents.

rejected before analysis, so if this was the case then some penetration of the fungicide into the flesh must have occurred.

A relatively large amount (*ca* 4.6%) of the common aroma volatile, dimethyl sulphide, was identified, but the one other sulphur-containing compound, methylthiophencarboxaldehyde (*ca* 0.9%), is very much less common. From the mass spectra, the orientation of substituents is not certain, but it is probably 5-methylthiophen-2-carboxaldehyde, this type of compound being quite well-known as an aroma volatile of beef [7].

On odour evaluation of the (GC) separated components of the aubergine essences, only one compound was considered to have aubergine character and this was the monoterpene, car-3-ene. The total amount of volatiles produced by aubergine was *ca* 2.4 μg/kg. This is an extremely low concentration in comparison with other vegetables, e.g. ref. [8], and may partly account for the delicate flavour of aubergine.

EXPERIMENTAL

Aubergines were purchased fresh from local retailers as required. The purple-skinned type was used.

Sample preparation. After removal of the skin, the aubergine flesh (*ca* 550 g) was chopped, mixed with H_2O (600 ml) and extracted for 4 hr in a Likens and Nickerson apparatus [1], as modified by MacLeod and Cave [2], using 2-methylbutane (25 ml) as solvent. It was necessary to carry out the extraction × 4 (aubergine total 2113 g), using the same extractant, in order to obtain a sufficiently concd sample. Extracts were concd to 0.25 ml by low temp.–high vacuum distillation [2].

Gas chromatography. Samples were analysed by routine temp. programmed GC using a heated FID and a 5.5 m × 4 mm i.d. glass column packed with 10% Carbowax 20M coated on 100–120 BSS mesh acid-washed Diatomite C.

Gas chromatography/mass spectrometry. Components of the essences were identified by GC/MS (both EI and CI).

Odour assessment. Aromas of separated components were assessed at an odour port following GC. An outlet splitter set at 10:1 diverted the major fraction of the eluent through a heated line to the outside of the column oven for aroma assessment by three assessors. An injection vol. of 10 μl was necessary.

Quantitative assessment. Essences were prepared in such a manner that known aliquots of aubergine were analysed. Quantitative data were derived by peak area measurements both from the traces obtained from the TIC monitor during GC/MS and from the FID trace during routine GC. Known amounts of a selection of identified compounds (octane, toluene, hexanal, *cis*-hex-3-en-1-ol, hexadecane and biphenyl) were injected under the same analytical conditions, in order to enable calculation of absolute amounts of components in the essences.

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