Volatile Compounds Associated with the Fragrance and Flavour of Chaenomeles Juice

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SUMMARY

In this paper, volatile compounds associated with the fragrance and flavour of chaenomeles juice are reported for fruits of different taxa in the genus *Chaenomeles* (*C. japonica*, *C. speciosa*, *C. japonica* x *C. speciosa* and *C.* x *superba*). Thirty-three genotypes were investigated and sixty volatile compounds were identified. These compounds included thirteen terpenic hydrocarbons, fourteen alcohols, five ketones, fourteen aldehydes and fourteen esters. Samples of *C. japonica* had the richest aroma profile. Its major components were methanol, ethanol, 1-penten-3-ol, α-terpineol, acetone, ethyl-vinyl-ketone, varelaldehyde, (*E*)-2-hexenal, ethyl acetate, linalyl acetate, geranyl acetate and ethyl antranylate. Components that were identified in all the species and that could contribute to the fruity, sweet, floral and acid notes of chaenomeles fragrance and flavour were methanol, terpinen-4-ol, α-terpineol, dodecanol, carvone, nonanal, neral, perialdehyde, undecanal, octyl acetate, citronellyl acetate, neryl acetate, geranyl acetate, ethyl antranyllate, α-pinene, ß-myrcene, γ-terpinene, ß-caryophyllene and α-humulene. Principal differences among species could be attributed to some aldehydes, ketones and esters with high volatility found in *C. japonica*, but not in *C. speciosa*, *C. japonica* x *speciosa* and *C.* x *superba*.

INTRODUCTION

The fruits from various species within the genus *Chaenomeles* are appreciated because of their characteristic fragrance and flavour, which make them well suited for industrial processing (Lesinska *et al.* 1988, Rumpunen *et al.* 1998). The compounds contributing to the fragrance and flavour of chaenomeles fruits are considered similar to volatile compounds in apples and quince, and partly similar to volatile compounds in many citrus fruits (Lesinska *et al.* 1988). Based on the chemical composition and characteristics of the fruits, several products have been proposed and developed (Lesinska 1987, Rumpunen 1995, 2002). For instance, it is possible to produce chaenomeles juice, wine, purée and aroma-extracts. In Latvia and Lithuania, syrup, liqueur, carbonated soft drinks, marmalades and sweets flavoured with chaenomeles have been produced. Furthermore, a fruit sugar extract has recently proven to be excellent as a flavouring in ice cream.

In the United States, the market for drinks containing fruit juices has increased at a rate faster than sales of pure fruit juices (Brown 1995). In Europe, the food industry is continually looking for new flavours. New fruit crops with novel aromas are therefore in demand and can at the same time contribute to the diversification of agriculture. The fragrance and flavour expressed in chaenomeles juice and fruit

peel is unique, and therefore most interesting for a range of applications. Depending on their characteristics and composition, the fragrance and flavour of chaenomeles fruits could be interesting to the food, perfume, cosmetic and pharmaceutical industries.

The literature on volatile compounds associated with chaenomeles fragrance and flavour is scarce. Only Lesinska *et al.* (1988) have previously studied the volatile profile of a *Chaenomeles* species, *C. japonica* (Japanese quince). In the present investigation, we studied volatile compounds associated with flavour and fragrance in samples of fruits and juice from three species and two hybrid taxa in the genus *Chaenomeles*.

MATERIALS AND METHODS

Fruits

Mature chaenomeles fruits were obtained from plant breeding institutes in Sweden and Finland. Thirty-three genotypes of different *Chaenomeles* species and hybrids were sampled: *C. japonica* (sites D, F, NV and RG), *C. speciosa* (site RG), *C. japonica* x *C. speciosa* (site RG) and *C.* x *superba* (site RG). The letters (D, F, NV and RG) represent different test plots in the orchards where the plants were cultivated. The soil differed between test plots, in that the NV soil was sandier than the D and RG soils, which contained considerably more clay. The plants from which the fruits were sampled were grown from seed and planted in the field over a period of four years. Thus, the plants sampled were of different ages. However, all fruits of Japanese quince were sampled at the same developmental stage, when the fruit skin had turned yellow and the seeds had turned brown, indicating maturity. For the other taxa, which do not usually develop a completely yellow skin, sampling was carried out when the seed coat had turned brown. The fruits were then sent by surface transport to Spain for analysis. Background data on sampling sites of fruits and the genetic origin of plants are given in Table 1.

Extraction of juice

Fruits were fractionated into pulp, juice and seeds. The juice was extracted by halving and squeezing the fruit at room temperature (20 ± 2 ºC) using a Frutelia AV5 juice extractor from Moulinex (France). The juice was then analysed fresh.

Isolation of volatile compounds

The volatile compounds in chaenomeles juice headspace (HS) were extracted by solid-phase microextraction (SPME), and analysed by gas chromatography (GLC) and mass-spectrometry (GLC-

Table 1. Site for sampling of fruits, and origin of the *Chaenomeles* taxa studied.

Site[a]	Country	Taxon	Seed origin
NV	Sweden	*C. japonica*	orchard, crossing, Babtai, Lithuania
RG	Sweden	*C. japonica*	orchard, open pollination, Dobele, Latvia
RG	Sweden	*C. japonica*	orchard, open pollination, Babtai, Lithuania
D	Sweden	*C. japonica*	orchard, open pollination, Babtai, Lithuania
F	Finland	*C. japonica*	orchard, open pollination, Dobele, Latvia
RG	Sweden	*C. speciosa*	botanical garden, open pollination, Prague, Check Rep.
RG	Sweden	*C. japonica* x *C. speciosa*	orchard, open pollination, Dobele, Latvia
RG	Sweden	*C.* x *superba*	botanical garden, open pollination, Stuttgart, Germany

[a]Letters NV, RG and D represent different test plots at the Department of Horticultural Plant Breeding, Swedish University of Agricultural Sciences, Kristianstad (Sweden) and F represents a test plot at the Department of Plant Biology, University of Helsinki, Helsinki (Finland).

MS). In the SPME device, polydimethylsiloxane (PDMS) of 100 mm thickness was used as a polymeric coating. Solid-phase microextraction was carried out according to Steffen & Pawliszyn (1996) and Jia *et al.* (1998). To facilitate the extraction of polar constituents, one volume of juice sample was mixed with a half volume of saturated sodium chloride solution. The equilibrium time was reached after 45 minutes at room temperature (20 ± 2 ºC). At equilibrium the microfibre containing the extracted volatiles was introduced directly into the GLC and GLC-MS chromatographic systems.

Chromatographic analysis

The volatile compounds were analysed using a HP5890 Series II Plus gas chromatograph equipped with a flame ionisation detector (FID) and a HP5 capillary column (30 m x 0.25 mm inner diameter) with 0.25 mm film thickness of cross-linked 5% phenylmethylsiloxane. The oven temperature was programmed to start at 60 ºC for 4 min, then to increase at a speed of 1 ºC/min for 4 min and then to increase at a speed of 2.5 ºC/min to 155 ºC. The injector was kept at 250 °C and the detector at 275 °C. Helium was used as the carrier gas at a flow rate of 1ml/min. The samples were split at 100:1 during injection. For GLC-MS analysis, data were collected using a HP5972 MS detector coupled to a HP5890 Series II Plus gas chromatograph with the same column as described above. The flow of carrier gas was 1.3 ml/min and a split ratio of 16:1 was used. The column temperature was kept at 50 ºC for 2 min and then increased by 1.5 ºC/min to 85 °C and then increased by 2.5 °C/min to the final temperature of 160 ºC.

Data processing

Peaks were identified by comparison with mass spectra and Kovats retention index of authentic compounds. The concentration of each compound was calculated by the internal normalisation method. All results were then expressed as an average with standard deviation (SD) for each compound.

RESULTS AND DISCUSSION

The analysis of the volatile compounds in the headspace of fresh chaenomeles juice using SPME yielded a total of sixty identified and quantified compounds (Tables 2–6). HS-SPME is a technique based on the physico-chemical equilibrium among the three phases in the system: the sample matrix, the headspace and the fibre coating (Zhang & Pawliszyn 1993, 1995). The traditional fibre PDMS has very good stability and it is therefore the first fibre normally tested. The PDMS fibre has very high sensitivity for non-polar compounds, but less sensitivity for polar compounds (Roberts *et al.* 2000). It is therefore important to also take into account the affinity of the fibre for each volatile compound during analysis (Zhang *et al.* 1994).

Alcohols

Among the volatile compounds a total of fourteen alcohols were quantified (Table 2). Most alcohols were detected in samples of *C. japonica*. In this species methanol, ethanol and 1-penten-3-ol were present in the highest amounts. By contrast, the samples of *C. speciosa*, *C.* x *superba* and *C. japonica* x *C. speciosa* had a poorer profile. For *C. speciosa* and *C.* x *superba* only eight alcohols were detected and quantified, and for *C. japonica* x *C. speciosa* only seven. In *C. speciosa* and *C.* x *superba* methanol and 1-penten-3-ol were present in the highest amounts, whereas in *C. japonica* x *C. speciosa* the most abundant alcohols were methanol and ethanol. Differences in flavour and fragrance observed among species could be attributed to the different profile of alcohols revealed. Differences between *C. speciosa* and *C. japonica* could thus be attributed to the presence of ethanol, (*E*)-2-hexen-1-ol, heptanol, octanol and anethole in the profile of volatile compounds in *C. japonica*. Differences between *C. japonica* and *C.* x *superba* could be attributed to the absence of ethanol, (*E*)-2-hexen-1-ol, heptanol, nerol, citronellol and anethole. Finally, differences between *C. japonica* and *C. japonica* x *C. speciosa* could be attributed to 1-penten-3-ol, (*E*)-2-hexen-1-ol, heptanol, octanol, carveol and geraniol.

Table 2. Alcohols in samples of fresh chaenomeles juice (ppm ± SD).

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
Methanol	0.71 ±1.83	3.46 ±2.17	4.14 ±2.51	2.15 ±2.94	3.93	6.92	4.86
Ethanol	12.47 ±18.68	2.20 ±3.18	n.d.	13.76 ±10.82	n.d.	n.d.	2.47
1-Penten-3-ol	3.30 ±9.33	0.38 ±1.21	2.76 ±5.44	4.00 ±9.81	3.40	6.35	n.d.
Trans-2-hexen-1-ol	n.d.	0.06 ±0.10	0.02 ±0.04	0.03 ±0.07	n.d.	n.d.	n.d.
1-Heptanol	n.d.	n.d.	tr.	0.01 ±0.02	n.d.	n.d.	n.d.
Octanol	n.d.	0.01 ±0.01	tr.	0.01 ±0.02	n.d.	0.01	n.d.
Terpinen-4-ol	0.03 ±0.04	0.02 ±0.01	0.01 ±0.01	0.02 ±0.03	0.01	0.04	0.02
α-Terpineol	0.07 ±0.09	1.41 ±2.06	0.15 ±0.16	1.43 ±0.48	0.30	3.34	0.63
Nerol + Citronellol	0.07 ±0.12	0.45 ±1.21	0.24 ±0.58	0.07 ±0.06	0.01	n.d.	0.04
Carveol	0.03 ±0.08	0.02 ±0.03	0.02 ±0.04	0.12 ±0.22	0.50	2.11	n.d.
Geraniol	0.02 ±0.04	0.05 ±0.06	0.01 ±0.02	0.34 ±0.24	0.11	0.77	n.d.
Anethole	0.02	0.05 ±0.05	tr.	0.01 ±0.01	n.d.	n.d.	0.01
Dodecanol	0.01 ±0.01	0.02 ±0.02	0.02 ±0.02	0.01 ±0.01	0.03	0.01	0.01

Table 3. Aldehydes in samples of fresh chaenomeles juice (ppm ± SD).

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
Varelaldehyde	0.65 ±0.46	0.30 ±0.33	tr.	0.11 ±0.21	0.26	n.d.	n.d.
Hexanal	n.d.	0.05 ±0.08	0.01 ±0.01	0.01 ±0.01	n.d.	n.d.	n.d.
Furfural	n.d.	0.66 ±1.00	n.d.	n.d.	n.d.	n.d.	n.d.
Trans-2-hexenal	0.07 ±0.17	0.07 ±0.14	0.28 ±0.68	0.34 ±0.60	n.d.	n.d.	n.d.
Heptanal	n.d.	n.d.	n.d.	0.02 ±0.03	n.d.	n.d.	n.d.
Octanal	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.
Nonanal	0.01 ±0.01	0.01 ±0.01	0.01 ±0.01	0.01 ±0.01	tr.	0.05	0.01
Citronellal	0.01 ±0.02	0.02 ±0.03	0.02 ±0.03	0.01 ±0.02	n.d.	n.d.	n.d.
Decanal	tr.	tr.	tr.	n.d.	n.d.	0.01	tr.
Neral	tr.	0.16 ±0.47	0.01 ±0.01	0.01 ±0.02	0.02	0.03	tr.
Geranial	0.02 ±0.02	0.03 ±0.06	0.05 ±0.05	0.05 ±0.02	0.01	0.03	n.d.
Perialdehyde	0.02 ±0.02	0.01 ±0.02	0.02 ±0.04	0.03 ±0.04	0.03	0.05	0.01
Undecanal	0.01 ±0.01	0.01 ±0.02	0.01 ±0.02	0.01 ±0.01	tr.	0.03	tr.
Dodecanal	0.04 ±0.04	0.16 ±0.20	0.13 ±0.15	0.06 ±0.10	0.01	0.01	n.d.

Table 4. Ketones in samples of fresh chaenomeles juice (ppm ± SD).

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
Acetone	0.19 ±0.55	0.47 ±0.55	3.05 ±6.07	0.91 ±1.38	n.d.	n.d.	0.84
Methyl-vinyl-ketone	n.d.	n.d.	0.14 ±0.35	n.d.	n.d.	n.d.	n.d.
Ethyl-vinyl-ketone	4.92 ±8.82	5.22 ±5.92	6.88 ±7.62	0.96 ±1.86	n.d.	n.d.	1.06
Carvone	0.09 ±0.20	0.05 ±0.06	0.04 ±0.08	0.05 ±0.04	0.03	0.08	0.12
β-Ionone	0.01	0.01 ±0.01	0.01 ±0.01	0.01 ±0.01	n.d.	n.d.	0.01

Aldehydes

Similar results were obtained for aldehydes as for alcohols. A total of fourteen aldehydes were identified and quantified in the chaenomeles fresh juice (Table 3). *C. japonica* had the richest profile of aldehydes, of which valeraldehyde was present in the highest amount. By contrast, only seven, seven and five aldehydes were quantified for *C. speciosa*, *C.* x *superba* and *C. japonica* x *C. speciosa*, respectively.

The aldehydes are considered to be the most important contributors to the floral and fruity aroma of the chaenomeles fruits. Therefore it is noteworthy that for samples of *C.* x *superba* and *C. japonica* x *C. speciosa*, the most volatile aldehydes were not present in the profile of aldehydes. As previously mentioned for alcohols, the aldehydes from valeraldehyde to octanal and citronellal could also contribute to the different aroma perceived among fruits from the different species.

Ketones

In general, ketones are less abundant in the profile of volatile compounds in fruits. However, a total of five and four ketones (Table 4) were quantified in *C. japonica* and *C. japonica* x *C. speciosa*, respectively. Of the ketones, ethyl-vinyl-ketone and acetone were present in the highest amounts. As previously noticed for alcohols and aldehydes, *C. speciosa* and *C.* x *superba* presented a poorer profile, since only carvone was identified as part of their profile of volatile compounds.

Esters

Fourteen esters associated with floral notes of the fragrance and flavour were identified and quantified from the headspace of chaenomeles juice (Table 5). Octyl acetate, citronellyl acetate, neryl acetate, geranyl acetate and ethyl antranylate can be considered important contributors to the chaenomeles fragrance and flavour, since these esters were identified in all the species and in every taxa analysed. For esters too, *C. japonica* proved to be the richer source compared to *C. speciosa*, *C.* x *superba* and *C. japonica* x *C. speciosa*. The major esters quantified in *C. japonica* were ethyl acetate, linalyl acetate, geranyl acetate and ethyl antranylate. Ethyl acetate, considered to be an important component of the fruity aroma, was not detected in *C.* x *superba*. Linalyl acetate, being a major component of the *C. japonica* aroma profile, was not identified in *C. speciosa* and *C.* x *superba*. Principal differences between *C. japonica* on the one hand, and *C. speciosa* and *C.* x *superba* on the other, could be attributed to methyl butyrate, ethyl caproate,

Table 5. Esters in samples of fresh chaenomeles juice (ppm ± SD).

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
Ethyl acetate	0.80 ±1.27	0.17 ±0.34	0.52 ±1.16	4.18 ±2.48	1.30	n.d.	0.08
Methyl butyrate	n.d.	0.02 ±0.04	0.16 ±0.39	n.d.	n.d.	n.d.	n.d.
Ethyl caproate	0.03	0.03 ±0.03	0.03 ±0.01	0.04 ±0.04	n.d.	n.d.	n.d.
Bencyl acetate	n.d.	0.02 ±0.02	tr.	0.02 ±0.03	n.d.	n.d.	0.03
Ethyl caprylate	0.11	0.13 ±0.10	0.05 ±0.08	0.05 ±0.02	n.d.	n.d.	0.09
Octyl acetate	tr.	0.03 ±0.03	tr.	0.01 ±0.01	tr.	tr.	0.01
Linalyl acetate	0.05 ±0.11	0.19 ±0.24	0.06 ±0.07	0.23 ±0.46	n.d.	n.d.	0.01
Terpenyl acetate	0.03 ±0.03	0.04 ±0.07	0.02 ±0.04	0.17 ±0.38	0.03	0.06	n.d.
Citronellyl acetate	0.01 ±0.01	0.02 ±0.03	0.02 ±0.04	0.02 ±0.02	0.01	0.05	tr.
Neryl acetate	0.02 ±0.02	0.02 ±0.03	0.03 ±0.04	0.04 ±0.03	0.03	0.08	tr.
Geranyl acetate	0.09 ±0.06	0.09 ±0.08	0.07 ±0.06	0.28 ±0.20	0.05	0.15	0.02
Buthyl caprylate	n.d.	tr.	tr.	0.01 ±0.01	n.d.	n.d.	n.d.
Ethyl antranylate	0.29 ±0.21	0.43 ±0.44	0.11 ±0.06	0.30 ±0.26	0.14	0.80	0.11
Sebacate	n.d.	0.01 ±0.01	0.01 ±0.01	n.d.	n.d.	n.d.	0.01

bencyl acetate, ethyl caprylate, linallyl acetate, butyl caprylate and sebacate. It was also noticed that *C. japonica* x *C. speciosa* had a richer ester profile than *C. speciosa* and *C.* x *superba*. The differences in fragrance and flavour between *C. japonica* and *C.* x *superba* could be attributed to methyl butyrate, ethyl caproate, terpenyl acetate and butyl caprylate.

Terpenic hydrocarbons

Although thirteen terpenic hydrocarbons were identified in the headspace of fresh chaenomeles juice (Table 6), these components were present in comparatively small quantities (Table 7). The contribution of the terpenic hydrocarbons to the flavour is normally related to a balsamic and a woody aroma. Terpenic hydrocarbons are present in many fruit juices, especially in citrus juices. Of the terpenic hydrocarbons, α-pinene, ß-myrcene, ß-caryophyllene and α-humulene are the most important contributors to the fragrance and flavour of chaenomeles since they were detected in samples of all the species studied. Among the species, *C. japonica* was the richest in terpenic hydrocarbons. In every genotype of *C. japonica*, α-pinene, ß-pinene, ß-myrcene, α-phellandrene, D-limonene, terpinolene, ß-caryophyllene, α-humulene and valencene were detected and quantified. Therefore, these terpenic hydrocarbons are considered to be important contributors to the fragrance and flavour of this species. *C. speciosa*, *C.* x *superba* and *C. japonica* x *C. speciosa* had a poorer profile of terpenic hydrocarbons, yielding a total of eight, nine, and nine compounds, respectively. Principal differences among species could be attributed to sabinene, α-terpinene, terpinolene and valencene.

Perspectives

The total amounts of volatile compounds, grouped into chemical classes, are given in Table 7. Genotypes of *C. japonica* revealed a similar but not identical profile of volatiles depending on sampling site. In general, alcohols (39–73%), ketones (6–53%) and esters (6–18%) were the major components, with the total amount ranging from 17 ppm (site RG) to 30 ppm (site F). In the samples of *C.* x *superba,* alcohols represented 92% of the volatiles with a total amount of 21 ppm, which is of the same order as for *C. japonica*. In this respect *C. speciosa* was an exception, with both a poorer profile of volatiles and a lower quantity (10 ppm in total).

Lesinska *et al.* (1988) have reported a total of twenty volatile compounds in *C. japonica*, of which alcohols and esters were the major volatile components identified. Our results are in agreement with

Table 6. Terpenic hydrocarbons in samples of fresh chaenomeles juice (ppm ± SD).

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
α-Pinene	tr.	tr.	tr.	tr.	tr.	0.01	0.01
Sabinene	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	0.01
β-Pinene	tr.	0.01 ±0.01	0.01 ±0.01	tr.	0.01	0.02	n.d.
β-Myrcene	tr.	0.01 ±0.01	tr.	0.02 ±0.01	0.01	0.07	0.01
δ3-Carene	n.d.	0.08 ±0.10	0.01 ±0.01	0.01 ±0.01	n.d.	0.01	0.05
α-Phellandrene	tr.	0.01 ±0.01	0.01 ±0.01	0.02 ±0.01	tr.	n.d.	0.02
α-Terpinene	n.d.	tr.	n.d.	tr.	n.d.	0.01	n.d.
D-Limonene	tr.	0.01 ±0.01	tr.	0.01 ±0.02	0.01	0.12	n.d.
γ-Terpinene	n.d.	tr.	tr.	tr.	tr.	0.01	tr.
Terpinolene	tr.	0.01 ±0.01	tr.	0.02 ±0.02	n.d.	n.d.	n.d.
β-Caryophyllene	0.05 ±0.08	0.01 ±0.01	0.02 ±0.04	0.02 ±0.02	0.01	0.01	0.01
α-Humulene	0.02 ±0.01	0.10 ±0.01	0.01 ±0.01	0.03 ±0.05	0.02	0.02	0.02
Valencene	0.01 ±0.01	0.01 ±0.02	tr.	tr.	n.d.	n.d.	0.05

Table 7. Total amount of volatile compounds (ppm) in samples of fresh chaenomeles juice reported in chemical classes.

	C. japonica				*C. speciosa*	*C.* x *superba*	*C. japonica* x *C. speciosa*
	NV (*n*=8)	RG (*n*=10)	D (*n*=6)	F (*n*=6)	RG (*n*=1)	RG (*n*=1)	RG (*n*=1)
Alcohols	16.73	8.13	7.37	21.96	8.29	19.55	8.04
Aldehydes	0.83	1.48	0.54	0.66	0.33	0.21	0.02
Ketones	5.21	5.75	10.12	1.93	0.03	0.08	2.03
Esters	1.43	1.20	1.08	5.35	1.56	1.14	0.36
Terpenic hydrocarbons	0.08	0.25	0.06	0.13	0.06	0.28	0.18
Total	24.28	16.81	19.17	30.03	10.27	21.26	10.63

these data, but it is important to highlight the presence of aldehydes, ketones and terpenic hydrocarbons, which were not identified by Lesinska *et al.* (1988). These components contribute floral, fruity, balsamic and woody notes to the unique fragrance and flavour of chaenomeles juice.

The volatile aroma profile revealed for *C. speciosa* was totally different to the profile published by Horvart *et al.* (1994), and no other of our samples matched Horvart's '*C. speciosa*'. This could be due to large genotypic differences, large environmental interaction or even mislabelling of species, since the nomenclature within the genus *Chaenomeles* has long been confusing.

The fragrance and flavour of chaenomeles seem to be related to the fragrance and flavour of other scenting quince fruits, including true quince (*Cydonia oblonga*) and *Pseudocydonia sinensis*. However, a systematic and rigorous comparison between volatile compounds of *Chaenomeles* species and those of other species would be an enormous task, well beyond the scope of this investigation. Since this kind of comparison may be of interest, however, we suggest a single comparison with major volatile compounds in *e.g.* orange juice. A comparison could be based on the presence of 1-heptanol, octanol, linalool, terpinen-4-ol, α-terpineol, octanal, acetone, ethyl acetate, α-pinene, sabinene, ß-mircene, α-phellandrene, α-terpinene, limonene, γ-terpinene and valencene (Shaw *et al.* 1993, Moshonas & Shaw 1994, 1995, 1997a, 1997b, Tonder *et al.* 1998, Laencina *et al.* 1999, Jordan *et al.* 2001).

Within the near future, it would be interesting to optimise on a large scale a method for extraction of chaenomeles flavour, looking for its industrial applications. For this purpose adsorption (Parliment 1981), solvent extraction, distillation (Parliment 1997) and various membrane technologies (Paulson *et al.* 1985, Koseouglu *et al.*, 1990, Kane *et al.* 1995) should be studied.

CONCLUSION

All species within the genus *Chaenomeles* produce aromatic fruits rich in volatile compounds. Among the species studied, *C. japonica* yielded the richest profile of volatile compounds associated with chaenomeles fragrance and flavour. Alcohols and esters constituted the major fractions quantified. Principal differences between the fragrance and flavour of *C. japonica* on the one hand, and *C. speciosa*, *C.* x *superba* and *C. japonica* x *C. speciosa* on the other, could be attributed to aldehydes, ketones and esters of high volatility.

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