# Characteristics and Composition of Chaenomeles Fruit Juice

P. Hellín[a], R. Vila[a], M.J. Jordán[a], J. Laencina[a], K. Rumpunen[b], J.M. Ros[a]*

[a]Department of Food Science and Technology and Human Nutrition, University of Murcia, Murcia, Spain
[b]Balsgård–Department of Horticultural Plant Breeding, Swedish University of Agricultural Sciences, Kristianstad, Sweden

*Correspondence to jmros@um.es

## SUMMARY

In this paper, characteristics and chemical composition of chaenomeles fruit juice are reported for different taxa in the genus *Chaenomeles* (*C. japonica*, *C. speciosa*, *C. cathayensis*, *C. japonica* x *C. speciosa*, and *C.* x *superba*). Average fruit weight was 27–211 g and the juice yield was 42–50% based on fresh weight of fruits. The chaenomeles juice was very acidic, with a pH of 2.5–2.8, and the titratable acidity was at most 4.2% calculated as anhydrous citric acid. The content of vitamin C and phenols was in general high, 45–109 mg ascorbic acid and 210–592 mg phenol per 100 ml juice, respectively. Three main organic acids were detected in the juice: malic acid, quinic acid and succinic acid. Of the organic acids malic acid was present in the highest amount, at most 5.1 g/100 ml. Ten amino acids were detected: phosphoserine, aspartic acid, threonine, serine, asparagine, glutamic acid, alanine, phenyalanine, γ-aminobutyric acid and lysine. The most abundant amino acid was glutamic acid (up to 14 mg/100 ml), followed by phosphoserine and aspartic acid (6 mg/100 ml). Five cations were detected: sodium, ammonium, potassium, magnesium and calcium. Of the cations, potassium was present in the highest amount (up to 241 mg/100 ml). Two inorganic anions were present in high amounts: fluoride (up to 139 mg/100 ml) and chloride (9 mg/100 ml). Nine carbohydrates were detected: stachyose, raffinose, sucrose, glucose, xylose, rhamnose, fructose, inositol and sorbitol. Of the carbohydrates, fructose (up to 2.3 g/100 ml), glucose (up to 1.1 g/100 ml) and sorbitol (up to 0.5 g/100 ml) were present in the highest amounts. Due to its characteristics and composition, chaenomeles juice is considered a potential source of valuable compounds and an interesting ingredient for the food industry.

## INTRODUCTION

Japanese quince (*Chaenomeles japonica*) is an East Asian dwarf shrub, with interesting potential as a fruit crop. The scenting yellow fruits are rich in flavour, juice and fibre (Lesinska *et al.* 1988, Thomas *et al.* 2000, Thomas & Thibault 2002). They are very firm and too acidic to be consumed fresh (Rumpunen *et al.* 2000), but useful after processing. Japanese quince is currently being domesticated and introduced as a fruit crop in Northern Europe (Rumpunen 2002). Besides Japanese quince, the genus *Chaenomeles* (Rosaceae) comprises three more species: *C. cathayensis*, *C. speciosa* and *C. thibetica*. These species are, however, less adapted to the North European climate but may be useful as donors of valuable traits in plant breeding aimed at improving Japanese quince as a fruit crop.

Chaenomeles juice could be a useful ingredient for the food industry due to its flavour, high acidity and clear nature. Another property of great interest is its presumed high antioxidant capacity, due to the content of vitamin C and phenolic compounds. Thus, the juice may be used as an acidifying agent with antioxidant properties in various products. However, only a few scientific papers have been found in which some data on chaenomeles fruit biochemistry are reported (Lesinska 1987, Lesinska *et al.* 1988, Golubev *et al.* 1991, Rumpunen 1995). Therefore, the characteristics and chemical composition of chaenomeles fruits and its juice were studied. Japanese quince was the main focus, but a few samples of other taxa in the genus *Chaenomeles* were also included in the study.

## MATERIALS AND METHODS

### Fruit samples

Mature chaenomeles fruits were obtained from breeding institutes in Sweden, Finland and Latvia. Background data on sites for sampling of fruits and the genetic origin of plants are given in Table 1. Several genotypes of different *Chaenomeles* taxa were sampled: *C. japonica* (sites C, D, F, NV and RG), *C. speciosa* (site RG), *C. cathayensis* (site RG), *C. japonica* x *C. speciosa* (site RG) and *C.* x *superba* (site RG). The letters (C, D, F, NV and RG) represent different test plots in the orchards where the plants were cultivated and fruits sampled. 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 seeds, and planted in the field during 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 seed coat had turned brown, indicating maturity. For the other taxa, which did 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.

### Fruit characteristics

Fruit colour was measured using a Minolta CR 200 triestimule colorimeter. Measures were expressed as L*, a* and b* parameters (Abbott 1999). The colour measurement was carried out at least on three different parts of the fruit skin. Water activity of the fruits was measured with a Novasina Sprint model apparatus (Pfäffikon, Switzerland).

### Fruit fractionation

Fruits were fractionated into pulp, juice and seeds. The juice was extracted by halving and squeezing the fruit. For this purpose, a Frutelia AV5 juice extractor from Moulinex (France) was used, and chaenomeles juice was then analysed fresh.

### Physico-chemical analysis of juice

Characteristics of chaenomeles juice studied were pH, density, soluble solids, viscosity, turbidity, insoluble solids, titratable acidity, proteins and the content of vitamin C and phenolic compounds. These parameters were determined following the methods of the International Federation of Fruit Juice Producers, the Association of Official Analytical Chemists and others (Singleton & Rossi 1965, Ros *et al.* 1995, Antolovich *et al.* 2000). The samples were analysed in triplicate.

### HPLC analysis

Samples of juice were centrifuged (14.000 r.p.m. x 5 min) and directly injected for HPLC analysis. Organic acids, amino acids, inorganic cations/anions and carbohydrates were analysed as described below. Quantitative estimates were obtained using external standards.

**Organic acids**

Organic acids were separated in an Interaction ORH-801 column with an ORH-801 guard column (Interaction, San José, CA, USA), using 5 mM sulphuric acid as eluent. Organic acids were detected by spectrophotometry at 210 nm UV. For separation, an isocratic flow rate of 0.6 ml/min was used and the column was kept at room temperature (Hellín *et al.* 2001). The identity of the detected acids was confirmed with a diode array detector.

**Amino acids**

Amino acids were separated in an Ultropac 7 Cation Exchange Resin column (Pharmacia, Uppsala, Sweden) using a gradient buffer of increasing ionic strength as eluent. Amino acids were detected by spectrophotometry after post-column ninhydrine derivatisation.

**Inorganic cations and anions**

Inorganic cations were separated in an IonPac CS column (Dionex, Sunnyvale, CA, USA) using a water/methane-sulphonic acid gradient as eluent. The inorganic cations were detected by conductivity. For separation, a flow rate of 1.0 ml/min was used and the column was kept at room temperature. Inorganic anions were separated in an IonPac AS column (Dionex, Sunnyvale, CA, USA) using a sodium carbonate/sodium bicarbonate gradient as eluent. The inorganic anions were detected by conductivity. For separation, a flow rate of 1.5 ml/min was used and the column was kept at room temperature.

**Carbohydrates**

Carbohydrates were separated in an Interaction CHO-682 column with a CHO-682 guard column (Interaction, San José, CA, USA) using high quality water as eluent. Carbohydrates were detected by refractive index detection (RID). An isocratic flow rate of 0.4 ml/min was used and the column was kept at 85 ºC (Hellín *et al.* 2001).

**Polysaccharides**

Polysaccharides were investigated by HPSEC in three Ultrahydrogel columns connected in series (500, 250, 120) with an Ultrahydrogel guard column (Waters, Milford, MA, USA). As eluent 0.4 M sodium acetate (pH 3.0) was used at an isocratic flow rate of 0.8 ml/min. Polysaccharides were detected using

**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 |
| C | Latvia | *C. japonica* | orchard, open pollination, Dobele, Latvia |
| RG | Sweden | *C. speciosa* | botanical garden, open pollination, Prague, Czech Rep. |
| RG | Sweden | *C. cathayensis* | botanical garden, open pollination, Prague, Czech 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), F represents a test plot at the Department of Plant Biology, University of Helsinki, Helsinki (Finland) and C represents a test plot at Dobele State Horticulture Plant Breeding Experimental Station, Dobele (Latvia).

refractive index detection (RID), and the column was kept at room temperature (Ros *et al.* 1996a, Hellín *et al.* 2001).

**Statistics**
All results are presented with average and standard deviation (SD) of samples for each site and taxon, respectively.

## RESULTS AND DISCUSSION

**Fruit characteristics**
The unitary weight of fruits differed between the species studied. *C. cathayensis* had the biggest fruits, with an average weight of 211 g, and *C. japonica* (sampled at site F), had the smallest fruits, with an average weight of 27 g (Table 2).

The characteristic colour of the fruits was yellow, represented by the parameter b* with a value from 42 to 58, whereas the range of colour parameters L* and a* was from 55 to 63 and from -4 to 6, respectively (Table 2).

All chaenomeles fruits analysed had a water activity of 0.98–0.99, in accordance with their fresh fruit nature.

**Fruit fractionation**
Juice was the main fraction (42–50%, Table 3) obtained by the simple Moulinex Frutelia juice extractor. The residual pulp fraction constituted 40–47% and a rather large seed fraction constituted 5–9%. It should be remembered that the yield of juice is dependent on the apparatus and extraction method employed. The yield would probably have been larger if stronger physical methods and various enzymes had been used for juice extraction. Using the same extractor, we obtained 55–60% apple juice and about 45% carrot juice. For comparison the reported juice yield from oranges is 50–55% and that for lemons is slightly lower (Kimball 1999).

The large residual pulp fraction of chaenomeles fruits was rich in polysaccharides, particularly in cellulose and pectins, of which galacturonic acid constituted a significant part (Thomas *et al.* 2000,

**Table 2.** Characteristics of chaenomeles fresh fruits: weight and colour (L*, a*, b*).

| Site | Samples[a] (*n*) | Weight (*x* g ± SD) | Colour (L* ± SD) | Colour (a* ± SD) | Colour (b* ± SD) |
|---|---|---|---|---|---|
| *C. japonica* | | | | | |
| NV | 11 | 45.5 ± 13.4 | 60.5 ± 2.1 | 3.0 ± 2.7 | 54.1 ± 2.3 |
| RG | 13 | 39.0 ± 11.8 | 58.7 ± 3.2 | 5.9 ± 3.5 | 50.6 ± 5.6 |
| D | 11 | 45.3 ± 9.4 | 62.6 ± 2.0 | 2.5 ± 1.9 | 55.4 ± 5.7 |
| F | 10 | 27.4 ± 7.9 | 59.3 ± 3.6 | -0.2 ± 2.3 | 52.5 ± 5.7 |
| C | 9 | 57.7 ± 9.4 | 55.0 ± 2.5 | 5.2 ± 4.3 | 44.3 ± 8.5 |
| *C. speciosa* | | | | | |
| RG | 4 | 133.3 ± 77.6 | 58.9 ± 2.4 | -3.8 ± 9.0 | 42.5 ± 4.9 |
| *C. cathayensis* | | | | | |
| RG | 4 | 211.1 ± 111.2 | 59.3 ± 4.2 | -1.3 ± 8.3 | 44.8 ± 9.1 |
| *C. japonica* x *C. speciosa* | | | | | |
| RG | 2 | 69.0 ± 12.7 | 61.7 ± 2.4 | -3.6 ± 8.1 | 57.7 ± 4.5 |
| *C.* x *superba* | | | | | |
| RG | 1 | 102.0 | 59.4 | 0.0 | 41.7 |

[a]Number of genotypes analysed

**Table 3.** Fractions of seed, pulp and juice (expressed as % fresh weight) obtained by processing of chaenomeles fruits.

| Site | Samples[a] ($n$) | Seed ($x$ % ± SD) | Pulp ($x$ % ± SD) | Juice ($x$ % ± SD) | Yield ($x$ % ± SD) |
|---|---|---|---|---|---|
| *C. japonica* | | | | | |
| NV | 19 | 7 ± 1 | 42 ± 5 | 48 ± 5 | 97 ± 2 |
| RG | 24 | 8 ± 2 | 45 ± 4 | 44 ± 6 | 97 ± 2 |
| D | 14 | 5 ± 2 | 42 ± 4 | 50 ± 4 | 97 ± 1 |
| F | 21 | 9 ± 3 | 45 ± 8 | 43 ± 9 | 97 ± 1 |
| C | 11 | 6 ± 1 | 42 ± 5 | 50 ± 5 | 98 ± 1 |
| *C. speciosa* | | | | | |
| RG | 5 | 8 ± 4 | 44 ± 5 | 43 ± 6 | 95 ± 3 |
| *C. cathayensis* | | | | | |
| RG | 7 | 5 ± 2 | 43 ± 7 | 42 ± 6 | 90 ± 9 |
| *C. japonica* x *C. speciosa* | | | | | |
| RG | 2 | 7 ± 1 | 40 ± 0 | 49 ± 2 | 96 ± 1 |
| *C.* x *superba* | | | | | |
| RG | 1 | 6 | 47 | 42 | 95 |

[a]Number of genotypes analysed

Thomas & Thibault 2002). The pulp can therefore be considered an interesting fibre and pectin source. The pulp could also be useful in production of bioactive carbohydrates of an oligomeric and polymeric nature (Ros *et al.* 1996b, 1998, 2000, Roberfroid 1999, Samuelsen 2000, Yamada 2000). Another application could be as a substrate for microorganisms and production of polysaccharide hydrolases (Hellín *et al.* 1998, 2001). Finally, the most obvious use of the fruit fibre is as a healthy food ingredient (Carson *et al.* 1994, Yamada 1996).

**Juice characteristics**

Chaenomeles juice had a rather low pH of 2.5–2.8 (Table 4). For comparison, apple juice has a pH of 3.5–3.8 (Lea 1995), orange juice 3.3–3.8, grapefruit juice 2.8–3.0, and lemon juice 2.0–2.3 (Primo 1982). The pH of grape juice varies between 3 and 4, depending on variety, weather and soil (McLellan & Race 1995).

The low pH of chaenomeles juice was accompanied by a high acidity, 2.8–4.2% calculated as citric acid (Table 4). For comparison, the titratable acidity for apple juice is 0.2–0.7% (Lea 1995), for grape juice 1.0% (McLellan & Race 1995), for orange juice 0.5–3.5%, for grapefruit juice 1.5–5.0% and for lemon juice 5.0–9.0% (Primo 1982, Hendrix & Redd 1995).

The density (1.025–1.033 g/ml) and viscosity (0.945–1.230 cp) of chaenomeles juice did not vary very much among samples (Table 4) and was just somewhat lower than the density of apple juice (1.049 g/ml, Lea 1995).

The content of soluble solids in chaenomeles juice was 7–9 ºBrix (Table 4). This is similar to the content of soluble solids in lemon juice (8–10 °Brix), but lower than that in orange juice (9–15 ºBrix), grapefruit juice (6–12 °Brix) (Primo 1982, Hendrix & Redd 1995), and apple juice (11–14 ºBrix) (Dever *et al.* 1991, Lea 1995). The content of soluble solids in grape juice could be twice as high as that in chaenomeles juice, reaching 20 °Brix (McLellan & Race 1995).

For chaenomeles juice estimates of turbidity were lower than 400 NTU, corresponding to clear juices. For comparison, a typical cloudy orange juice has a turbidity of around 3500 NTU. The amount of insoluble solids (the juice residual pulp) differed considerably among samples, with estimates from 1.7 to 8.3% (Table 4). The protein content was 33–70 mg BSA/100 ml of juice (Table 4).

**Table 4.** pH, density, soluble solids, viscosity and turbidity of fresh chaenomeles juice.

| Site | Samples[a] ($n$) | pH ($x$ ± SD) | Density ($x$ g/ml ±SD) | Soluble solids ($x$ °Brix ± SD) | Viscosity ($x$ cp ± SD) | Turbidity ($x$ NTU ± SD) |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 19 | 2.5 ± 0.1 | 1.025 ± 0.004 | 7.0 ± 1.1 | 1.094 ± 0.048 | 91 ± 86 |
| RG | 18 | 2.6 ± 0.1 | 1.030 ± 0.004 | 8.1 ± 0.6 | 1.209 ± 0.129 | 54 ± 40 |
| D | 12 | 2.5 ± 0.1 | 1.027 ± 0.003 | 7.4 ± 0.7 | 1.098 ± 0.169 | 82 ± 52 |
| F | 21 | 2.6 ± 0.1 | 1.033 ± 0.003 | 9.0 ± 0.7 | 1.097 ± 0.133 | 354 ±309 |
| C | 9 | 2.7 ± 0.1 | 1.029 ± 0.003 | 7.5 ± 0.7 | 0.945 ± 0.350 | 335 ±378 |
| *C. speciosa* | | | | | | |
| RG | 3 | 2.6 ± 0.3 | 1.028 ± 0.003 | 8.8 ± 0.2 | 1.170 | 44 ± 52 |
| *C. cathayensis* | | | | | | |
| RG | 4 | 2.7 ± 0.2 | 1.028 ± 0.005 | 8.6 ± 1.2 | 1.230 | 33 ± 48 |
| *C. japonica* x *C. speciosa* | | | | | | |
| RG | 1 | 2.7 | 1.033 | 8.4 | 1.210 | 9 |
| *C.* x *superba* | | | | | | |
| RG | 1 | 2.8 | 1.030 | 9.0 | | 5 |

[a]Number of genotypes analysed

## Vitamin C and phenolic compounds

In chaenomeles juice high amounts of vitamin C and phenolic compounds were detected (Table 5). The content of vitamin C was 45–109 mg as ascorbic acid/100 ml. For comparison, the content of vitamin C in orange juice is 25–80 mg/100 ml, in grapefruit juice 25–60 mg/100 ml and in lemon juice 30–70 mg/100 ml (Primo 1982, Hendrix & Redd 1995, Lee & Coates 1999). The vitamin C content in apple juice is very low, 0.07 mg/100 ml (Gardner *et al.* 2000). Among the taxa studied, samples of *C. cathayensis*, *C. speciosa* and *C.* x *superba* had the highest amounts of vitamin C (100–109 mg/100 ml). Ascorbic acid was not found by HPLC analysis, suggesting that all vitamin C is in the dehydroascorbic acid form. This

**Table 5.** Insoluble solids, titratable acidity (as anhydrous citric acid), proteins (as BSA), vitamin C (as ascorbic acid) and phenols (as phenol) in fresh chaenomeles juice.

| Site | Samples[a] ($n$) | Insoluble solids ($x$ % ± SD) | Titratable acidity ($x$ % ±SD) | Proteins ($x$ mg/100 ml ± SD) | Vitamin C ($x$ mg/100 ml ± SD) | Phenols ($x$ mg/100 ml ± SD) |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 19 | 8.3 ± 3.0 | 3.5 ± 0.7 | 32.6 ± 3.8 | 67.1 ± 26.0 | 228.2 ± 47.1 |
| RG | 18 | 8.1 ± 5.2 | 4.0 ± 0.5 | 42.5 ± 4.9 | 78.5 ± 40.8 | 254.1 ± 47.6 |
| D | 12 | 5.6 ± 3.3 | 3.8 ± 0.4 | 42.0 ± 2.0 | 63.9 ± 17.1 | 278.8 ± 42.4 |
| F | 21 | 5.2 ± 2.5 | 4.0 ± 1.0 | 58.7 ± 10.0 | 45.3 ± 18.0 | 459.2 ± 110.7 |
| C | 9 | 1.7 ± 0.9 | 3.2 ± 0.6 | | 66.3 ± 23.3 | 209.6 ± 54.5 |
| *C. speciosa* | | | | | | |
| RG | 3 | 5.8 ± 2.6 | 4.2 ± 0.9 | 70 | 101.8 ± 86.8 | 367.3 ± 118.1 |
| *C. cathayensis* | | | | | | |
| RG | 4 | 4.3 ± 1.3 | 2.8 ± 0.2 | 60 | 102.8 ± 86.8 | 591.5 ± 138.9 |
| *C. japonica* x *C. speciosa* | | | | | | |
| RG | 1 | 6.0 | 4.1 | | 75.0 | 483.0 |
| *C.* x *superba* | | | | | | |
| RG | 1 | 4.0 | 3.1 | | 109.0 | 353.0 |

[a]Number of genotypes analysed

**Table 6.** Content of organic acids in fresh chaenomeles juice.

| Site | Samples[a] ($n$) | Malic acid ($x$ g/100 ml ± SD) | Quinic acid ($x$ g/100 ml ± SD) | Succinic acid ($x$ mg/100 ml ± SD) |
|---|---|---|---|---|
| *C. japonica* | | | | |
| NV | 9 | 3.18 ± 0.58 | 1.14 ± 0.58 | 9.98 ± 5.39 |
| RG | 10 | 3.58 ± 1.05 | 0.93 ± 0.62 | 9.23 ± 4.60 |
| D | 6 | 4.22 ± 1.03 | 1.21 ± 0.21 | 8.20 ± 3.22 |
| F | 6 | 4.22 ± 0.91 | 1.25 ± 0.46 | 21.43 ± 6.46 |
| *C. speciosa* | | | | |
| RG | 1 | 3.19 | 2.27 | 174.00 |
| *C. cathayensis* | | | | |
| RG | 1 | 5.09 | 1.70 | 52.50 |
| *C. japonica* x *C. speciosa* | | | | |
| RG | 1 | 3.06 | 0.62 | 27.10 |

[a]Number of genotypes analysed

result was confirmed using a spectrophotometric diode array detector, and will be the subject of further research.

The amount of phenolic compounds in chaenomeles juice was 210–592 mg phenol/100 ml. The high levels of phenolic compounds detected are interesting since phenolic compounds may have both antioxidant and bactericidal properties (Nowak *et al.* 1992). For comparison, the content of phenolic compounds in orange juice is 755 mg/100 ml, in grapefruit juice 535 mg/100 ml, in apple juice 339 mg/100 ml, in pineapple juice 358 mg/100 ml (Gardner *et al.* 2000), in pear juice 150 mg/100 ml and in white grape juice 200 mg/100 ml (Spanos & Wrolstad 1992).

**Organic acids**

In chaenomeles juice three organic acids were detected: malic acid, quinic acid and succinic acid (Table 6). Other typical organic acids normally found in fruits, such as citric acid, oxalic acid and tartaric acid (Pérez *et al.* 1997), were not found in detectable amounts. In addition, no free galacturonic acid was detected in chaenomeles juice. The content of organic acids in chaenomeles juice differed between samples. Malic acid, the main organic acid, was present in the samples at concentrations from 3.06 to 5.09 g/100 ml of juice. The highest amount was found in a sample of *C. cathayensis*. The range of quinic acid and succinic acid was 0.62–2.27 g and 8–174 mg per 100 ml juice, respectively. This was the same amount as had previously been reported by Lesinska (1987) and Rumpunen (1995). For comparison, the content of malic acid is 0.52 g/100 ml for cv. Red Delicious apple juice, 0.29 g/100 ml for grape juice and 0.37 g/100 ml for pear juice (van Gorsel *et al.* 1992). Viljakainen *et al.* (2002) reported a malic acid content in juice of Nordic berries [bilberry (*Vaccinium myrtillus*), lingonberry (*Vaccinium vitis-idaea*), cranberry (*Vaccinium oxycoccus*), cloudberry (*Rubus chamaemorus*), red raspberry *(Rubus idaeus*), black crowberry (*Empetrum nigrum* ssp. *hermaphroditum*), currants (*Ribes nigrum, R. rubrum*, and *R.* x *pallidum*), gooseberry (*Ribes uva-crispa*) and strawberry (*Fragaria* x *ananassa*)] from 0.3 to 1.6 g/100 ml juice. In addition, the Nordic berries also contained citric acid (0.2–2.5 g/100 ml). Citric acid, which according to our study was not a constituent of chaenomeles juice, is present in *e.g.* apple juice (11.4 mg/100 ml, cv. Summerred, Heimler & Pieroni 1992). The quinic acid content in pear juice is 0.22 g/100 ml (van Gorsel *et al.* 1992). Succinic acid and fumaric acid have previously been reported in apple, but only in low concentrations (0.2 mg/100 ml juice).

The very high content of malic acid in chaenomeles juice makes it undrinkable if not sweetened. Acidity may be reduced through inoculation of a malolactic microorganism, *Oenococcus oeni* (Viljakainen & Laakso 2002). Malic acid is then converted to lactic acid, whereas other substrates, such as soluble

**Table 7.** Amino acids (mg/100 ml ± SD) in fresh chaenomeles juice.

| Site | Samples[a] (*n*) | Phosphoserine | Aspartic acid | Threonine | Serine | Asparagine |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 8 | 5.88 ± 1.04 | 2.88 ± 1.69 | 0.46 ± 0.13 | 1.91 ± 0.95 | 1.65 ± 1.05 |
| RG | 2 | 4.25 ± 0.21 | 6.40 ± 0.28 | 0.85 ± 0.07 | 3.20 ± 1.13 | 8.15 ± 6.15 |
| D | 3 | 3.40 ± 1.47 | 4.87 ± 0.55 | 0.67 ± 0.21 | 1.77 ± 0.35 | 1.10 ± 0.72 |
| F | 3 | 4.03 ± 0.25 | 5.00 ± 0.79 | 0.83 ± 0.25 | 1.90 ± 0.69 | 1.60 ± 0.30 |
| *C. speciosa* | | | | | | |
| RG | 1 | 9.40 | 2.00 | 0.20 | 0.80 | 4.00 |
| *C. cathayensis* | | | | | | |
| RG | 1 | 4.30 | 3.40 | 0.30 | 1.20 | 2.00 |

| Site | Samples[a] (*n*) | Glutamic acid | Alanine | Phenylalanine | GABA | Lysine |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 8 | 12.46 ± 3.66 | 1.18 ± 0.68 | 1.49 ± 1.31 | 0.81 ± 0.12 | 0.51 ± 0.21 |
| RG | 2 | 13.75 ± 2.47 | 0.75 ± 0.07 | n.d. | 0.90 ± 0.00 | 1.80 ± 0.00 |
| D | 3 | 9.87 ± 2.79 | 0.43 ± 0.06 | 0.40 ± 0.00 | 0.35 ± 0.21 | 0.37 ± 0.15 |
| F | 3 | 14.33 ± 2.44 | 1.13 ± 0.15 | 0.93 ± 0.38 | 0.50 ± 0.00 | 0.67 ± 0.25 |
| *C. speciosa* | | | | | | |
| RG | 1 | 8.30 | 1.10 | n.d. | n.d. | n.d. |
| *C. cathayensis* | | | | | | |
| RG | 1 | 8.20 | 0.50 | n.d. | n.d. | n.d. |

[a]Number of genotypes analysed

sugars and citric acid, initially remain intact. Upon exhaustion of malic acid, degradation of sugar and citric acid is initiated simultaneously.

Malic acid and succinic acid are currently used by the food industry as acidifying additives (E-296 and E-363, respectively). Quinic acid has no E number but has non-food applications. The presence of quinic acid in chaenomeles fruits may make the juice interesting for the chemical and pharmaceutical industries. Quinic acid is *e.g.* used in organic chemistry as a chiral building block for synthesis of several compounds (Barco *et al.* 1997, Huang 1999).

Due to its high content of organic acids, chaenomeles juice, like lemon juice (Saura *et al.* 1990), can be used as a natural acidulant in a wide range of foods (juices, canned fruits and vegetables, meat, and milk products). Its acidulant properties become even more interesting in combination with its high anti-oxidant properties.

**Amino acids**

Amino acids constitute another family of acidic juice constituents, also related to organic acids. In chaenomeles juice ten amino acids were detected and identified (Table 7): phosphoserine, aspartic acid, threonine, serine, asparagine, glutamic acid, alanine, phenylalanine, γ-aminobutyric acid (GABA) and lysine. Among the amino acids detected in chaenomeles juice, only threonine, phenylalanine and lysine are essential to humans, while γ-aminobutyric acid is an important neurotransmitter in the brain. The most abundant amino acid in chaenomeles juice was glutamic acid (8–14 mg/100 ml), followed by phosphoserine (3–9 mg/100 ml) and aspartic acid (2–6 mg/100 ml). In most samples, the amount of the other amino acids was lower than 2 mg/100 ml juice. Glutamic acid has previously not been reported in

**Table 8.** Cations and anions (mg/100 ml ± SD) in fresh chaenomeles juice.

| Site | Samples[a] (*n*) | Sodium | Ammonium | Potassium | Magnesium | Calcium |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 8 | 3.49 ± 1.09 | 0.79 ± 0.50 | 161.13 ± 11.43 | 5.38 ± 1.62 | 10.38 ± 1.74 |
| RG | 2 | 2.85 ± 0.64 | 0.85 ± 0.49 | 208.50 ± 33.23 | 5.35 ± 1.06 | 10.65 ± 1.06 |
| D | 3 | 3.73 ± 1.27 | 1.03 ± 0.29 | 161.00 ± 15.10 | 4.70 ± 0.75 | 12.43 ± 0.46 |
| F | 3 | 3.00 ± 1.66 | 0.77 ± 0.06 | 213.00 ± 26.06 | 8.50 ± 2.31 | 15.40 ± 1.35 |
| *C. speciosa* | | | | | | |
| RG | 1 | 5.70 | n.d. | 241.00 | 5.70 | 19.00 |
| *C. cathayensis* | | | | | | |
| RG | 1 | 4.70 | 0.50 | 153.00 | 3.80 | 15.20 |

| Site | Samples[a] (*n*) | Fluoride | Chloride |
|---|---|---|---|
| *C. japonica* | | | |
| NV | 8 | 84.88 ± 31.19 | 5.38 ± 2.45 |
| RG | 2 | 42.95 ± 31.47 | 4.10 ± 3.82 |
| D | 3 | 86.00 ± 8.40 | 6.80 ± 1.76 |
| F | 3 | 101.87 ± 27.21 | 3.45 ± 0.07 |
| *C. speciosa* | | | |
| RG | 1 | 139.00 | 8.70 |
| *C. cathayensis* | | | |
| RG | 1 | 83.00 | 8.70 |

[a]Number of genotypes analysed

fruit juices except for juice extracted from citrus fruits, but in chaenomeles juice it was the most important amino acid. This is also in agreement with previously reported data for chaenomeles juice (Lesinska 1987). For comparison, citrus juices are rich in aspartic acid (up to 470 mg/100 ml in grapefruit), glutamic acid (up to 280 mg/100 ml in grapefruit), serine (up to 28 mg/100 ml in lemon), proline (up to 295 mg/100 ml in orange) and arginine (up to 150 mg/100 ml in lemon and orange) (Belitz & Grosch 1987). Apple juice (Lea 1995) mainly contains asparagine (89.3 mg/100 ml), aspartic acid (10.7 mg/100 ml), and γ-aminobutyric acid, alanine and serine (1.0 mg/100 ml). Grape juice (van Gorsel *et al.* 1992) mainly contains proline (101 mg/100 ml), arginine (59.2 mg/100 ml), and alanine (17.2 mg/100 ml). Aspartic acid is present in most fruit juices and always in significant amounts (van Gorsel *et al.* 1992) *e.g.* in apple juice of cv. Red Delicious (15.5 mg/100 ml), in grape juice (7.7 mg/100 ml), and in pear juice (12.8 mg/100 ml).

## Inorganic ions

Five cationic and two anionic components were detected and identified in chaenomeles fruit juice (Table 8): sodium, ammonium, potassium, calcium and magnesium, fluoride and chloride. All of these ions appeared in every sample and each ion was detected in similar amounts in the different genotypes. The most important cation was potassium (153–241 mg/100 ml), followed by calcium (10–19 mg/100 ml) and magnesium (4–9 mg/100 ml). Fluoride was detected in the range of 43 to 139 mg/100 ml, whereas chloride varied from 4 to 9 mg/100 ml. The content of carbonate, nitrate, phosphate and sulphate was lower than 1 mg/100 ml. The low content of sodium observed (3–6 mg/100 ml) is interesting from a human nutrition viewpoint because a high intake of sodium may increase blood pressure.

**Table 9.** Carbohydrates (mg/100 ml ± SD) in fresh chaenomeles juice.

| Site | Samples[a] (*n*) | Stachyose | Raffinose | Sucrose | Glucose | Xylose |
|---|---|---|---|---|---|---|
| *C. japonica* | | | | | | |
| NV | 8 | 9.5 ± 8.1 | 7.8 ± 7.0 | 57.0 ± 93.5 | 308.3 ± 181.6 | 94.0 ± 36.7 |
| RG | 2 | 2.5 ± 0.8 | 4.1 ± 1.6 | 12.2 ± 10.7 | 630.5 ± 194.0 | 73.1 ± 87.1 |
| D | 3 | 3.0 ± 1.8 | 20.5 ± 19.7 | 98.1 ± 90.3 | 530.5 ± 208.0 | 133.5 ± 92.1 |
| F | 3 | 39.8 ± 60.0 | 5.8 ± 3.9 | 72.9 ± 51.9 | 474.8 ± 132.5 | 211.9 ± 184.9 |
| *C. speciosa* | | | | | | |
| RG | 1 | n.d. | 4.0 | 32.0 | 414.0 | 91.0 |
| *C. cathayensis* | | | | | | |
| RG | 1 | n.d. | 14.0 | 23.0 | 1065.0 | 229.0 |
| *C. japonica* x *C. speciosa* | | | | | | |
| RG | 1 | 6.6 | n.d. | 28.8 | 372.4 | 44.7 |

| Site | Samples[a] (*n*) | Rhamnose | Fructose | Inositol | Sorbitol |
|---|---|---|---|---|---|
| *C. japonica* | | | | | |
| NV | 8 | 12.4 ± 6.1 | 817.2 ± 358.9 | 8.3 ± 5.0 | 121.1 ± 68.8 |
| RG | 2 | 44.0 ± 26.9 | 1159.9 ± 624.8 | 11.7 ± 4.1 | 269.3 ± 104.9 |
| D | 3 | 33.8 ± 39.5 | 1218.4 ± 654.3 | 14.0 ± 5.3 | 245.1 ± 68.5 |
| F | 3 | 67.5 ± 33.2 | 1152.8 ± 547.6 | 31.5 ± 29.0 | 389.3 ± 180.7 |
| *C. speciosa* | | | | | |
| RG | 1 | 9.0 | 1035.0 | 4.0 | 519.0 |
| *C. cathayensis* | | | | | |
| RG | 1 | 96.0 | 2293.0 | 17.0 | 452.0 |
| *C. japonica* x *C. speciosa* | | | | | |
| RG | 1 | n.d. | 728.3 | 7.0 | 406.6 |

[a]Number of genotypes analysed

For comparison, in orange juice the content of inorganic ions is 116–265 mg/100 ml potassium, 6.3–29.4 mg/100 ml calcium, 9.8–17.1 mg/100 ml magnesium, 0.2–2.4 mg/100 ml sodium, 0.11–0.19 mg/100 ml fluoride and 3.6–13.2 mg/100 ml chloride (Hendrix & Redd 1995). In apple juice the content of inorganic ions is 90–150 mg/100 ml potassium, 3.0–12.0 mg/100 ml calcium and 4.0–7.0 mg/100 ml magnesium (Lea 1995). Thus the content of potassium in chaenomeles juice was similar to that in citrus juices and may be of importance for human intake if consumed in large amounts.

## Carbohydrates

Nine carbohydrates were detected and identified in chaenomeles juice (Table 9): stachyose, raffinose, sucrose, glucose, xylose, rhamnose, fructose, inositol and sorbitol. The content of carbohydrates differed between genotypes. The main carbohydrates were fructose (0.73–2.29 g/100 ml), glucose (0.31–1.07 g/100 ml), sorbitol (0.12–0.52 g/100 ml) and sucrose (0.01–0.10 g/100 ml). The highest amount of fructose was found in a sample of *C. cathayensis*. The results were similar to results previously reported by Lesinska (1987). However, there were some differences, mainly because we determined free carbohydrates in the juice and Lesinska determined carbohydrates in the fruit, including the carbohydrate constituents of the structural polysaccharides of the chaenomeles fruit cell-wall. HPSEC analysis indicated that complex polymeric carbohydrates were not present in the juice. The composition of polysaccharides in the fruit pulp has previously been reported by Golubev *et al.* (1991), by Thomas *et al.* (2000), and by

Thomas & Thibault (2002).

For comparison, the content of fructose in other fruits is *e.g.* in cv. Red Delicious apple juice 5.31 g/100 ml, in grape juice 10.53 g/100 ml and in pear juice 8.12 g/100 ml (van Gorsel *et al.* 1992). Viljakainen *et al.* (2002) reported a content of fructose in juice of Nordic berries from 1.8 to 5.6 g/100 ml. The content of fructose in juice from orange, grapefruit and lemon is 2.4 g/100 ml, 1.2 g/100 ml and 0.9 g/100 ml, respectively (Belitz & Grosch 1987).

The content of glucose in juice of other fruits is *e.g.* in apple juice 2.14 g/100 ml, in grape juice 9.59 g/100 ml and in pear juice 1.68 g/100 ml (van Gorsel *et al.* 1992). Viljakainen *et al.* (2002) reported a glucose content in juice of Nordic berries from 2.2 to 5.0 g/100 ml. The content of glucose in juice of orange, grapefruit and lemon is 2.4 g/100 ml, 2.0 g/100 ml and 0.5 g/100 ml, respectively (Belitz & Grosch 1987).

The content of sorbitol in juice of other fruits is *e.g.* in apple juice 0.20 g/100 ml and in pear juice 4.08 g/100 ml (van Gorsel *et al.* 1992).

The content of sucrose in juice from other fruits is *e.g.* in apple juice 0.82 g/100 ml, in grape juice 0.29 g/100 ml and in pear juice 0.55 g/100 ml (van Gorsel *et al.* 1992). Viljakainen *et al.* (2002) reported a content of sucrose in juice of Nordic berries from not detected to 0.51 g/100 ml. The content of sucrose in juice of oranges, grapefruits and lemons is 4.7 g/100 ml, 2.1 g/100 ml and 0.2 g/100 ml, respectively (Belitz & Grosch 1987).

## CONCLUSION

The different species in the genus *Chaenomeles* have fruits rich in juice, pulp and seeds. The juice is very acidic, has a low pH and a high content of vitamin C and phenolic compounds. The main organic acids detected in chaenomeles juice were malic acid, quinic acid and succinic acid. The main amino acids were glutamic acid, phosphoserine and aspartic acid, and the main carbohydrates were fructose, glucose and sorbitol. Due to its characteristics and composition, chaenomeles fruit juice should be useful for the food industry, especially as an acidulant with high antioxidant properties.

## LITERATURE


Abbott J.A. 1999. Quality measurement of fruits and vegetables. Postharvest Biology and Technology 15: 207–225.

Antolovich M., Prenzler P., Robards K., Ryan D. 2000. Sample preparation in the determination of phenolic compounds in fruits. Analyst 125: 989–1009.

Barco A., Benetti S., De Risi C., Marchetti P., Pollini G.P., Zanirato V. 1997. D-(-)-Quinic acid: a chiron store for natural product synthesis. Tetrahedron: Asymmetry 8: 3515–3545.

Belitz H.D., Grosch W. 1987. Fruits and fruits products. In: Food Chemistry. Springer-Verlag, Heidelberg.

Carson K.J., Collins J.L., Penfield M.P. 1994. Unrefined, dried apple pomace as a potential food ingredient. Journal of Food Science 59: 1213–1215.

Dever M.C., Cliff M., Veto L. 1991. Effect of apple storage on the quality of non-oxidative juice. Canadian Institute of Food Science and Technology 24: 252–258.

Gardner P.T., White T.A.C., McPhail D.B., Duthie G.G. 2000. The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. Food Chemistry 68: 471–474.

Golubev V.N., Kolechik A.A., Rigavs U.A. 1991. Carbohydrate complex of the fruit of *Chaenomeles maulei*. Chemistry of Natural Compounds 26: 387–390.

Heimler D., Pieroni, A. 1992. Influence of environmental factors (acid rains and long term storage) on the concentration of carboxylic acids in apple fruits. Agrochimica 36: 494–499.

Hellín P., Ros J.M., Laencina J. 1998. Growth of *Rhizopus nigricans* in solid substrate and submerged cultures of fruits and vegetables. In: Bertolini P., Sijmons P.C., Guerzoni M.E., Serra F. (Eds.) Non Conventional Methods for the Control of Postharvest Disease and Microbiological Spoilage. Office for Official Publications of the European Communities, Luxembourg.

Hellín P., Ros J.M., Laencina J. 2001. Changes in high and low molecular weight carbohydrates during *Rhizopus nigricans* cultivation on lemon peel. Carbohydrate Polymers 45: 169–174.

Hendrix C.M., Redd J.B. 1995. Chemistry and technology of citrus juices and their by-products. In: Ashurst P.R. (Ed.) Production and Packaging of Non-Carbonated Fruit Juices and Fruit Beverages. Blackie Academic & Professional, Glasgow.

Huang P.Q. 1999. D-Quinic acid, a versatile chiron in organic synthesis. Youji Huaxue 19: 364–373.

Kimball D.A. 1999. Citrus Processing. A Complete Guide. Aspen, Gaithersburg.

Lea A.G.H. 1995. Apple juice. In: Ashurst P.R. (Ed.) Production and Packaging of Non-Carbonated Fruit Juices and Fruit Beverages. Blackie Academic & Professional, Glasgow.

Lee H.S., Coates G.A. 1999. Vitamin C in frozen, fresh squeezed, unpasteurized, polyethylene-bottled orange juice: a storage study. Food Chemistry 65: 165–168.

Lesinska E. 1987. Characteristics of sugars and acids in the fruits of East Asian quince. Die Nahrung 31: 763–765.

Lesinska E., Przybylski R., Eskin N.A.M. 1988. Some volatile and nonvolatile flavor components of the dwarf quince (*Chaenomeles japonica*). Journal of Food Science 53: 854–856.

McLellan M.R., Race E.J. 1995. Grape juice. In: Ashurst P.R. (Ed.) Production and Packaging of Non-Carbonated Fruit Juices and Fruit Beverages. Blackie Academic & Professional, Glasgow.

Nowak H., Kujawa K., Zadernowski R., Roczniak B., Kozlowska H. 1992. Antioxidative and bactericidal properties of phenolic compounds in rapeseeds. Fat Science and Technology 94: 149–152.

Pérez A.G., Olías R., Espada J., Olías J.M., Sanz C. 1997. Rapid determination of sugars, nonvolatile acids, and ascorbic acid in strawberry and other fruits. Journal of Agricultural and Food Chemistry 45: 3545–3549.

Primo E. 1982. Cítricos y derivados. In: Química Agrícola III. Alimentos. Alhambra, Madrid.

Roberfroid M.B. 1999. Dietary fiber properties and health benefits of non-digestible oligosaccharides. In: Cho S.S., Prosky L., Dreher M. (Eds.) Complex Carbohydrates in Foods. Marcel Dekker, New York.

Ros J.M., Saura D., Coll L., Moliner M., Laencina J. 1995. Determination of uronic acids in the presence of neutral sugars. In: García-Viguera C., Castañer M., Gil M.I., Ferreres F., Tomás-Barberán F.A. (Eds.) Current Trends in Fruit and Vegetables Phytochemistry. Consejo Superior de Investigaciones Científicas (CSIC), Madrid.

Ros J.M., Schols H.A., Voragen A.G.J. 1996a. Extraction, characterisation and enzymatic degradation of lemon peel pectins. Carbohydrate Research 282: 271–284.

Ros J.M., Saura D., Coll L., Moliner M., Laencina J. 1996b. Oligouronides production in membrane reactor by enzymatic degradation of pectins from citrus peel. Progress in Biotechnology 14 - Pectins and Pectinases 983–990.

Ros J.M., Schols H.A., Voragen A.G.J. 1998. Lemon albedo cell walls contain distinct populations of pectic hairy regions. Carbohydrate Polymers 37: 159–166.

Ros J.M., Schols H.A., Laencina J., Voragen A.G.J. 2000. Pectic hairy regions of lemon fruits: a polysaccharide with potential bioactivity? In: Paulsen B.S. (Ed.) Bioactive Carbohydrate Polymers. Kluwer Academic Publishers, Dordrecht.

Rumpunen K. 1995. *Chaenomeles* - a novel source for pectic substances, organic acids and aromatic compounds. In: García-Viguera C., Castañer M., Gil M.I., Ferreres F., Tomás-Barberán F.A. (Eds.) Current Trends in Fruit and Vegetables Phytochemistry. Consejo Superior de Investigaciones Científicas (CSIC), Madrid.

Rumpunen K., Trajkovski V., Bartish I., Garkava L., Nybom H., Laencina J., Ros J.M., Jordan M.J., Hellin P., Tigerstedt P.M.A., Kauppinen S., Thibault J.-F., Thomas M., Gustafsson M., Norin I., Åkesson B., Gustafsson M., Gröön I., Kaufmane E., Ruisa S., Stanys V., Kviklys D. 2000. Domestication of Japanese quince (*Chaenomeles japonica*). Acta Horticulturae 538: 345–348.

Rumpunen K. 2002. *Chaenomeles*: potential new fruit crop for northern Europe. In: Janick J. & Whipkey A. (Eds.) Trends in new crops and new uses. ASHA Press, Alexandria, VA, USA 385–392.

Samuelsen A.B. 2000. Structural features of biologically active polysaccharide fractions from the leaves and seeds of *Plantago major* L. In: Paulsen B.S. (Ed.) Bioactive Carbohydrate Polymers. Kluwer Academic Publishers, Dordrecht.

Saura D., Cánovas J.A., Ros J.M., Núñez J.M., Laencina J. 1990. Lemon juice applications as natural acidulant in foods. Proceedings of the 1st International Congress on Food Technology and Development 3: 911–919.

Singleton V.L., Rossi J.A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16: 144–158.

Spanos G.A., Wrolstad R.E. 1992. Phenolics of apple, pear and white grapes juices and their changes with processing and storage - A review. Journal of Agricultural and Food Chemistry 40: 1478–1487.

Thomas M., Crépeau M.J.C., Rumpunen K., Thibault J.-F. 2000. Dietary fibre and cell-wall polysaccharides in the fruits of Japanese quince (*Chaenomeles japonica*). Lebensmittel-Wissenschaft und -Technologie 33: 124–131.

Thomas M., Thibault J.-F. 2002. Cell-wall polysaccharides in the fruits of Japanese quince (*Chaenomeles japonica*): extraction and preliminary characterisation. Carbohydrate Polymers 49: 345–355.

van Gorsel H., Li C., Kerbel E.L., Smits M., Kader A.A. 1992. Compositional characterization of prune juice. Journal of Agricultural and Food Chemistry 40: 784–789.

Viljakainen S.K., Laakso S.V. 2002. Acidity reduction in northern region berry juices by the malolactic bacterium *Oenococcus oeni*. European Food Research and Technology 214: 412–417.

Viljakainen S., Visti A., Laakso S. 2002. Organic acids and soluble sugars in the juice of Nordic berries. Acta Agriculturae Scandinavica, Sect. B, Soil and Plant Science 52: 101–109.

Yamada H. 1996. Contribution of pectins on health care. Progress in Biotechnology 14 - Pectins and Pectinases 173–190.

Yamada H. 2000. Bioactive plant polysaccharides from Japanese and Chinese traditional herbal medicines. In: Paulsen B.S. (Ed.) Bioactive Carbohydrate Polymers. Kluwer Academic Publishers, Dordrecht.