Sugar Composition of Varietal Juices Produced from Fresh and Stored Apples

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Varietal juices were produced from 11 apple cultivars from three apple-growing regions of Ontario before and after cold storage in two consecutive crop years. Juices were analyzed for individual sugars using HPLC. The ranges of concentrations (grams per 100 mL) found for juice produced from fresh and stored fruit, respectively, were as follows: sucrose 1.33–4.80, 0.62–3.30; fructose 4.12–6.76, 4.27-7.43; glucose 0.70–2.27, 0.88–2.65; xylose trace–0.11, trace–0.17; galactose 0.01–0.03, 0.01–0.03; raffinose trace–0.04, trace–0.05; stachyose nil–0.01, nil–0.02; sorbitol 0.09–0.61, 0.11–0.51; total sugar 8.26–13.21, 7.79–11.96; total soluble solids 9.7–15.0, 9.7–13.4%. Cultivar as well as cold storage significantly influenced the content of most sugars. Season affected only the glucose and raffinose contents, while growing area did not have a significant effect. Most commercial apple juices had compositions similar to that of the authentic varietal juices except that they contained measurable quantities of ethanol and (hydroxymethyl)furfural.

INTRODUCTION

Sugars contribute to the nutritional and sensory qualities of apples and apple juice. Fructose, glucose, sucrose, and the sugar-alcohol sorbitol are major components of apple juice. The minor sugar contents reported for apples or apple juice are as follows: 0.01–0.25 g/100 g D-xylose (Aso and Matsuda, 1951; Guichard, 1954; Siegelman, 1954; Ash and Reynolds, 1955; Whiting and Coggins, 1960; Buchloh and Neubeller, 1969; Chong et al., 1972; Mäkinen and Söderling, 1980; Sharma et al., 1988; Chapman and Horvat, 1989; Prabha et al., 1990; Schols et al., 1991), trace–0.05 g/100 g galactose (Ash and Reynolds, 1955; Sharkasi, 1981; Sharma et al., 1988; Chapman and Horvat, 1989; Schols et al., 1991), 0.02–0.08 g/100 g raffinose (Chan et al., 1972; Chong et al., 1972), traces of arabinose (Wali and Hassan, 1965; Sharma et al., 1988; Schols et al., 1991), mannose (Guichard, 1954; Schols et al., 1991), rhamnose (Schols et al., 1991), and maltose (Lee et al., 1970, 1972; Prabha et al., 1990). It should be noted that xylose, arabinose, and galactose along with glucose, mannose, and rhamnose are noncellulosic components of cell walls in apples (Gross and Sams, 1984) and they are released upon acid (Garleb et al. 1989; Prabha et al., 1990) or enzymatic (Schols et al., 1991) hydrolysis of apple fiber. The sugar-alcohols reported in minor quantities for apples or apple juice are as follows: 0.01 g/100 L glycerol (Dizy et al., 1992); 0.0048–0.0128 g/100 g xylitol (Mäkinen and Söderling, 1980), and trace–0.024 g/100 g inositol (Esselen et al., 1947; Ash and Reynolds, 1955; Buchloh and Neubeller, 1969; Chapman and Horvat, 1989). The identity of fructose, glucose, sucrose, sorbitol, galactose, xylose, and inositol in apples had been confirmed using GC/MS by Chapman and Horvat (1989). Significantly, these authors did not find maltose in any of the examined fruits, although they detected it in sweet potatoes. There is considerable literature on the major sugar components of apple juice. The concentration ranges for the individual sugars are summarized in Table 1 for authentic and in Table 2 for commercial apple juices.

More apple juice is consumed, not only in Canada but worldwide, than any other juice except that made from oranges. In recent years, it has become apparent that apple juice is subject to adulteration (Brause, 1992). The sugar composition of apple juice provides excellent means for the detection of adulteration (Lee and Wrolstad, 1988b; Mattick, 1988). Unlike in grapes (Fuleki and Pelayo, 1993), the concentration of fructose in apples is much higher than that of glucose, and sorbitol is present as well. Most pear cultivars contain significantly higher concentrations of sorbitol than apple (Weiss and Sämann, 1979), and this can be used to detect substitution of apple juice with that of pears.

Using the Lane–Eynon method, Zubeckis (1962) determined the total reducing sugars in seven apple and three crabapple cultivars grown in Ontario for five consecutive years. Information on the individual sugar composition of apples grown in Ontario is available only for the cultivar McIntosh (Krotkov and Helson, 1946). Ryan (1972) described the individual sugar composition of 21 authentic commercially produced apple juices from four apple-growing regions of Canada. Furthermore, most studies on the composition of apple juice did not include juice produced from fruit stored for longer periods, although substantial quantities of stored apples are used by juice manufacturers. The present study was undertaken to rectify this situation. Although the project was initiated to provide a data base for authentication of fruit juices, it is expected that this information will be useful to food technologists, pomologists, and dietitians as well.

MATERIALS AND METHODS

The apples were obtained from the experimental orchards of the Agriculture Canada Research Station at Smithfield (Sf), the Horticultural Research Institute of Ontario at Vineland Station (V), and Simcoe (S) in the 1989 and 1990 seasons. In addition to nine commercially important cultivars, two new scab-resistant apple cultivars (Moira, Trent) from the breeding program of Agriculture Canada, Smithfield Experimental Farm (Heeney, 1981), were also included in this study. The apples were harvested at commercial maturity and stored in a common cold storage at 2 °C and 94–96% relative humidity. To alleviate any small differences in maturity at harvest, the fruit was stored for about 1 month before pressing to produce juice from "fresh" apples. The length of storage prior to pressing was about 6 months for "stored" apples.

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Table 1. Sugar Composition of Authentic Apple Juice As Reported in the Literature[a]

origin	no. of samples (cultivars)	unit of measurement	sucrose	glucose	fructose	sorbitol	total sugar	TSS, %	F/G	HF/HG[b]	analytical method[c]	reference
U.S.A. (DE)	2 (2)	%	4.26–4.84	1.06–1.64	4.65–7.70	na[d]	9.97–14.18	na	4.39–4.70	2.09–2.45	Pl	Thompson and Whittier (1912)
U.S.A. (VA)	20 (20)	%	0.2–3.6	0.5–3.5	5.0–8.5	na	7.9–13.8	10.5–16.3[e]	1.43–11.60	1.38–3.62	Ch, Pl	Eoff (1917)
England	31 (11)	%[f]	0.99–5.55	0.96–2.28	4.40–8.60	na	7.57–12.67	11.0–15.7[e]	2.29–5.77	1.80–3.89	Ch	Evans (1928)
U.S.A.	3 (3)	%	2.22–5.63	3.15–3.62	4.56–5.83	na	11.20–13.39	13.6–17.4	1.43–1.85	1.22–1.62	na	Carpenter and Smith (1934)
Japan	5 (5)	g/100 mL	2.97–6.31	1.60–2.82	4.92–5.64	na	11.16–14.43	na	1.65–3.53	1.40–2.02	Ch, PC	Aso and Matsuda (1951)
France	33 (33)	g/100 mL	0.66–6.14	1.23–6.46	6.92–13.58	na	10.95–19.40	12.1–21.5	1.82–6.82	1.54–4.77	Pl, Ch	Tavernier and Jacquin (1952)
England	14 (14)	%	0.35–4.50	0.78–2.77	5.60–7.70	na	8.07–13.40	10.0–15.0	2.18–9.23	1.95–3.75	PC	Brown and Harvey (1971)
Canada	20	g/100 mL	0.65–2.40	1.72–3.93	4.29–6.48	0.57–1.67	9.02–13.34[g]	10.5–13.3	na	na	GC	Ryan (1972)
U.S.A.	8 (8)	%	0.7–2.7	1.9–4.1	5.6–8.5	na	8.3–14.2	na	1.68–3.68	1.54–3.19	HPLC	Brause and Raterman (1982)
U.S.A	93 (16)	g/100 mL	0.88–5.62	0.89–3.99	3.00–10.50	0.16–1.20	na	9.8–16.9[e]	1.67–6.09	1.43–3.31	HPLC	Mattick and Moyer (1983)
England	30 (3)	g/100 mL[h]	0.4–3.4	1.3–2.7	5.0–6.7	na	7.7–11.3	9.3–13.5	2.3–4.2	na	Ez, Ch	Burroughs (1984)
U.S.A.	1	%	1.51	2.97	5.82	na	10.3	na	1.96	1.76	HPLC	Zyren and Elkins (1985)
U.S.A. (MI)	2 (2)	g/100 mL[i]	0.60–1.80	1.39–1.70	4.20–8.71	0.36–0.39	6.2–12.2	12.1–13.1[e]	3.02–5.11	2.64–3.64	HPLC	Lee and Wrolstad (1988a)
U.S.A. (WA)	2 (1)	g/100 mL[i]	0.19–1.51	2.71–3.44	7.75–8.13	0.26–0.35	11.7–12.0	11.8–12.3[e]	2.36–2.87	1.91–2.33	HPLC	Lee and Wrolstad (1988a)
New Zealand	1 (1)	g/100 mL[i]	1.35	4.85	10.9	0.45	17.1	14.8[e]	2.25	2.09	HPLC	Lee and Wrolstad (1988a)
Mexico	1 (1)	g/100 mL[i]	3.32	2.41	8.13	0.29	13.9	14.0[e]	3.38	2.38	HPLC	Lee and Wrolstad (1988a)
Hungary	45 (3)	%[h]	1.92–3.04	0.80–1.23	6.76–7.26	na	10.39–10.96	13.0–13.75	5.89–6.24	na	Ez, Ch	Pátkai and Török (1989)
Germany	12 (3)	g/100 mL[h]	0.70–2.68	2.34–3.37	5.86–7.09	na	9.27–13.14	10.4–14.0[e]	2.10–2.50	1.79–2.50	Ez	Zache et al. (1990)
Turkey	8 (3)	%	1.35–2.45	1.23–3.05	5.77–7.98	na	8.74–12.47	10.6–14.0	2.29–5.88	1.90–3.95	Ez	Eksi and Karendeniz (1991)
Canada	16 (4)	g/100 mL[h]	2.13–3.90	1.08–2.75	5.92–7.31	na	9.32–12.58	10.08–14.10[e]	2.58–5.57	2.04–3.34	HPLC	Cliff et al. (1991)
U.S.A.	3 (1)	g/100 mL	0.82 ± 0.13	2.14 ± 0.43	5.31 ± 0.94	0.20 ± 0.04	8.27	na	2.48	2.23	HPLC	Gorsel et al. (1992)

[a] Minimum and maximum values within the column are in boldface. [b] Fructose/glucose ratio assuming a complete inversion of sucrose. [c] Ch, chemical; Ez, enzymatic; GC, gas chromatography; HPLC, high-pressure liquid chromatography; PC, paper chromatography; Pl, polarography. [d] Not available. [e] Given as °Brix. [f] Calculated for fruit weight. [g] Includes sorbitol. [h] Range of means. [i] Calculated from normalized values.

Table 2. Sugar Composition of Commercial Apple Juice As Reported in the Literature[a]

origin	no. of samples	unit of measurement	sucrose	glucose	fructose	sorbitol	total sugar	TSS, %	F/G	HF/HG[b]	analytical method[c]	reference
U.S.A.	3	g/100 mL	1.86–3.17	2.71–2.93	6.41–6.49	na[d]	11.17–12.30	na	2.22–2.37	1.85–1.92	HPLC	Palmer and Brandes (1974)
Germany	38	g/100 mL[e]	0.25–2.98	2.16–3.97	4.76–6.84	na	na	11.2–14.2[f]	2.1–3.0	1.71–2.62	Ch, Ez	Wucherpfennig et al. (1977)
U.S.A.	1	%	1.29	3.18	7.53	na	12.0	12.2	2.37	2.13	HPLC	Hurst et al. (1979)
U.S.A.	20	%	nil–2.2	2.0–4.0	5.3–7.4	na	9.7–12.0	12.0 ± 1.0[g]	1.53–2.95	1.47–2.30	HPLC	Brause and Raterman (1982)
Argentina	2	%	0.8–1.3	3.7–3.9	6.3–7.0	na	11.0–12.0	12.0 ± 0.1[g]	1.61–1.92	1.56–1.75	HPLC	Brause and Raterman (1982)
Chile	1	%	1.2	2.9	6.1	na	10.2	12.0 ± 1.0[g]	2.08	1.91	HPLC	Brause and Raterman (1982)
Israel	1	%	1.9	3.0	5.9	na	10.8	12.0 ± 1.0[g]	1.95	1.73	HPLC	Brause and Raterman (1982)
New Zealand	2	%	0.9–4.1	1.7–3.7	5.6–6.6	na	11.2–11.4	12.0 ± 1.0[g]	1.82–3.37	1.69–2.01	HPLC	Brause and Raterman (1982)
S. Africa	1	%	1.9	3.0	6.1	na	11.0	12.0 ± 1.0[g]	2.03	1.78	HPLC	Brause and Raterman (1982)
Spain	1	%	1.7	2.6	6.2	na	10.5	12.0 ± 1.0[g]	2.35	2.03	HPLC	Brause and Raterman (1982)
U.S.A.	1	%	1.4	2.3	6.7	0.25	10.4	na	2.91	2.45	HPLC	Shaw and Wilson (1982)
U.S.A.	6	g/100 mL	1.06 ± 0.33	3.09 ± 1.40	6.39 ± 0.95	na	12.10	na	na	na	GC	Li and Schuhman (1983)
New Zealand	2	%	2.05–3.19	3.02–3.37	6.79–7.29	0.34–0.44	12.71–13.00	na	2.16–2.25	1.80–1.88	HPLC	Melton and Laas (1985)
Sweden	16	g/100 mL	0.61–2.28	1.71–2.73	5.18–6.72	0.23–0.5	8.89–10.90	11.2–13.9[g]	2.00–3.33	1.92–2.47	HPLC	Fuchs et al. (1987)
Switzerland	1	g/100 mL	2.249	2.073	5.764	0.45	10.086	11.56	2.78	2.13	HPLC	Bloeck et al. (1986)
Spain	11	g/100 mL	1.03 ± 0.15	3.31 ± 0.51	5.67 ± 0.81	0.34 ± 0.18	10.73 ± 0.99	12.2 ± 0.6[g]	1.67	na	HPLC, Ez	Dizy et al. (1992)
England	2	g/100 mL	1.39–1.41	2.66–3.64	6.78–7.97	na	10.83–13.02	10.5–11.3	2.19–2.55	1.99–2.21	Ez	Contreras et al. (1992)

[a] Minimum and maximum values within the column are in boldface. [b] Fructose/glucose ratio assuming a complete inversion of sucrose. [c] Ch, chemical; Ez, enzymatic; GC, gas chromatography; HPLC, high-pressure liquid chromatography. [d] Not available. [e] Calculated from normalized values. [f] Converted from °Oechsle values. [g] Given as °Brix.

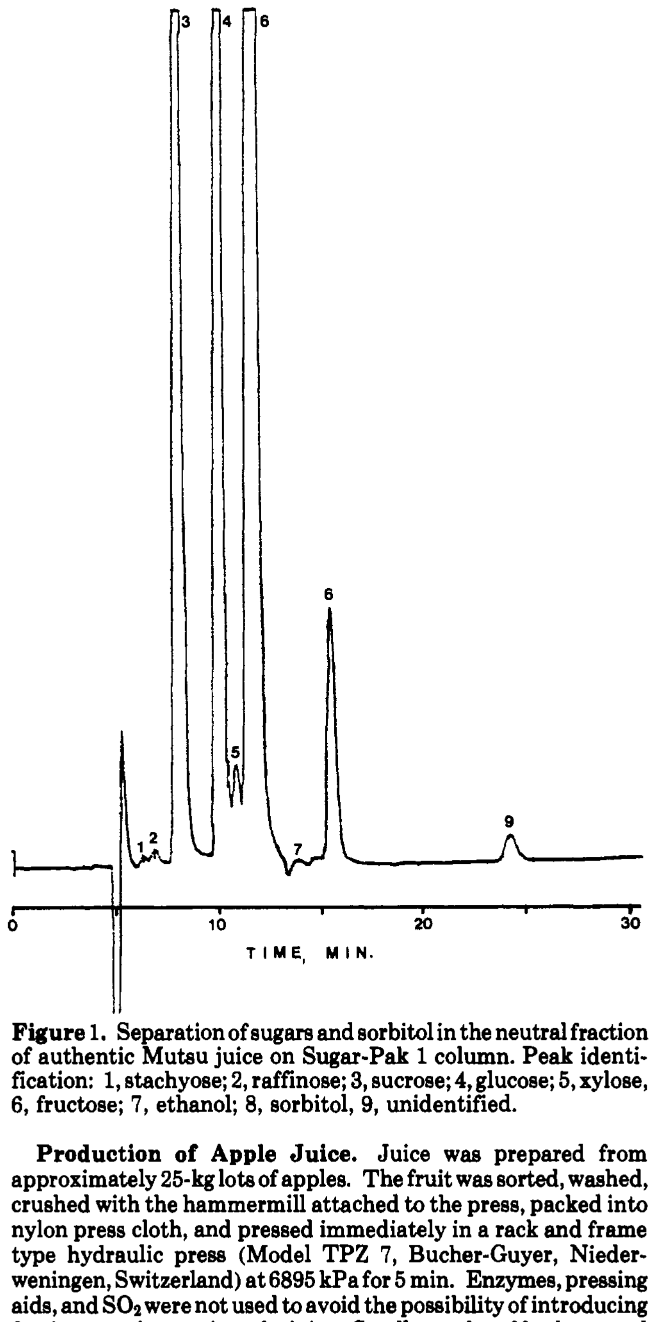

Figure 1. Separation of sugars and sorbitol in the neutral fraction of authentic Mutsu juice on Sugar-Pak 1 column. Peak identification: 1, stachyose; 2, raffinose; 3, sucrose; 4, glucose; 5, xylose, 6, fructose; 7, ethanol; 8, sorbitol, 9, unidentified.

Production of Apple Juice. Juice was prepared from approximately 25-kg lots of apples. The fruit was sorted, washed, crushed with the hammermill attached to the press, packed into nylon press cloth, and pressed immediately in a rack and frame type hydraulic press (Model TPZ 7, Bucher-Guyer, Niederweningen, Switzerland) at 6895 kPa for 5 min. Enzymes, pressing aids, and SO_2 were not used to avoid the possibility of introducing foreign constituents into the juice. Small samples of fresh pressed juice were stored in glass containers at −30 °C.

Analytical Procedures. The sample preparation method was designed to inactivate native enzymes and separate neutral from acid components. The procedures used were the same as described for grape juice (Fuleki and Pelayo, 1993) except that centrifuging after heating of the neutralized juice was omitted. No (hydroxymethyl)furfural (HMF) formation was observed as a result of this mild heat treatment. The methods used for determination of total soluble solids (TSS), individual sugars, sugar-alcohols, and statistical analyses were described in a previous publication (Fuleki and Pelayo, 1993).

Since the peaks for stachyose and raffinose were very small, where peak area integration values are not reliable, regression equations based on peak heights were established for the chromatographic procedure described previously (Fuleki and Pelayo, 1993) and 50-mL injection volume as follows:

$$\text{stachyose 1 g/L} = (\text{peak height, mm} - 1.36601)/3.2902$$

$$\text{raffinose 1 g/L} = (\text{peak height, mm} - 1.83088)/3.659804$$

The quantity of galactose and raffinose was determined enzymatically on some of the juice samples following the procedures provided with the test kit by the manufacturer (Boehringer Mannheim GmbH, Mannheim, Germany). The measurements were carried out on a Zeiss DMR21 spectrophotometer (C. Zeiss, Oberkochen, Germany).

The ratio of the theoretical levels of fructose to glucose after complete inversion of sucrose (HF/HG) was calculated using Mattick and Moyer's (1983) modification of Evans's (1928) index as follows: HF/HG = [(g of fructose/100 mL) + 0.526 (g of sucrose/100 mL)]/[(g of glucose/100 mL) + 0.526 (g of sucrose/100 mL)].

RESULTS AND DISCUSSION

A chromatogram of the neutral fraction of an authentic juice made from fresh apples is shown in Figure 1. Raffinose, sucrose, glucose, xylose, fructose, ethanol, sorbitol, and HMF were identified as described earlier (Fuleki and Pelayo, 1993). No HMF and variable but only small quantities of ethanol were found in the authentic juices, while measurable quantities of both compounds were present in most of the commercial juices.

The presence of galactose and raffinose in juices prepared from fresh and stored apples was confirmed by enzymatic analyses. Galactose content of the six authentic juice samples analyzed enzymatically ranged from 0.01 to 0.03 g/100 mL. Since the R_t of galactose is very close to that of xylose and both minor sugars elute between the large glucose and fructose peaks (Fuleki and Pelayo, 1993), galactose was not detected on the chromatograms. Raffinose is a minor component of sugar beets, and oligosaccharides had been suggested as indicators of beet medium invert sugar addition to fruit juices (Swallow et al., 1991); therefore, the natural occurrence of raffinose and stachyose in apple juice is significant.

In addition to the chromatographic peaks for the above compounds there were, in most authentic and commercial apple juices, a very small and a much larger peak eluting at around 6.2 and 24 min, respectively. The compound eluting of around 6.2 min did not absorb in the UV and coeluted with the stachyose standard. On the basis of the above data the compound in this peak was tentatively identified as stachyose. Stachyose concentation in the examined cultivars ranged from 0 to 0.01 and from 0 to 0.02 g/100 mL of juice produced from fresh and stored apples, respectively. The UV absorption maxima of the unidentified peak eluting at around 24 min were at 202, 196, and 210 nm. Spectral analysis with the diode array detector indicated that there were at least two compounds present in this peak (Figure 2). The size of the peak was cultivar dependent, present in relatively large quantities in RI Greening, Moira, and Trent.

Authentic Varietal Apple Juice. The results of the analyses on authentic juices produced from fresh and stored fruit of 11 apple cultivars grown in three apple-growing regions of Ontario in 1989 and 1990 are presented in Table 3. A comparison of the results with those in the literature shows that the values reported here were within the literature ranges for most components. Sorbitol was the only exception, for which 31 samples were below the minimum reported in the literature.

Effects of Cultivar. It is well established in the literature that cultivar will affect the amount of total sugars as well as the proportion of individual sugars in apples (Lott, 1943; Dako et al., 1970; Lee et al., 1970; Hansen and Rumpf, 1979; Sharma et al., 1988; Fourie et al., 1991; Blanco et al., 1992) and apple juice (Eoff, 1917; Evans, 1928; Tavernier and Jacquin, 1952; Brown and Harvey, 1971; Brause and Raterman, 1982; Lee and Mattick, 1989).

The data presented here support this view. The sugar composition of the cultivars was compared using Duncan's multiple-range test on the 1989 and 1990 data. The results

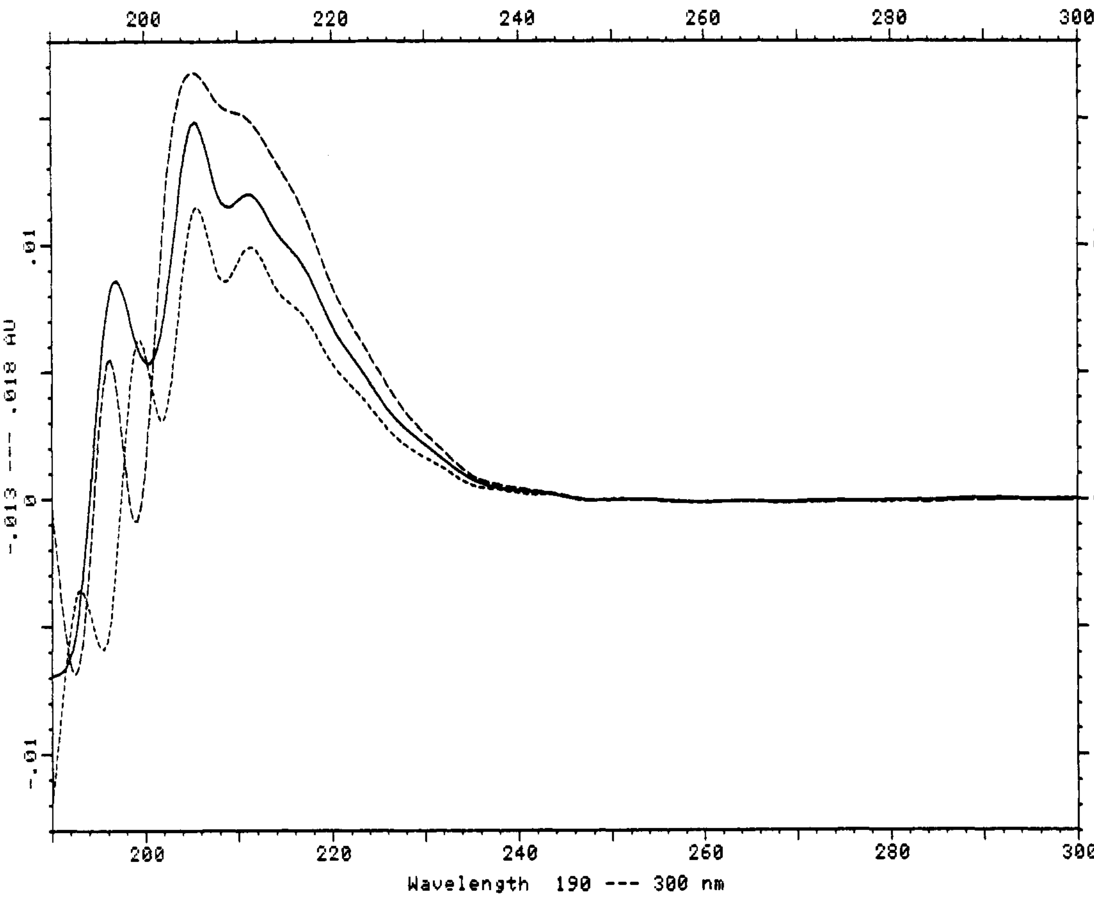

Figure 2. Spectral analysis of the unidentified peak in the neutral fraction of RI Greening apple juice eluting at 24.2 min: peak center (—), early (- - -), and late (– – –) eluting segment.

from Sf, where we had the largest number of cultivars available (Table 4), show that there were significant differences in glucose, fructose, raffinose, total sugar, ratios of fructose/glucose (F/G), and HF/HG. A similar pattern emerged when the five cultivars that were available from both Sf and S in 1989 and 1990 were compared. However, the difference in xylose content was also significant in this case, while that of the total sugar became nonsignificant.

Effects of Growing Area. The effects of growing area on the sugar composition of fresh and stored apples were compared with those cultivars that were analyzed from both locations (S and Sf) in the same year. The results showed no significant difference except for raffinose, which was significantly lower in the juice produced from stored apples grown at S.

According to the literature, quoted by Smock and Neubert (1950), the sugar content of apples varies from location to location. However, the studies they referred to did not evaluate the statistical significance of the differences found between locations. The large-scale 3-year study sponsored by the Processed Apple Institute found significant differences only in °Brix and sorbitol and glucose content of authentic varietal apple juice from eight states of the United States (Lee and Mattick, 1989). Since the number of cultivars studied in each state varied from one to seven, the differences found could be partly attributed to varietal differences. It should also be noted that the climatic differences among the surveyed states are considerably greater than those found among the apple-growing regions of Ontario.

Effects of Growing Season. Data on the influence of growing season on the sugar composition of the juice from those apple cultivars that were available in both years are presented by growing area in Table 5. The results show that the glucose content was significantly higher in 1989 in the six cultivars from S and the five cultivars that were available from both S and Sf. Raffinose content was significantly higher in 1989 at both locations.

A study carried out in the Washington, DC, area with 216 cultivars over a period of 6 years showed that warm and sunny seasons resulted in the highest concentrations of sugars as long as the lack of precipitation was not a limiting factor (Caldwell, 1928). Trautner and Somogyi (1978) reported significant seasonal differences in sucrose, glucose, and fructose contents of the ripe fruit of four apple cultivars in the 3 years studied. However, the apples for their study were obtained from a commercial supplier; therefore, it is unlikely that the fruit originated from the same orchard every year. It is known that cultural practices (e.g., overcropping) will affect the sugar composition of apples (Kondo, 1992). Mattick and Moyer (1983) in their large-scale 3-year study found no significant differences from year to year in the sucrose, glucose, fructose, sorbitol, total sugar, °Brix, F/G, or HF/HG of apple juice.

Effects of Storage. Since sortouts from storages and overstored apples are utilized for juice production, the composition of juice made from apples stored for 6 months was also studied. The sugar compositions of juice made from apples for which both fresh and stored fruits were available were compared by year (Table 6). The results show highly significant differences in every one of the identified components and their indexes except raffinose, sorbitol, total sugar in both years, and TSS in 1989. The sucrose content decreased while both the fructose and glucose concentrations increased on storage, indicating that sucrose was inverted. About one-third of the decrease in sucrose could not be accounted for by the increase in fructose and glucose contents, suggesting that some sugar

Table 3. Sugar Composition of Juice Produced from Fresh and Stored Fruit of Apple Cultivars Grown at Three Apple-Growing Regions of Ontario

				g/100 mL									
cultivar	region[a]	storage[b]	year	sucrose	glucose	fructose	xylose	raffinose	sorbitol	total	TSS, %	F/G	HF/HG[c]
Delicious	S	F	1989	2.94	2.05	5.89	0.11	0.02	0.27	11.28	13.0	2.87	2.07
	S	S	1989	1.72	2.64	6.66	0.15	0.01	0.25	11.43	13.2	2.52	2.13
	S	F	1990	3.72	1.41	5.27	0.08	0.01	0.33	10.82	12.5	3.74	2.15
	S	S	1990	2.46	2.19	5.89	tr[d]	0.01	0.27	10.83	13.0	2.69	2.06
	Sf	F	1989	2.73	2.08	6.07	0.11	0.02	0.33	11.34	12.6	2.91	2.13
	Sf	S	1989	1.30	2.48	6.63	0.15	0.02	0.29	10.87	12.4	2.67	2.31
	Sf	F	1990	2.72	1.79	5.69	0.09	tr	0.18	10.47	12.0	3.18	2.21
	Sf	S	1990	1.43	2.42	6.68	0.17	0.01	0.24	10.95	12.6	2.75	2.34
	V	F	1989	2.63	2.06	5.60	0.10	0.01	0.33	10.73	12.5	2.71	2.03
	V	S	1989	1.32	2.65	6.22	0.15	0.01	0.23	10.58	12.3	2.34	2.07
	V	F	1990	2.64	1.79	5.68	tr	0.01	0.17	10.30	12.3	3.17	2.22
	V	S	1990	1.14	2.56	6.59	tr	tr	0.19	10.49	12.5	2.57	2.27
Empire	S	F	1989	4.20	0.79	5.19	0.08	tr	0.25	10.51	12.0	6.56	2.47
	S	S	1989	2.50	1.47	6.02	0.15	0.02	0.33	10.49	11.5	4.08	2.63
	S	F	1990	2.61	0.99	4.83	0.09	tr	0.09	8.61	10.2	4.88	2.63
	S	S	1990	1.34	1.35	5.15	0.14	tr	0.22	8.20	9.8	3.83	2.85
	Sf	F	1989	4.53	0.96	5.70	0.09	0.01	0.36	11.65	13.3	5.94	2.42
	Sf	S	1989	2.74	1.45	5.72	0.12	0.02	0.42	10.47	12.2	3.95	2.48
	Sf	F	1990	3.90	1.05	5.63	0.10	0.01	0.33	11.02	12.4	5.38	2.48
	Sf	S	1990	2.77	1.41	5.78	0.16	0.02	0.35	10.49	12.0	4.10	2.52
	V	F	1989	4.34	0.70	5.30	0.08	0.02	0.39	10.83	12.8	7.52	2.54
	V	S	1989	2.73	1.35	6.03	0.13	0.02	0.39	10.65	12.4	4.47	2.68
Golden Delicious	S	F	1989	2.60	1.95	6.09	0.10	0.01	0.19	10.94	12.5	3.12	2.25
	S	S	1989	1.30	2.10	6.39	0.15	tr	0.18	10.12	11.7	3.05	2.54
	Sf	F	1989	4.34	1.56	6.76	0.11	0.02	0.42	13.21	15.0	4.32	2.35
	Sf	S	1989	1.70	1.80	6.61	0.15	0.02	0.25	10.53	11.9	3.67	2.78
	Sf	F	1990	3.20	1.86	6.76	0.10	0.01	0.32	12.25	13.7	3.65	2.39
	Sf	S	1990	1.62	1.76	7.08	0.17	0.01	0.29	10.93	12.8	4.03	3.04
	V	F	1989	1.72	2.27	5.54	0.11	0.02	0.16	9.82	11.6	2.44	2.03
	V	S	1989	1.81	2.16	6.80	0.14	0.02	0.25	11.18	12.6	3.14	2.49
	V	F	1990	1.33	1.67	5.01	0.08	0.02	0.17	8.28	9.7	3.01	2.41
	V	S	1990	0.62	1.91	5.42	0.05	0.01	0.11	8.12	9.9	2.84	2.57
Idared	S	F	1989	3.21	1.45	4.99	tr	0.03	0.24	9.93	11.9	3.43	2.12
	S	S	1989	2.21	1.69	5.40	0.04	0.01	0.28	9.63	11.6	3.19	2.30
	S	F	1990	3.48	1.00	4.90	tr	0.02	0.11	9.52	11.5	4.88	2.37
	S	S	1990	2.16	1.51	5.47	tr	tr	0.27	9.42	11.4	3.61	2.49
	Sf	F	1989	2.58	1.51	5.25	tr	0.04	0.16	9.55	11.0	3.47	2.30
	Sf	S	1989	1.31	1.81	5.57	0.05	0.05	0.24	9.03	10.5	3.07	2.50
	Sf	F	1990	4.43	0.91	5.01	0.08	0.03	0.27	10.73	12.3	5.48	2.26
	Sf	S	1990	2.32	1.57	5.41	tr	0.01	0.32	9.64	11.5	3.45	2.38
McIntosh	S	F	1989	3.12	1.05	5.76	0.09	0.01	0.20	10.23	11.6	5.49	2.75
	S	S	1989	1.21	1.59	6.14	0.15	tr	0.20	9.29	10.6	3.85	3.04
	S	F	1990	3.08	0.80	6.14	0.08	tr	0.22	10.32	12.7	7.64	3.20
	S	S	1990	1.45	1.21	6.01	0.14	tr	0.31	9.12	10.9	4.95	3.43
	Sf	F	1989	2.36	1.00	5.79	0.08	tr	0.20	9.43	11.2	5.80	3.14
	Sf	S	1989	0.80	1.50	6.45	0.12	tr	0.25	9.12	10.7	4.29	3.57
	Sf	F	1990	2.53	1.17	6.04	tr	tr	0.25	10.00	12.0	5.16	2.95
	Sf	S	1990	1.34	1.36	6.92	0.14	0.01	0.39	10.16	11.9	5.08	3.69
Moira	Sf	F	1989	2.51	1.50	4.99	0.08	tr	0.13	9.21	11.0	3.32	2.23
	Sf	S	1989	1.27	1.53	4.62	0.10	tr	0.27	7.79	9.7	3.02	2.41
	Sf	F	1990	2.89	1.03	4.90	0.08	tr	0.09	8.99	11.0	4.73	2.51
Mutsu	S	F	1989	2.89	1.43	4.67	0.07	0.01	0.22	9.29	12.4	3.27	2.10
	S	S	1989	2.11	1.90	5.80	0.14	0.01	0.29	10.25	11.7	3.06	2.30
	S	F	1990	4.80	0.89	4.90	0.09	tr	0.53	11.21	12.8	5.53	2.18
	S	S	1990	3.30	1.31	5.60	0.15	0.01	0.48	10.85	12.8	4.28	2.41
Northern Spy	S	F	1989	4.50	1.47	5.40	0.04	0.01	0.61	12.03	14.4	3.66	2.02
	S	S	1989	2.12	2.12	6.41	0.11	0.01	0.34	11.11	12.7	3.02	2.32
	S	F	1990	4.12	0.89	4.37	tr	tr	0.31	9.70	12.5	4.90	2.14
	S	S	1990	3.01	1.68	4.27	0.05	0.01	0.31	9.33	12.9	2.54	1.79
	Sf	F	1989	3.00	1.29	4.48	0.04	tr	0.19	9.00	11.4	3.46	2.11
	Sf	S	1989	2.29	1.68	5.24	0.08	0.03	0.27	9.59	11.2	3.13	2.24
	Sf	F	1990	4.72	1.08	4.89	tr	tr	0.36	11.06	13.4	4.51	2.07
	Sf	S	1990	3.21	1.57	5.37	0.09	0.01	0.41	10.66	13.1	3.41	2.16
RI Greening	Sf	F	1989	3.33	0.84	4.12	0.10	tr	0.29	8.68	11.0	4.88	2.26
	Sf	S	1989	2.29	0.93	4.78	0.16	tr	0.34	8.50	11.1	5.15	2.81
	Sf	F	1990	3.68	0.85	4.40	0.07	tr	0.30	9.30	11.7	5.15	2.27
	Sf	S	1990	2.40	0.88	4.90	0.17	tr	0.32	8.67	11.4	5.56	2.87
Spartan	S	F	1989	3.99	0.95	5.62	0.08	0.01	0.50	11.15	13.0	5.92	2.53
	S	S	1989	2.39	1.52	7.43	0.11	0.04	0.51	12.00	13.4	4.90	3.13
	Sf	F	1989	3.41	1.16	5.75	0.10	0.01	0.34	10.77	12.8	4.97	2.56
	Sf	S	1989	1.83	1.87	7.05	0.14	0.03	0.39	11.31	12.9	3.77	2.83
	Sf	F	1990	2.81	1.12	5.13	0.08	tr	0.13	9.27	11.1	4.60	2.55
	Sf	S	1990	1.71	1.44	5.63	0.13	0.01	0.25	9.17	10.9	3.91	2.79

Table 3 (Continued)

cultivar	region[a]	storage[b]	year	sucrose	glucose	fructose	xylose	raffinose	sorbitol	total	TSS, %	F/G	HF/HG[c]
				g/100 mL									
Trent	Sf	F	1989	2.25	1.67	5.34	0.04	0.02	0.37	9.69	11.8	3.20	2.29
	Sf	S	1989	1.39	2.09	6.12	0.13	0.01	0.41	10.15	12.0	2.93	2.43
	Sf	F	1990	2.43	1.71	6.31	tr	0.01	0.38	10.85	12.7	3.69	2.54
	Sf	S	1990	1.27	1.93	6.53	0.16	0.03	0.42	10.34	12.4	3.38	2.77
means (n = 77)				2.57	1.53	5.67	0.09	0.01	0.29	10.17	12.0	4.01	2.48
SD				1.02	0.48	0.74	0.05	0.01	0.10	1.04	1.0	1.17	0.37
min				0.62	0.70	4.12	tr	tr	0.09	7.79	9.7	2.34	1.79
max				4.80	2.65	7.43	0.17	0.05	0.61	13.21	15.0	7.64	3.69
authentic juice													
lit. min (ref)[e]				0.19 (8)	0.5 (6)	3.00 (9)	na[f]	na	0.16 (9)	6.2 (8)[g]	9.3 (3)	1.43 (4)	1.22 (4)
lit. max (ref)				6.31 (1)	6.46 (12)	13.58 (12)	na	na	1.67 (11)	19.40 (12)[g]	21.5 (12)	11.60 (6)	4.77 (12)
commercial juice													
lit. min (ref)				nil (2)	1.7 (2)	5.18 (7)	na	na	0.23 (7)	8.89 (7)[g]	10.5 (5)	1.53 (2)	1.47 (2)
lit. max (ref)				4.1 (2)	4.0 (2)	7.97 (5)	na	na	0.50 (7)	13.00 (10)[g]	14.2 (13)	3.37 (12)	2.62 (13)

[a] S, Simcoe; Sf, Smithfield; V, Vineland. [b] F, fresh; S, stored. [c] Fructose/glucose ratio assuming a complete inversion of sucrose. [d] For statistical calculations, trace (tr) was assumed to be 0.01 and 0.005 g/100 mL for xylose and raffinose, respectively. [e] 1, Aso and Matsuda (1951); 2, Brause and Raterman (1982); 3, Burroughs (1984); 4, Carpenter and Smith (1934); 5, Contreras et al. (1992); 6, Eoff (1917); 7, Fuch et al. (1987); 8, Lee and Wrolstad (1988a); 9, Mattick and Moyer (1983); 10, Melton and Laas (1985); 11, Ryan (1972); 12, Tavernier and Jacquin (1952); 13, Wucherpfennig et al. (1977). [f] na, not available. [g] Excludes sorbitol.

Table 4. Effect of Cultivar on Sugar Composition of Juice Produced from Fresh Apples Grown at Smithfield[a]

cultivar	N	sucrose	glucose	fructose	xylose	raffinose	sorbitol	total	TSS, %	F/G	HF/HG[b]
		g/100 mL									
Delicious	2	2.73	1.94a	5.88b	0.10	0.01b	0.23	10.90abc	12.3	3.05d	2.17ed
Empire	2	4.22	1.01c	5.67bc	0.10	0.01b	0.35	11.33ab	12.8	5.66a	2.45bc
Gldn Delicious	2	3.77	1.71ab	6.76a	0.11	0.02b	0.37	12.72a	14.4	3.99bcd	2.37bcd
Idared	2	3.51	1.21c	5.13bcd	0.05	0.04a	0.22	10.11bc	11.7	4.48abcd	2.28cde
McIntosh	2	2.45	1.09c	5.92b	0.05	0.01b	0.23	9.72bc	11.6	5.48ab	3.05a
Moira	2	2.70	1.27bc	4.95cde	0.08	0.01b	0.11	9.10c	11.0	4.03bcd	2.37bcd
Northern Spy	2	3.86	1.19c	4.69de	0.03	0.01b	0.28	10.03bc	12.4	3.99bcd	2.09e
RI Greening	2	3.51	0.85c	4.26e	0.09	0.01b	0.30	8.99c	11.4	5.02abc	2.27cde
Spartan	2	3.11	1.14c	5.44bcd	0.09	0.01b	0.24	10.02bc	12.0	4.79abc	2.56b
Trent	2	2.34	1.69ab	5.83b	0.03	0.02b	0.38	10.26bc	12.3	3.45cd	2.42bc
significance[c]		ns	**	***	ns	***	ns	*	ns	*	***

[a] Means within each column followed by the same letter are not significantly different using Duncan's multiple range test ($p = 0.05$). [b] Fructose/glucose ratio assuming a complete inversion of sucrose. [c] *, **, ***, significant at the $p \leq 0.05$, 0.01, and 0.001 confidence level, respectively, by analysis of variance; ns, not significant.

Table 5. Effect of Growing Season on Sugar Composition of Juice Produced from Fresh Apples

location and year	N	sucrose	glucose	fructose	xylose	raffinose	sorbitol	total	TSS, %	F/G	HF/HG[a]
		g/100 mL									
Simcoe											
1989	6	3.48	1.37	5.32	0.07	0.01	0.30	10.53	12.6	4.21	2.26
1990	6	3.64	1.00	5.07	0.06	0.01	0.27	10.03	12.0	5.26	2.45
significance[b]		ns	*	ns	ns	*	ns	ns	ns	ns	*
Smithfield											
1989	10	3.10	1.36	5.43	0.08	0.01	0.28	10.24	12.1	4.23	2.38
1990	10	3.33	1.26	5.48	0.06	0.01	0.26	10.39	12.2	4.55	2.42
significance[b]		ns	ns	ns	ns	*	ns	ns	ns	ns	ns
Simcoe and Smithfield											
1989	10	3.32	1.37	5.45	0.07	0.02	0.28	10.48	12.2	4.36	2.35
1990	10	3.53	1.11	5.28	0.06	0.01	0.25	10.22	12.2	4.98	2.45
significance[b]		ns	*	ns	ns	*	ns	ns	ns	ns	ns

[a] Fructose/glucose ratio assuming a complete inversion of sucrose. [b] *, **, ***, significant at the $p \leq 0.05$, 0.01, and 0.001 confidence level, respectively, by analysis of variance; ns, not significant.

was lost through respiration. This conclusion is also supported by the decrease in TSS during storage. The increase of HF/HG indicates a proportionately greater loss of glucose, which is the substrate of respiration.

A sizeable decrease in sucrose and in most cases small increases in glucose and fructose contents during storage of apples have been reported in the literature (Evans, 1928; Griffiths et al., 1950; Kidd et al., 1952; Telegdy Kováts and Lindner, 1961; Gorin, 1973; Hansen and Rumpf, 1979; Trautner and Somogyi, 1979). The significant increase in xylose content can be explained by the breakdown of cell-wall components. The xylose content of cell walls increases in postclimacteric apple (Gross and Sams, 1984), and it can be liberated by hydrolysis (Garleb et al., 1989; Prabha et al., 1990; Schols et al., 1991).

The results in Table 6 show a slight increase in sorbitol content upon storage, but this was not statistically significant. A closer examination of the data presented in Table 3 suggests that cultivar influences the metabolism of sorbitol during storage. The stored fruit of the majority of the cultivars (Empire, Idared, McIntosh, Moira, Northern Spy, RI Greening, Spartan, and Trent) had, in general,

Table 6. Effect of Storage on Sugar Composition of Apple Juice

treatment	N	g/100 mL							TSS, %	F/G	HF/HG[a]
		sucrose	fructose	glucose	xylose	raffinose	sorbitol	total			
1989 and 1990											
fresh	38	3.25	5.40	1.33	0.07	0.01	0.28	10.33	12.2	4.42	2.36
stored	38	1.89	5.97	1.75	0.12	0.01	0.30	10.03	11.8	3.59	2.59
significance[b]		***	***	***	***	ns	ns	ns	ns	***	***
1989											
fresh	21	3.20	5.44	1.42	0.08	0.01	0.29	10.43	12.3	4.25	2.32
stored	21	1.83	6.10	1.83	0.12	0.02	0.30	10.18	11.8	3.49	2.57
significance[b]		***	***	***	***	ns	ns	ns	*	***	***
1990											
fresh	17	3.31	5.35	1.23	0.06	0.01	0.26	10.21	12.1	4.62	2.41
stored	17	1.97	5.81	1.65	0.10	0.01	0.30	9.84	11.9	3.07	2.61
significance[b]		***	*	***	*	ns	ns	ns	ns	***	**

[a] Fructose/glucose ratio assuming a complete inversion of sucrose. [b] *, **, ***, significant at the $p \leq 0.05$, 0.01, and 0.001 confidence level, respectively, by analysis of variance; ns, not significant.

Table 7. Sugar Composition of Commercial Pure Apple Juice[a]

brand	container[b] and size, mL	grade	g/100 mL						TSS, %	F/G	HF/HG[d]	HMF,[e] mg/L
			sucrose	fructose	glucose	xylose	sorbitol	total				
domestic												
A	M, 1360	C	2.68	5.78	2.12	0.09	0.42	11.09	12.2	2.73	2.04	na[f]
	G, 1000	C	2.19	5.79	1.42	0.02	0.29	9.72	11.2	4.08	2.70	na
	T, 250	C	2.48	5.46	1.29	0.08	0.30	9.61	11.0	4.25	2.61	na
	T, 1000	C	1.62	5.87	2.05	0.02	0.24	9.81	11.0	2.86	2.32	na
B[g]	G, 1000	ND	1.80	6.52	2.08	**0.14**	0.39	10.93	11.8	3.13	2.46	na
	M, 1360*	ND	1.33	5.96	1.95	na	0.28	9.52	11.9	3.06	2.52	46.4
	G, 1360	ND	1.89	5.64	1.80	na	0.29	9.61	11.7	3.14	2.38	36.5
C	M, 1360*	C	0.62	6.24	2.35	na	0.35	9.56	11.7	2.66	2.45	**49.5**
D	M, 1360	C	1.48	6.52	1.75	0.08	0.29	10.13	11.8	3.72	2.88	na
	P, 2000	C	2.22	6.42	1.95	0.03	0.25	10.51	11.0	3.30	2.44	na
E	M, 1360	C	1.63	6.12	2.38	0.11	0.29	10.33	11.4	2.57	2.16	na
F	M, 1360	C	**2.94**	5.73	1.88	0.10	0.37	11.01	12.1	3.05	2.13	na
	M, 1360*	C	0.46	5.95	2.10	na	0.36	8.87	11.2	2.84	2.65	36.2
G	P, 1360	C	2.36	5.79	**1.28**	0.10	0.32	9.85	11.4	**4.53**	2.79	na
H	G, 1360	C	1.47	5.96	2.32	0.12	0.37	10.24	11.0	2.57	2.18	na
I	M, 1360	C	1.21	5.99	2.10	0.12	0.33	9.75	10.6	2.85	2.42	na
	M, 1360*	C	0.60	5.97	2.09	na	0.25	8.91	10.8	2.86	2.62	43.0
J	M, 1360	C	0.81	5.95	1.71	0.08	**0.19**	8.74	**10.2**	3.47	**2.98**	na
K	M, 1360	C	0.85	**5.37**	2.53	0.08	0.29	9.12	10.9	2.12	1.95	na
	G, 1360	C	0.54	5.89	**3.78**	0.05	0.19	10.46	11.5	**1.56**	**1.52**	na
	M, 1360*	C	0.31	5.72	2.66	na	0.29	8.98	10.8	2.15	2.09	44.3
L	G, 1360*	C	1.39	5.52	1.50	na	0.25	**8.66**	10.5	3.68	2.80	41.7
M	G, 250*	ND	1.06	6.78	2.42	na	0.32	10.59	11.8	2.80	2.46	37.2
imported												
N	M, 1360	C	1.07	5.86	2.64	tr[h]	0.35	9.92	11.3	2.22	2.01	41.2
O	M, 1360	C	0.90	5.81	2.66	tr	0.33	9.70	11.2	2.18	2.00	42.4
P	G, 1894	ND	1.03	6.24	1.86	0.10	0.40	9.63	11.3	3.36	2.82	na
Q	G, 236*	ND	**0.16**	6.09	2.92	na	0.42	9.59	11.3	2.09	2.05	36.0
R	G, 946*	ND**	2.03	6.58	2.21	na	0.50	11.33	13.1	2.97	2.33	**35.6**
S	G, 750*	C	0.69	**7.23**	2.79	na	**0.84**	**11.55**	**13.8**	2.59	2.41	43.8

[a] Minimum and maximum values within the column are in boldface. [b] M, metal can; G, glass bottle; T, Tetra Pak; P, plastic bottle; *, single sample. [c] F, fancy; C, choice; S, standard; ND, not declared; **, organically grown. [d] Fructose/glucose ratio assuming a complete inversion of sucrose. [e] HMF, (hydroxymethyl)furfural. [f] na, not available. [g] Sweetened with concentrate. [h] tr, traces.

higher sorbitol content, while some (Delicious, Golden Delicious) had lower sorbitol content than the fresh apples. The cultivar effect would explain why the literature in most cases reports an increase in sorbitol concentration upon storage (Fidler and North, 1970; Hansen and Rumpf, 1979; Ismail et al., 1980; Ackerman et al., 1992), while Stoll (1967) found a decrease in Golden Delicious apples.

Sucrose is readily inverted during storage of apples, juice/concentrate manufacturing, and storage. Furthermore, excessively high sorbitol content is present in apples with watercore (Williams, 1966). Therefore, the sorbitol/sucrose ratio proposed by Sharkasi et al. (1981) is not a reliable index of apple juice/concentrate authenticity. The sorbitol/total sugar ratio proposed by the same authors is a more reliable index.

The total sugar plus sorbitol determined by HPLC and TSS measurements for all analyzed authentic varietal apple juice samples (Table 3) correlated highly (r = 0.91638), but the latter measurement was always higher. Since TSS measures not only the sugars and sorbitol but all dissolved substances which have a different refractive index from that of water (acids, salts, etc.), this was to be expected. Other authors (Tables 1 and 2) also found that the TSS was always higher than the total sugar. A regression equation was established using all relevant data in Table 3 for the calculation of the total sugar plus sorbitol content in apple juice from the TSS measurement:

$$\text{total sugar g/100 mL} = \text{TSS} \times 0.93 - 1.05$$

Commercial Apple Juice. To get an indication of the changes in sugar content as a result of commercial processing and on the authenticity of juices available in Ontario, the sugar compositions of commercial apple juices

Table 8. Sugar Composition of Commercial Apple Juice from Concentrate[a]

brand	container[b] and size, mL	grade[c]	g/100 mL sucrose	fructose	glucose	xylose	sorbitol	total	TSS, %	F/G	HF/HG[d]	HMF,[e] mg/L
domestic												
A	M, 1360	ND	0.83	6.82	2.85	tr[f]	0.27	10.76	12.1	2.39	2.21	39.8
B	M, 1360	ND	1.53	5.27	2.42	tr	0.44	9.66	10.7	2.18	1.89	**tr**
D	G, 284*	C	1.17	4.71	1.73	na[g]	0.41	**8.01**	**9.8**	2.72	2.27	36.0
E	M, 284	C	1.35	6.32	2.63	0.09	0.40	10.78	**12.7**	2.40	2.11	na
	G, 1000	C	1.85	5.97	2.49	0.03	0.59	10.93	12.7	2.40	2.01	na
F	T, 250	C	1.99	4.51	2.52	tr	0.27	9.29	10.4	1.79	1.56	40.7
G	T, 250	C	0.82	5.56	3.60	tr	0.22	10.20	11.5	1.54	1.49	na
H	T, 250	C	1.95	5.09	**1.13**	na	0.16	8.16	10.7	**4.51**	**2.84**	38.4
I	T, 250	C	1.57	5.63	2.33	0.07	**0.64**	10.24	11.3	2.42	2.05	36.1
J	T, 250	C	1.27	4.88	3.09	tr	0.24	9.48	10.7	1.58	1.48	na
K	T, 1000	C	1.29	6.14	2.74	0.08	0.33	10.57	11.6	2.24	1.99	na
L	T, 250	C	1.19	6.33	2.91	0.10	0.42	10.95	12.4	2.18	1.97	na
M	T, 250	C	1.80	6.45	2.31	tr	0.19	10.76	12.5	2.79	2.27	72.6
	T, 1000	C	1.71	6.17	2.28	tr	0.20	10.37	12.0	2.70	2.22	**81.8**
	T, 1360	C	1.51	**6.92**	2.52	tr	0.27	11.21	12.7	2.75	2.33	49.5
N	G, 1360	C	1.01	6.51	2.69	**0.22**	0.20	10.63	12.6	2.42	1.87	na
O	T, 1000	C	1.02	5.67	3.00	tr	0.34	10.02	11.7	1.89	1.75	na
P	T, 1000	C	**0.34**	5.59	**3.76**	**nil**	0.19	9.88	11.0	1.49	1.46	na
	T, 250	C	**7.32**	**2.61**	1.98	nil	**0.08**	**11.99**	12.1	**1.32**	**1.11**	tr
Q	G, 284*	C	1.31	5.19	1.96	na	0.35	8.80	10.7	2.65	2.22	42.4
imported												
R	G, 1890	ND	1.07	6.14	2.25	tr	0.38	9.84	10.9	2.73	2.38	na
S	T, 254	ND	1.42	6.24	2.39	tr	0.53	10.56	11.6	2.61	2.23	na
T	G, 1894	ND	1.17	5.81	2.73	tr	0.35	10.05	10.8	2.13	1.92	na
V	G, 1420	ND	0.88	5.61	3.35	nil	0.59	10.42	11.7	1.68	1.59	na

[a] Minimum and maximum values within the column are in boldface. [b] M, metal can; G, glass bottle; T, Tetra Pak; *, single sample. [c] C, choice; ND, not declared. [d] Fructose/glucose ratio assuming a complete inversion of sucrose. [e] HMF, (hydroxymethyl)furfural. [f] tr, traces. [g] na, not available.

and ciders purchased locally in 1989 and 1990 were examined (Tables 7 and 8).

Most commercial "pure apple juice" had similar sugar composition (Table 7) to that found in pure authentic varietial juices (Table 3). In some cases, the sucrose, glucose, and sorbitol contents and F/G and HF/HG values were outside the range of authentic Ontario juices but still within the literature ranges for authentic apple juice. In sample J the TSS did not reach the minimum value (10.5%) required for "Choice" grade by Canadian standards.

The sugar composition of commercial "apple juice from concentrate" is presented in Table 8. Most of these juices showed sugar compositions similar to those of the authentic ones. Brand P, 250-mL size, was a notable exception: the sucrose content was higher and the fructose and sorbitol contents and F/G and HF/HG values were lower than those found in authentic juices in this study or in the literature. Undeclared addition of sucrose is suspected in this sample. Two juices (D and F) had lower concentrations of TSS than that required for "Choice" grade. The four commercial sweet ciders analyzed had sugar compositions similar to those of authentic apple juices.

While HMF is not present in apples, it is produced in the juice and concentrate as a result of thermal stress during heat processing, concentration, and storage (Pollard and Timberlake, 1971). In this study, HMF was not detected in the authentic juices but it was present in all except one of the commercial products analyzed for this compound. Curiously, the highest concentration of HMF was detected in a cider (114 mg/L). Severe browning was observed in this product, which may have been stored for too long at high temperatures. Zubeckis (1966) found 0–37.5 ppm of HMF in commercial apple juices sold in Ontario, while laboratory-prepared juices made from fresh apples contained no HMF and only traces were found in those made from apples kept in cold storage for 7 months.

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