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Compositional profiles of fruit juice concentrates and sweeteners

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Sugar, nonvolatile acid, mineral, and UV spectral profiles were determined for seven commercial fruit juice concentrates—'hard' pear, 'soft' pear, white grape, pineapple, prune, fig and raisin—and three sweeteners—invert beet, invert cane and high fructose corn syrup (HFCS). Sugar and nonvolatile acids were quantitated by high performance liquid chromatography (HPLC). Sugar analyses included glucose, fructose, sucrose and sorbitol content and nonvolatile acid determinations included quinic, malic, citric, tartaric, shikimic, and fumaric acids. L-Malic content was also determined by enzymic procedures. Mineral composition was measured by induction coupled plasma spectroscopy (ICP). Fruit juice concentrates and sweeteners have characteristic compositional profiles that are useful for evaluating juice quality and authenticity.

INTRODUCTION

Adulteration of apple and other fruit juices can range from simple addition of sugar solutions acidified with organic acids to addition of cheaper, more available fruit juices (Mattick, 1987). Deviations in sugar patterns have been used as evidence of adulteration in apple juice (Fitelson, 1970), pear juice (Koeppen, 1974; Sharkasi *et al.*, 1982), blackberry juice concentrates (Wrolstad *et al.*, 1982), and prune juice (Flynn & Wendt, 1970). The application of carbon stable isotope ratio analysis (SIRA) has been very useful in detecting the addition of corn and cane sugars to apple juice (Doner *et al.*, 1980; Doner & Phillips, 1981). When sweeteners are used to adulterate, organic acids will also have to be added to obtain the specified sugar : acid ratio. The development of enzymic methods for analysis of L-malic acid has been a breakthrough for detecting the addition of synthetic malic acid (Evans *et al.*, 1983). This method is supplemented by analysis for fumaric acid which is an impurity of commercial malic acid, being formed as a by-product in manufacturing (Junge & Spadinger, 1982).

Adulteration of apple juice with cheaper fruit juices can be more difficult to detect. Blumenthal and Helbling (1977) used a combination of sorbitol, citric acid and proline analyses to detect addition of pear juice to apple juice while Sharkasi *et al.* (1982) measured deviations in the sorbitol : sucrose and sorbitol : total sugar ratios for the same type of adulteration. Tartaric acid content is very useful as an indicator for addition of grape juice (Wucherpfennig, 1976). Increased efforts need to be given to characterization of potential adulterants so their identities in a suspect product can be established.

The major objective of this paper is to determine the sugar, nonvolatile acid, mineral, and UV spectral profiles of a selection of fruit juice concentrates and sweeteners that could serve as potential adulterants for apple or other fruit juices. While any unique characteristics will be particularly useful for detecting adulteration, the compositional information will also find application in quality evaluation and product formulation.

MATERIALS AND METHODS

Samples

The apple juice concentrate sample, 70–71° Brix, was supplied by Tree Top Inc., Selah, WA. It was produced

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from a mixture of Golden and Red Delicious varieties during the 1983 season and did not contain any essence. 'Soft' and 'hard' pear juice concentrates, 70–71° Brix, were obtained from the same firm. The 'soft' pear concentrate had been processed from Bartlett pears while the 'hard' pear concentrate was made from a mixture of Anjou and Bartletts.

Prune juice concentrate, 70–71° Brix, was obtained from Sun Diamond Growers of California, Yuba City, CA; raisin and fig juice concentrates, 70–71° Brix, from Sun Maid Growers of California, Fresno, CA; Thompson seedless white grape juice concentrate, 68° Brix, from Marko Zaninovich, Inc., Delano, CA; pineapple juice concentrate, 61° Brix, from Castle and Cooke Foods, Honolulu, HI; invert beet syrup (Type '50'), 77% solids, from Amalgamated Sugar Co., Ogden, UT; invert cane syrup (Type '50'), 77% solids, from California and Hawaiian Sugar Co., San Francisco, CA; and High Fructose Corn Syrup (HFCS), 77% solids, from Archer Daniels Midland (ADM) Corn Sweeteners, Cedar Rapids, IA.

Concentrates and sweeteners were diluted with deionized distilled water to 12·5° Brix, poured into 25 and 100 ml plastic bottles and stored at −23°C.

Apparatus

High performance liquid chromatograph (HPLC)
Varian Model LC 5000 equipped with a column heater and Varian Refractive Index and UV-50 Variable wavelength detectors (Varian Instrument Group, Walnut Creek, CA), and a Model HP 3380A recording integrator (Hewlett-Packard Corp., Avondale, PA).

HPLC columns
For sugars: Aminex HPX-87C Monosaccharide Analysis Column, 9 μm particle size, 25 cm × 7·8 mm i.d. fitted with a 3 cm × 4·6 mm i.d. Carbo-C microguard column (Bio-Rad Laboratories, Richmond, CA).

For acids: a Supelcosil LC-18 column, 5 μm particle size, 25 cm × 4·6 mm i.d. (Supelco, Inc., Bellefonte, PA) connected in series to a Nucleosil C_{18} column, 10 μm particle size, 25 cm × 4·6 mm i.d. (Alltech Associates, Inc., Deerfield, IL). This system utilized a Bio-Sil ODS-10 microguard column (Bio-Rad Laboratories, Richmond, CA).

C-18 mini columns
C_{18} SEP-PAK cartridges (Waters Associates, Milford, MA) were activated by passing 5 ml methanol through the cartridge followed by 5 ml distilled water.

UV-vis spectrophotometer
A Varian Model DMS 100 interfaced with a Varian DS-15 Data Station (Varian Instrument Group, Walnut Creek, CA) was utilized.

Reagents

HPLC mobile phase for sugar analysis
Mobile phase was prepared by adding 200 mg of $Ca(NO_3)_2$ to 1 liter of glass distilled, deionized water and filtering through a 0·45 μm Type HA Millipore filter (Millipore Corp., Bedford, MA).

HPLC mobile phase for acids
Mobile phase was prepared by mixing 20 g of KH_2PO_4 and 20 g of NaCl in 1 liter of glass distilled, deionized water, adjusting to pH 2·4 with concentrated phosphoric acid, and filtering through a 0·45 μm type HA Millipore filter.

HPLC sugar standards
These were prepared by adding 2·000 g each of reagent grade glucose (Amachem Co.), sucrose (J. T. Baker Chem. Co.), fructose (Sigma Chem. Co.), and sorbitol (Fisher Scientific Co.) to a 100 ml volumetric flask and diluting to volume with distilled water.

Sugar internal standard
This was prepared by adding 1·000 g of reagent grade mannitol (Mallinckrodt Inc.) to a 100 ml volumetric flask and diluting to volume with distilled water.

Organic acid standards I
These were prepared by adding 200 mg quinic acid, 500 mg malic acid, 500 mg tartaric acid (Sigma Chem. Co.) and 400 mg citric acid (Mallinckrodt Inc.) to a 100 ml volumetric flask and diluting to volume with distilled water.

Organic acid standards II
These were prepared by adding 40 mg shikimic acid (Calbiochemical Co.) and 10 mg fumaric acid (Aldrich Chem. Co., Inc.) to a 100 ml volumetric flask and diluting to volume with distilled water.

Determination of pH, titratable acidity and °Brix

Titratable acidity was determined according to AOAC procedure 9.017–9.019 (1984) and pH was determined using a Corning Model 125 pH meter. °Brix was measured with a table model Bausch and Lomb refractometer (Bausch and Lomb Optical Co., Rochester, NY) at 20°C.

HPLC determination of sugars and nonvolatile acids

The procedure of Hong and Wrolstad (1986) was used for sugar analyses and that of Coppola and Starr (1986) for acid analyses.

UV spectral analyses

Single strength juice samples were further diluted with distilled water (1:270) and scanned from 400 to 200 nm.

Conditions: 1·0 cm quartz cells, 1 nm slit width, and 50 nm/min scan rate. First and second derivative spectra were recomputed from original zero-order absorbance spectra.

Minerals

Samples were sent to the US Food and Drug Administration Laboratories, Cincinnati, OH, for determination of Al, As, B, Ba, Be, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sr and Zn by induction coupled plasma spectroscopy (ICP).

RESULTS AND DISCUSSION

Sugar profiles of fruit juice concentrates and sweeteners

The sugar compositions of invert cane, invert beet, and HFCS, as well as 'soft' pear, 'hard' pear, white grape, prune, pineapple, fig and raisin juice concentrates, are listed in Table 1. The data are presented as percentages of the summation of sugars and sorbitol. The glucose: fructose and sorbitol: sucrose ratios are also included. Figure 1 shows typical HPLC sugar chromatograms for some of the sweeteners and juice concentrates. Baseline resolution is achieved for the four sugars of interest in less than 20 min. The peaks for the reducing sugars, fructose and glucose, are much broader than those for the nonreducing carbohydrates, sucrose, mannitol and sorbitol. This may be caused by mutarotation of the reducing sugars.

Invert cane and invert beet have a similar profile consisting of 40–50% sucrose with the remainder being equal proportions of glucose and fructose. HFCS contains 80% fructose and 20% glucose. Absence of a maltose peak (retention time = 7·97 min) reflects the advances in corn syrup technology with complete hydrolysis of starch to monosaccharides taking place and/or maltose being removed in the ion-exchange resin refining process. This is significant as maltose levels have been used as an indicator for corn syrup addition to products such as honey (Doner *et al.*, 1979).

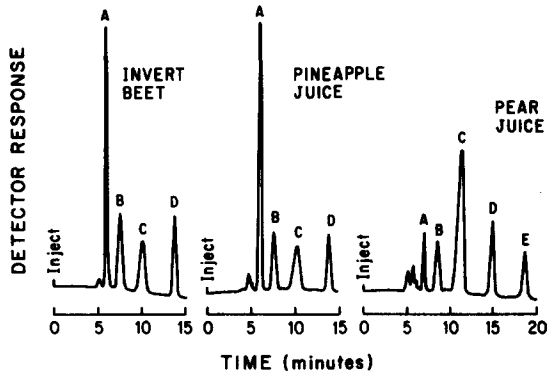

Fig. 1. HPLC chromatograms of invert beet, pineapple juice and 'soft' pear juice concentrate. Peaks: A, sucrose; B, glucose; C, fructose; D, mannitol (internal standard); E, sorbitol.

'Soft' pear juice concentrate is an industrial term for concentrates that have been made from ripened pears while 'hard' pear juice concentrate is processed from firm, unripened fruit. The sugar profile for pears is characterized by its high fructose content, low glucose: fructose ratio, and high sorbitol content. The results are within the range of reports in the literature for pear (Wrolstad & Shallenberger, 1981). The sorbitol: sucrose ratios, 0·26 for soft pear and 0·67 for hard pear, are considerably lower than the values for Bartlett (1·4) and Anjou (2·6) pear juice that were reported by Sharkasi *et al.* (1982). Sucrose inversion which can occur during processing and storage will have a pronounced effect on this ratio. Both the 'hard' and 'soft' pear concentrate samples have relatively low sucrose content. 'Hard' pear juice concentrate contains considerably more sorbitol than the 'soft' pear juice sample. Sorbitol levels are quite variable in pear fruit (Wrolstad & Shallenberger, 1981); differences in variety, maturity and post-harvest storage may all contribute to the observed differences.

White grape juice concentrate contains only glucose and fructose with no detectable sucrose or sorbitol. The

Table 1. Sugar composition of fruit juices and sweeteners[a]

Sample	Sucrose % TS + S[b]	Glucose % TS + S[b]	Fructose % TS + S[b]	Glucose/fructose ratio	Sorbitol % TS + S[b]	Sorbitol/sucrose ratio
Invert cane	47·6	26·7	25·8	1·04	0·0	0·00
Invert beet	39·2	30·7	30·1	1·02	0·0	0·00
HFCS	0·0	19·4	80·6	0·24	0·0	0·00
Soft pear	7·7	14·3	63·6	0·22	14·4	0·26
Hard pear	4·5	18·3	55·1	0·33	22·1	0·67
White grape	0·0	42·9	57·1	0·75	0·0	0·00
Prune	0·0	45·6	24·7	1·85	29·7	0·00
Pineapple	52·8	21·8	25·4	0·86	0·0	0·00
Fig	0·6	49·1	50·3	0·98	0·0	0·00
Raisin	0·0	45·7	54·2	0·83	0·0	0·00

[a] Results are means of duplicate analyses.
[b] Per cent of sucrose and glucose and fructose and sorbitol by summation.

fructose content is slightly higher than the glucose content, 57% and 43% respectively, which is in agreement with the values reported by Hurst *et al.* (1979)—55% for fructose and 45% for glucose. The HPLC chromatogram for grape juice showed a small distinct peak before mannitol which had the same retention time as glycerol (13·2 min).

Raisin and fig juice concentrates both have patterns similar to white grape in that they contain mainly glucose and fructose in nearly equal amounts, 49% and 50% for fig and 46% and 54% for raisin. A glucose: fructose ratio approximating 1·00 agrees with reports of Hurst *et al.* (1979) and (McBean *et al.*, 1971). Fig does contain a trace amount of sucrose.

Prune juice concentrate shows a distinctly different sugar profile, containing nearly twice as much glucose as fructose and very high sorbitol levels (30% of total sugars). These results agree with reports of Hurst *et al.* (1979) and Wrolstad and Shallenberger (1981).

Pineapple juice concentrate has a profile similar to the 'invert' sugar syrups. It contains 53% sucrose and 47% reducing sugars with glucose and fructose being present in approximately the same amounts. This is consistent with the values reported by Kline *et al.* (1970). Fully mature pineapple fruits contain about 2/3 sucrose and 1/3 reducing sugars in equal proportion. However, there is some sucrose inversion which occurs during juice processing and storage (Mehrlich & Felton, 1980).

The glucose: fructose ratio along with sorbitol and sucrose content are useful indices for distinguishing these juice concentrates and sweeteners. If apple juice were adulterated with prune juice concentrate, the high sorbitol content and high glucose: fructose ratios of prune should allow for its detection if the level of adulteration is substantial. (Refer to the sugar data base published by Mattick and Moyer (1983) and Wrolstad and Shallenberger (1981).) The glucose: fructose ratio is five times higher for prune than apple, while invert cane, invert beet, white grape, pineapple, fig and raisin juice concentrates all have glucose: fructose ratios which are 2–3 times greater than apple. The glucose: fructose ratios for HFCS, 'soft' pear and 'hard' pear, however, are within the range of authentic apple juice (0·21–0·54). While sucrose content has limited use in detecting adulteration because of its wide variability, gross adulteration with commercial sugars might be detected. Invert cane, invert beet and pineapple juice contain twice as much sucrose as apple juice while the other juices and HFCS contain much lower or no sucrose at all.

Table 2. Titratable acidity (TA) and pH of fruit juices[a]

Sample	pH	TA	
Soft pear	4·08	0·27	(as malic acid)
Hard pear	4·13	0·29	(as malic acid)
White grape	3·77	0·24	(as malic acid)
Prune	3·86	0·93	(as quinic acid)
Pineapple	3·42	0·87	(as citric acid)
Fig	4·31	0·20	(as citric acid)
Raisin	3·36	0·35	(as tartaric acid)

[a] Results are means of duplicate analyses.

Nonvolatile acid profiles of fruit juices

Table 2 lists the pH and titratable acidity for the apple, 'soft' pear, 'hard' pear, white grape, prune, pineapple, fig and raisin juice concentrate samples while Table 3 gives the nonvolatile acid composition. Results for the individual acids are presented both as mg/100 ml and as a percentage of the total acids by summation. Pineapple and prune juice concentrates are highest in total acids while white grape is the lowest. Precipitation of tartaric acid during processing of grape juice probably accounts for that sample's low acidity. 'Hard' pear is over 50% higher in total acids than 'soft' pear juice concentrate. Fruits typically reach a maximum in total acidity during ripening which is then followed by an almost linear decline (Ulrich, 1970); differences in maturity probably account for much of the difference in acidity between the two pear samples.

Figure 2 shows the HPLC chromatograms of the juice concentrate nonvolatile acids. The chromatograms

Table 3. Nonvolatile acid composition of fruit juices[a]

Sample	Tartaric		Quinic		Malic		Shikimic		Citric		Fumaric		Total acids (mg/100 ml)[a]
	mg/100 ml[b]	%TA[c]	mg/100 ml[b]	%TA[c]	mg/100 ml[b]	%TA[c]	mg/100 ml[b]	%TA[c]	mg/100 ml[b]	%TA[c]	mg/100 ml[b]	%TA[c]	
Soft pear	0·0	0·0	73·1	20·4	172·5	48·1	5·35	1·49	106·7	30·0	1·13	0·31	359
Hard pear	0·0	0·0	34·3	6·3	491·1	89·6	6·28	1·15	6·4	3·0	0·18	0·03	548
White grape	67·8	32·9	0·0	0·0	100·3	49·0	0·90	0·44	36·3	17·7	0·12	0·06	205
Prune	0·0	0·0	831·4	88·2	97·5	10·3	2·00	0·21	10·5	1·1	0·96	0·10	942
Pineapple	0·0	0·0	11·8	1·2	279·2	28·6	0·16	0·00	684·7	70·1	0·32	0·03	976
Fig	0·0	0·0	4·4	1·9	30·1	12·9	1·10	0·47	197·6	84·5	0·56	0·24	234
Raisin	392·0	73·3	54·8	10·0	27·9	5·1	0·40	0·07	74·2	13·5	0·25	0·05	550

[a] Results are means of duplicate analyses.
[b] Normalized to 12·5° Brix.
[c] Per cent total acids.

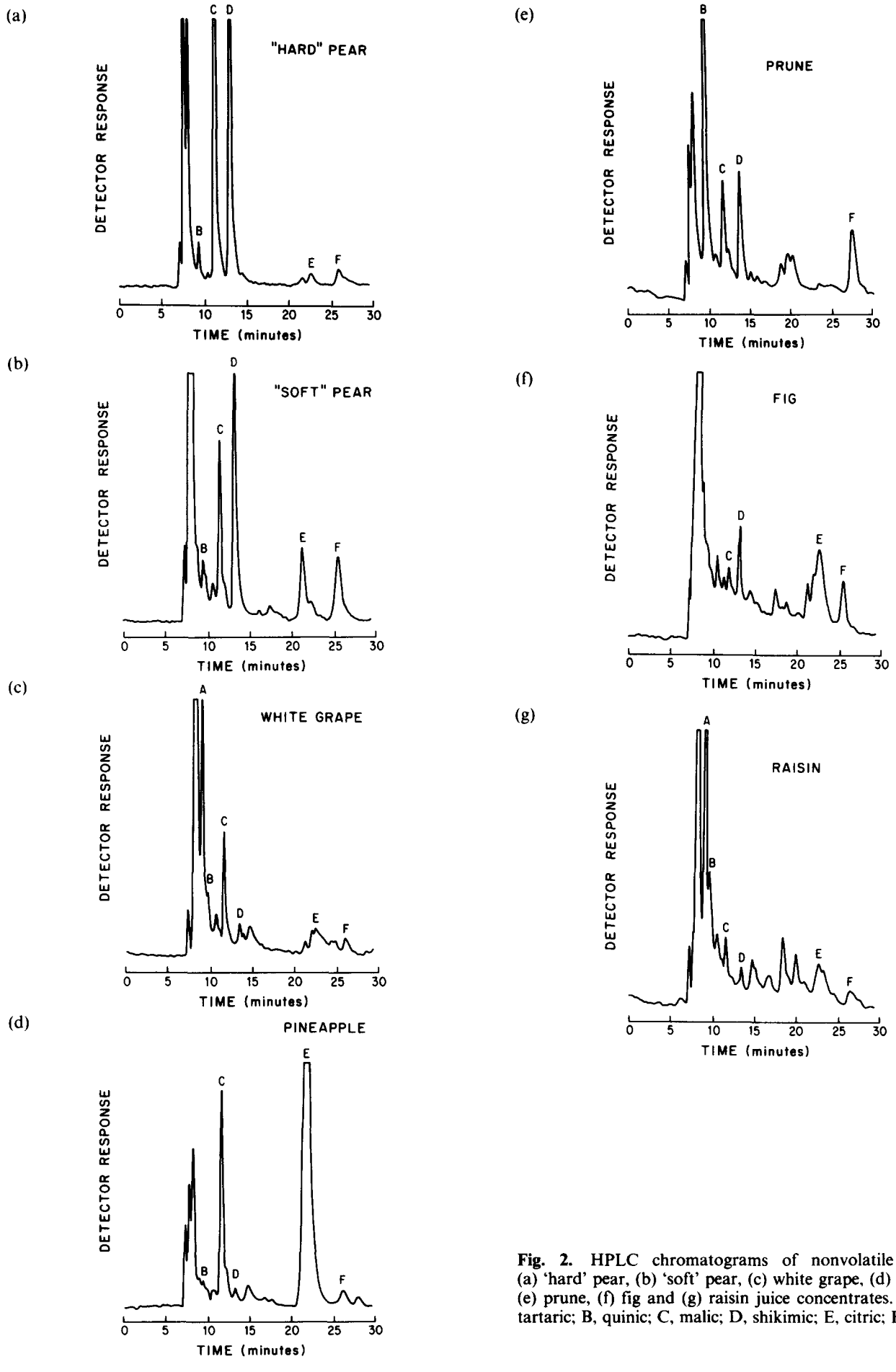

Fig. 2. HPLC chromatograms of nonvolatile acids in (a) 'hard' pear, (b) 'soft' pear, (c) white grape, (d) pineapple, (e) prune, (f) fig and (g) raisin juice concentrates. Peaks: A, tartaric; B, quinic; C, malic; D, shikimic; E, citric; F, fumaric.

for 'soft' and 'hard' pear are qualitatively similar, except that 'hard' pear has a pronounced shoulder on the citric acid peak which is identical in retention time to succinic acid. Succinic acid has been reported to be present in pears in trace quantities (Li & Hansen, 1964). In addition to the differences in total acids, the relative amounts of the individual acids differ between 'soft' and 'hard' pear. 'Hard' pear contains proportionately more malic acid, 90% versus 48%, while 'soft' pear is relatively higher in quinic and citric acids. Akhavan and Wrolstad (1980) showed that decreased malic acid and to a lesser extent citric acid were responsible for the reduction in acidity of Bartlett pears during ripening. Preferential use of these acids as respiratory substrate will result in proportionately higher amounts of quinic acid. Varietal differences could also contribute to the differences in the acid profile as while Bartlett pears have been reported to contain as much as 37% citric acid (Li & Hansen, 1964), only trace quantities of citric were reported for Anjou and Bosc (Chen *et al.*, 1982). 'Soft' pear contains over five times as much fumaric acid as 'hard' pear. The quantities of this minor acid in authentic juice concentrates are particularly significant as levels in excess of 3 ppm in apple juice has been suggested as an indicator for the presence of synthetic malic acid (Junge & Spadinger, 1982; Evans *et al.*, 1983). Zyren and Elkins (1985) commented that the standard needed to be revised upwards for juice made from concentrates. 'Soft' pear, prune, pineapple and fig juice concentrates all have in excess of 3 ppm fumaric acid. Trace quantities of tartaric acid have been reported to occur in pears (Li & Hansen, 1964). Poor resolution between the sugar and tartaric acid peaks makes it difficult to ascertain trace quantities, but the shoulder on the sugar peak in the 'soft' pear sample could be due to tartaric acid.

Malic acid (49%) and tartaric acid (33%) are the major acids of white grape juice concentrate, potassium acid tartrate precipitation probably accounting for the relatively low total acidity and tartaric acid concentrations. The levels of malic, tartaric, and citric acids are similar to those of previous reports (Wrolstad *et al.*, 1981). Raisin juice concentrate contains more tartaric (73%) than malic acid (28%). Quinic, citric, shikimic, and fumaric acids are also present in both these samples as well as several unidentified peaks. Succinic, pyruvic, α-oxoglutaric, glyceric, glycolic, and dimethylsuccinic acids have all been identified as trace acids in grapes (Peynaud & Ribereau-Gayon, 1971) and might account for some of the unidentified peaks in both chromatograms.

Pineapple juice concentrate is highest of the samples in total acids, citric acid accounting for 70% and malic 29% of the total acids. These values are similar to those reported by Ryan and Dupont (1973). Singleton and Gortner (1965) found that citric acid occurs at low concentrations until the last 60 days of fruit development when it increases rapidly to levels several times that of malic acid. Trace quantities of quinic, shikimic and fumaric are also present, which has not been previously reported. These acids seem to be ubiquitous in fruits so it is not surprising that they are found in minor quantities. Ascorbic and oxalic acids have also been reported to be present in pineapple (Mehrlich & Felton, 1980).

Fig juice concentrate has a profile similar to pineapple containing 85% citric and 13% malic acid. In addition to quinic, shikimic and fumaric acids, there are several unidentified peaks.

Prune juice has a distinctly different profile, containing 88% quinic and 10% malic acid. This pattern is similar to that reported for prune juice by Ryan and Dupont (1973). French and Petite varieties are the major source for production of prune juice in California, the largest processing area in the USA (Stebbins, R. L., pers. comm., 1986). Italian prunes have a reverse pattern, containing 88% malic and 10% quinic (Fernandez-Flores *et al.*, 1970; Romani & Jennings, 1971). In addition to shikimic, citric and fumaric acids there are several unidentified minor peaks in the chromatogram (Fig. 2).

Table 4 compares the L-malic acid content of the samples as measured by enzymic procedures with total malic as determined by HPLC. There is reasonable agreement except for the white grape, prune and raisin juice samples. The results suggest that the high fumaric content of 'soft' pear, fig, and pineapple is not due to presence of synthetic malic acid.

The AOAC approved HPLC method for apple juice and cranberry juice cocktail nonvolatile acids (Coppola & Starr, 1986) needs some modification to improve the quantitation of white grape, prune, fig and raisin juice acids. Removal of interfering UV-absorbing compounds by sample clean-up with ion exchange resins or through use of a refractive index detector should

Table 4. Comparison of L-malic and total malic acid of fruit juice concentrates as determined by HPLC and enzymic methods

Sample	Malic acid (mg/100 ml)		L-malic : total malic
	HPLC	Enzymatic	
Soft pear	170·1	176·2	1·04
	175·0	189·7	1·08
Hard pear	459·8	467·1	1·02
	522·4	481·5	0·92
White grape	100·3	141·2	1·40
	97·5	161·1	1·65
Prune	85·3	147·3	1·73
	109·6	150·2	1·37
Pineapple	290·7	312·5	1·07
	267·7	304·8	1·14
Fig	28·6	26·1	0·91
	31·7	28·2	0·89
Raisin	29·7	45·0	1·51
	26·1	43·4	1·66

Table 5. Mineral composition of fruit juices and sweeteners[a,b]

Sample:	Al	B	Ba	Ca	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Zn
Sample detection limit:	0·30	0·04	0·01	0·04	0·03	0·10	0·80	0·20	0·02	0·03	0·09	0·30	0·03	0·02
Invert beet	—[c]	—	—	1·8	0·19	0·4	0·25	2·8	—	156	—	1	—	0·36
Invert cane	—	—	—	9·6	0·15	0·3	8	2·7	—	35	—	—	—	—
HFCS	—	—	—	0·5	—	—	—	—	—	—	—	—	—	—
Raisin juice	13·0	11·7	0·39	355	0·33	53·8	695	479	4·50	1	—	1 120	4·84	2·62
	13·3	13·0	0·47	344	0·33	53·4	543	480	4·51	137	0·30	1 100	4·73	2·61
Pineapple juice	0·7	2·1	0·57	671	2·16	5·3	5 740	694	61·60	36	2·40	283	3·36	2·86
	1·0	2·2	0·70	659	2·09	5·3	nd	686	60·60	34	2·40	275	3·31	2·84
Hard pear	2·3	13·1	0·90	447	2·74	17·4	8 090	432	5·84	198	0·40	664	0·98	3·40
	2·5	14·5	1·12	452	2·72	17·5	nd	434	5·91	193	0·30	663	1·03	3·49
Soft pear	4·2	15·6	3·89	606	2·26	22·1	8 700	528	3·32	275	0·30	494	3·65	6·35
	4·6	17·5	4·81	614	2·25	22·2	nd	527	3·38	269	0·40	491	3·66	6·30
White grape	3·3	14·2	0·34	500	1·60	4·7	3 210	369	4·66	101	—	799	2·84	3·15
	3·3	15·8	0·43	504	1·58	4·6	nd	368	4·72	98	—	792	2·82	3·08
Fig	1·9	5·3	0·60	144	0·37	10·1	8 060	204	0·61	123	1·20	877	1·56	2·12
	2·1	5·7	0·73	139	0·36	9·8	nd	192	0·63	122	1·10	866	1·56	2·02
Prune	34·6	17·3	2·12	515	0·66	37·5	8 100	584	12·90	320	0·50	784	3·67	6·25
	37·4	18·4	2·58	510	0·67	37·2	nd	576	13·40	319	0·60	769	3·61	6·18

[a] Values are in μg/g units.
[b] Results are duplicate analyses except for the sweeteners.
[c] Less than detection limit (As, Cd, Cr, Mo, Pb and Be < detection limit in all samples).
nd, Not determined.

improve the analysis for those commodities as it did for red raspberry juice (Spanos & Wrolstad, 1987).

Mineral composition of fruit juices and sweeteners

The aluminium (Al), boron (B), barium (Ba), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), phosphorus (P), strontium (Sr) and zinc (Zn) contents of the sweeteners and the fruit juices are listed in Table 5. Inspection of the data shows that all the fruit juices are high in K except for raisin. White grape is next lowest in K which might be caused by potassium acid tartrate precipitation (Morris *et al.*, 1980). Ca, Mg and P are present in similar and substantial quantities in the juices. Prune is relatively high in Al and Ba. Raisin juice concentrate is relatively high in Al, Fe and P and low in Cu and K. Fig appears to be low in B, Ca, Mg, Cu and Fe. Pineapple exhibits a different profile, being high in Mn and low in B, Fe, Na and P.

The sweeteners are low in metal ions except for the Na content of invert beet and cane sugar. The absence of Na in HFCS supports White's conclusion that the Na:K ratio is not reliable for detecting adulteration of honey with corn syrup (White, 1977).

Spectral profiles of fruit juices

The UV spectra of the fruit juices are similar, all of them showing absorbance maxima at 280–290 nm which is characteristic of phenolics. The sweeteners, on the other hand, have insignificant absorbance at 280–290 nm. Table 6 lists the absorbance intensities at 280–290 nm of the fruit juices and the sweeteners in decreasing order. Raisin, prune and fig have markedly higher intensities than the other fruit juices.

Key findings

Prune juice is characterized by its high sorbitol content, high glucose : fructose ratio, high quinic acid content and high UV absorbance at 280–290 nm. Pear juice has high sorbitol levels and a low glucose : fructose ratio. 'Hard' pear and 'soft' pear differ in their total acidity and their nonvolatile acid profile, 'hard' pear containing proportionately more malic and fumaric acids and less citric and quinic than 'soft' pear. The substantial quantity of tartaric acid is unique to white grape and raisin juice concentrate, with raisin containing relatively more tartaric than white grape. White grape, raisin and fig have similar sugar profiles with essentially equal

Table 6. Absorbance of fruit juices (single strength = 12·5° Brix) at 280–290 nm

Sample	Absorbance at 280–290 nm
Raisin	378
Prune	354
Fig	149
Hard pear	32
Pineapple	23
Soft pear	14
White grape	10
Invert beet	0·21
HFCS	0·15
Invert cane	0

amounts of fructose and glucose and trace or no detectable sucrose. The sugar profile for pineapple (50% sucrose and equal amounts of glucose and fructose) is similar to invert beet and cane sugars.

The mineral, nonvolatile acid, and UV spectral profiles do not provide any characteristic markers for HFCS or cane and beet invert syrups.

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