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Technical paper

Sugar and Organic Acid Composition in the Fruit Juice of Different *Actinidia* Varieties

Ichiro Nishiyama[1*], Tetsuo Fukuda[2], Atsuko Shimohashi[1] and Tadachika Oota[1]

[1] *Department of Food and Nutrition, Komazawa Women's Junior College, Inagi, Tokyo 206-8511, Japan*
[2] *Fuchu Branch, Kagawa Agricultural Experiment Station, Sakaide, Kagawa 762-0024, Japan*

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Soluble sugars, sugar alcohol, and organic acid contents in *Actinidia* fruits at the eating-ripe stage were determined in various genotypes using high-performance liquid chromatography: five *A. deliciosa*, seven *A. chinensis*, two *A. rufa*, eight *A. arguta*, and three interspecific hybrids. The main soluble sugars in *A. deliciosa* and *A. rufa* fruits were glucose and fructose, although sucrose was present in smaller amounts. In contrast, sucrose was the predominant sugar in *A. arguta* fruits, followed by fructose and glucose. Most *Actinidia* fruits tested here contained *myo*-inositol as a sugar alcohol component. In particular, *myo*-inositol contents in *A. arguta* fruits were 0.575–0.982 g/100 g fresh weight, which is the highest level among all foods. Regarding the organic acid component, citric and quinic acids predominated over malic acid in all *Actinidia* fruits tested. Compared to *A. deliciosa* and *A. chinensis*, the proportion of quinic acid was higher in *A. rufa* and lower in *A. arguta*.

Keywords: *Actinidia* spp., kiwifruit, sugar, organic acid, *myo*-inositol

Introduction

The kiwifruit industry has made remarkable progress since the fruit was introduced to the world market from New Zealand in the 1950s (Ferguson, 2004). The export of fresh kiwifruit from New Zealand led to rapid expansion of kiwifruit plantings (Ferguson and Huang, 2007), and the fruit is now grown in many countries, especially in Italy, China, France, Greece, and Japan in the northern hemisphere, and in New Zealand and Chile in the southern hemisphere. Consequently, kiwifruit has become a commonly consumed fruit that is easily obtainable year-round in many countries.

Although the genus *Actinidia* is composed of 76 species and about 125 taxa (Ferguson and Huang, 2007), until recently, the kiwifruit market has been dominated by a single cultivar, *Actinidia deliciosa* 'Hayward.' Its fruit possess several beneficial attributes such as excellent flavor, green flesh color, high vitamin C content, and exceptionally long storage life. In 2000, the yellow-fleshed fruit of a novel cultivar, *A. chinensis* "Hort16A", which was developed in New Zealand, made its entry into the world market. In addition, some novel cultivars of kiwifruit and the related *Actinidia* crops have recently been introduced into the world market on a small scale; others are anticipated in the near future (Ferguson and Huang, 2007; Nishiyama, 2007). These *Actinidia* fruits have a wide diversity in size, shape, hairiness, flesh color, and flavor. Differences are also apparent in their vitamin C contents (Ferguson and MacRae, 1992; Nishiyama *et al.*, 2004), carotenoids such as lutein and β-carotene (McGhie and Ainge, 2002; Montefiori *et al.*, 2005; Nishiyama *et al.*, 2005), and a cysteine protease actinidin (Nishiyama and Oota, 2002; Nishiyama, 2007).

The fruit flavor can be affected by amounts of several constituents including sugars, organic and amino acids, and volatile aromatic compounds. In particular, the flavor of the fruit flesh is highly dependent on the balance between soluble sugars and non-volatile organic acids. Kiwifruit contain sugars such as glucose, fructose, and sucrose (Pérez *et al.*, 1997; Sanz *et al.*, 2004), and organic acids such as citric, quinic, malic, and ascorbic acids (Sanz *et al.*, 2004). These sugars present different sweetness level; also, the organic acid gives a different perception of acidity (Marsh *et al.*,

*To whom correspondence should be addressed.
E-mail: nishi@komajo.ac.jp

2004). Consequently, the composition of these sugars and organic acids, as well as sugar/acid balance, probably influences the taste of the flesh.

In this study, profiles of soluble sugars, sugar alcohol, and organic acids were examined in eating-ripe fruits of 25 different *Actinidia* varieties in order to elucidate fundamental data on their sensory and nutritional properties.

Materials and Methods

Fruit materials Fruit samples of five *A. deliciosa*, seven *A. chinensis*, two *A. rufa*, eight *A. arguta*, and three interspecific hybrid genotypes were used for experiments. Some characteristics of the fruit of each genotype are described in Table 1. Fruits of 'Elmwood' were obtained from Sawanobori Kiwifruit Farm in Tokyo, Japan. Fruits of 'Hongyang' and 'Kobayashi39' were generous gift from Kobayashi Farm in Shizuoka, Japan. Fruits of 'Hort16A' imported from New Zealand and fruits of 'Ananasnaya' imported from the US were purchased from markets in Tokyo. Fruits of all other genotypes were obtained from the experimental orchards at Kagawa Agricultural Experiment Station, Kagawa, Japan.

Fruits samples of *A. arguta* were ripened naturally at 15ºC. Fruits of other species were treated with 100 ppm ethylene in sealed polyethylene bags (0.03-mm thickness) at 15 ºC for 24 h, and allowed to ripen at the same temperature. Fruits at the eating-ripe stage were subjected to the experiments.

Preparation of samples Fruit extract for sugar and organic acid determination was prepared from six sample batches, each containing three (*A. deliciosa* and *A. chinensis*) or five fruits (*A. rufa* and *A. arguta*). Fruit samples of each cultivar were first peeled; the edible part, including seeds and cores, was then pulped using a domestic food processor (Cuisinart LPP2JW, Cuisinart, Stamford, CT, USA). The ex-

Table 1. *Actinidia* genotypes examined.

Species Genotype	Color of flesh	Density of hairs	Fruit weight (g)
A. deliciosa			
Hayward	green	dense	99.6 ± 7.8
Bruno	green	dense	109.8 ± 11.3
Abbott	green	dense	87.8 ± 12.0
Elmwood	green	dense	119.4 ± 12.9
Koryoku	deep green	dense	95.1 ± 7.8
A. deliciosa x *A. chinensis*			
Sanryoku	yellow green	sparse or absent	109.0 ± 10.1
A. chinensis			
Jiangxi 79-1 [a]	yellow	sparse or absent	94.5 ± 8.3
Golden king	yellow	sparse or absent	133.9 ± 12.4
Kuimi [b]	yellow	sparse or absent	106.5 ± 13.8
Sanuki gold	deep yellow	sparse or absent	163.4 ± 24.5
Hongyang [c]	yellow, partly red	absent	77.5 ± 3.7
Kobayashi39	yellow	sparse or absent	105.5 ± 6.4
Hort16A [d]	yellow	sparse or absent	87.2 ± 4.4
A. rufa			
Awaji	deep green	absent	9.0 ± 0.8
Fuchu	deep green	absent	15.0 ± 3.1
A. arguta			
Hirano	green	absent	6.2 ± 0.6
Gassan	green	absent	11.0 ± 1.4
Issai	green	absent	6.3 ± 0.8
Mitsuko	green	absent	8.2 ± 0.8
Kochi	green	absent	10.0 ± 1.2
Shimane	green	absent	7.4 ± 1.3
Nagano	green	absent	9.2 ± 1.0
Ananasnaya [e]	green	absent	6.1 ± 0.6
A. arguta x *A. deliciosa*			
Kosui [f]	deep green	absent	38.4 ± 5.1
Shinzan	deep green	absent	19.3 ± 2.5

Values are means ± SD. n = 18. [a]Synonymous with 'Koshin' or 'Red princess'. [b]Synonymous with 'Applekiwi' or 'Kaimitsu'. [c]Synonymous with 'Rainbow red'. [d]Known commercially as ZESPRI™ GOLD Kiwifruit. [e]Known commercially as 'Babykiwi'. [f]Random amplified polymorphic DNA analysis suggested the possibility that *A. rufa* is involved in the parentage.

tract was prepared from 10 g of pulp, as described previously (Sturm *et al.*, 2003). Extraction procedures were carried out under chilled conditions to minimize undesirable chemical reactions.

Standards Glucose, fructose, *myo*-inositol, and citric acid were purchased from Sigma (St. Louis, MO, USA). Sucrose was obtained from Fluka (Buchs, Switzerland). Malic and quinic acids were from Merck (Darmstadt, Germany). The standard stock solution of sugar and sugar alcohol was dissolved in acetonitrile-water (50:50). Organic acid standards were dissolved in 0.2 mol/L HCl.

HPLC analysis The soluble sugars and sugar alcohol in the extract were separated using an amino column (Asahipak NH2P-50 4E; Showa Denko, Tokyo, Japan). The instrument used was a liquid chromatograph (Model L-2000; Hitachi, Tokyo, Japan) equipped with a refractive index detector (Model L-2490; Hitachi) and a data processor (Model D-2500; Hitachi). Duplicate 5 µL samples were injected for each extract. Isocratic elution was performed using acetonitrile-water (75:25) at a flow rate of 1.5 mL/min. The column temperature was set at 35°C.

Organic acids were determined using reversed-phase chromatography on an analytical LiChroCART 250-4 LiChrospher 100 RP-18e (5 µm) column (Merck, Darmstadt, Germany) according to the method described by Lee (1993) with slight modifications. Duplicate 10 µL samples were injected for each extract. Isocratic elution was performed with 0.01 mol/L aqueous potassium dihydrogen phosphate solution (pH 2.8) at a flow rate of 1.0 mL/min. Eluted organic acids were monitored at 214 nm using a UV-Vis detector (Model L-2420; Hitachi).

The chromatographic peak corresponding to each sugar, sugar alcohol, and organic acid was identified by comparing the retention time with that of a standard. For confirmation, co-chromatography of a standard with the sample was also applied. A calibration curve was prepared using standards to determine the relationship between the peak area and concentration.

Statistical Analysis Data are presented as means ± SD of six determinations. Nonrepeated measures ANOVA was used to compare the concentrations of sugars, sugar alcohol, and organic acids between genotypes. Differences between 'Hayward' and other genotypes were examined using a Dunnett test. Differences were considered significant for $p < 0.05$.

Results and Discussion

Soluble sugars It is well established that the content of each soluble sugar in the kiwifruit remarkably increases during post-harvest ripening. However, the sugar composition of the fruit at the eating-ripe stage is comparatively stable

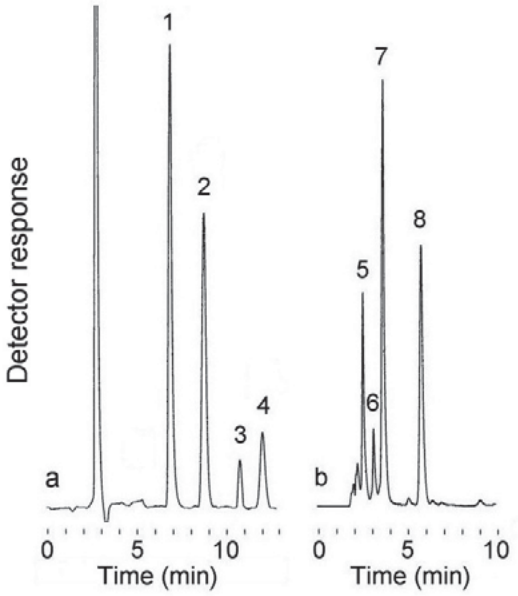

Fig. 1. HPLC elution profiles of sugars and sugar alcohol (a) and organic acids (b) extracted from 'Hayward' fruit. Sugars and sugar alcohol (a) were monitored using a refractive index detector. Organic acids (b) were monitored using a UV detector set at 214 nm. Peaks: fructose, 1; glucose, 2; *myo*-inositol, 3; sucrose, 4; quinic acid, 5; malic acid, 6; ascorbic acid, 7; citric acid, 8.

(MacRae *et al.*, 1992). For that reason, fruit at the eating-ripe stage were subjected to the experiments in the present study.

A chromatogram of sugars extracted from 'Hayward' fruit is shown in Fig. 1. Co-chromatography of the sample with authentic standards indicated that peaks 1, 2, 3, and 4 respectively represent fructose, glucose, *myo*-inositol, and sucrose. The peaks that correspond to glucose, fructose, and sucrose were detected in all *Actinidia* fruit tested in this study.

Table 2 shows sugar contents in the fruit of various *Actinidia* genotypes. In the different *A. deliciosa* and *A. rufa* cultivars, the main soluble sugars in the fruit were glucose and fructose, whereas sucrose was present in smaller amounts. Glucose and fructose are present in approximately equal amounts in these fruits. These results are consistent with previous observations using 'Hayward' fruit (van Gorsel *et al.*, 1992; Matsumoto *et al.*, 1983; Pérez *et al.*, 1997; Sanz *et al.*, 2004). Among *A. deliciosa* cultivars, the fruit of 'Abbott' and 'Koryoku' showed significantly higher total sugar content than 'Hayward' fruit. In contrast, total sugar content in 'Elmwood' fruit was significantly lower than that in 'Hayward' (Table 2).

The *A. chinensis* fruit displayed more variant profiles of sugar composition compared to other species. Sugar compositions in 'Sanuki gold', 'Kobayashi39', and 'Hort16A' fruit were similar to those in *A. deliciosa* and *A. rufa* fruit, as glucose and fructose were predominant over sucrose. In 'Jiangxi 79-1', 'Kuimi', and 'Hongyang' fruits, the three soluble sug-

Table 2. Concentration of soluble sugars in fruit of *Actinidia* genotypes.

Genotype	Concentration (g/100 g fresh weight)[a]									
	Glucose (G)		Fructose (F)		Sucrose (S)		G+F+S		*myo*-Inositol	
Hayward	3.52 ± 0.15		3.64 ± 0.14		1.28 ± 0.27		8.44 ± 0.33		0.116 ± 0.019	
Bruno	2.96 ± 0.33	*	3.12 ± 0.39	*	2.02 ± 0.55		8.09 ± 0.29		0.177 ± 0.038	
Abbott	4.06 ± 0.98	*	3.94 ± 0.83		2.33 ± 0.46		10.33 ± 2.26	*	0.100 ± 0.023	
Elmwood	2.46 ± 0.12	**	2.59 ± 0.11	**	1.43 ± 0.69		6.49 ± 0.83	*	0.032 ± 0.008	*
Koryoku	3.94 ± 0.25		3.79 ± 0.25		2.10 ± 0.70		9.82 ± 0.71	*	0.029 ± 0.006	*
Sanryoku	3.11 ± 0.08		3.17 ± 0.10	*	3.76 ± 0.32	**	10.04 ± 0.30	*	0.177 ± 0.039	
Jiangxi 79-1	3.33 ± 0.11		3.22 ± 0.12		3.21 ± 0.68	**	9.76 ± 0.86	*	0.084 ± 0.022	
Golden king	2.87 ± 0.32	*	2.47 ± 0.22	**	3.74 ± 0.40	**	9.08 ± 0.93		0.060 ± 0.022	
Kuimi	3.62 ± 0.21		3.39 ± 0.18		3.45 ± 0.33	**	10.47 ± 0.69	*	0.119 ± 0.048	
Sanuki gold	4.38 ± 0.67	**	3.85 ± 0.46		2.20 ± 0.14		10.42 ± 1.23	*	0.050 ± 0.013	
Hongyang	3.70 ± 0.18		3.63 ± 0.27		3.95 ± 0.78	**	11.28 ± 1.17	**	0.110 ± 0.020	
Kobayashi39	3.56 ± 0.27		3.51 ± 0.24		1.66 ± 0.15		8.72 ± 0.59		0.101 ± 0.031	
Hort16A	3.84 ± 0.28		4.15 ± 0.26	*	1.77 ± 0.34		9.76 ± 0.73	*	0.040 ± 0.014	
Awaji	2.56 ± 0.14	**	2.61 ± 0.13	**	1.39 ± 0.14		6.56 ± 0.31	*	0.058 ± 0.023	
Fuchu	3.00 ± 0.20	*	2.89 ± 0.24	**	1.03 ± 0.16		6.92 ± 0.57		trace	
Hirano	1.01 ± 0.06	**	1.15 ± 0.04	**	4.11 ± 1.67	**	6.27 ± 1.72	**	0.888 ± 0.084	**
Gassan	0.75 ± 0.17	**	0.91 ± 0.10	**	7.34 ± 1.44	**	8.99 ± 1.68		0.894 ± 0.104	**
Issai	0.85 ± 0.30	**	0.97 ± 0.30	**	7.80 ± 0.82	**	9.62 ± 0.39		0.777 ± 0.123	**
Mitsuko	0.72 ± 0.07	**	0.85 ± 0.05	**	6.02 ± 1.33	**	7.60 ± 1.39		0.703 ± 0.041	**
Kochi	0.89 ± 0.05	**	0.91 ± 0.06	**	5.76 ± 0.91	**	7.56 ± 0.93		0.904 ± 0.080	**
Shimane	0.83 ± 0.10	**	1.11 ± 0.13	**	4.29 ± 0.67	**	6.23 ± 0.52	**	0.982 ± 0.068	**
Nagano	0.78 ± 0.10	**	0.88 ± 0.11	**	4.86 ± 0.68	**	6.52 ± 0.79	**	0.604 ± 0.047	**
Ananasnaya	1.57 ± 0.15	**	1.78 ± 0.18	**	5.59 ± 0.81	**	8.94 ± 0.58		0.575 ± 0.068	**
Kosui	3.90 ± 0.27		3.52 ± 0.30		4.01 ± 1.91	**	11.42 ± 1.41	**	0.096 ± 0.022	
Shinzan	1.86 ± 0.17	**	2.11 ± 0.08	**	2.18 ± 0.70		6.15 ± 0.86	*	0.516 ± 0.138	**

[a]Values are means ± SD of six experiments. *, **: Significantly different vs. 'Hayward' at $p < 0.05$ and $p < 0.01$, respectively.

ars were present in similar amounts. In 'Golden king' fruit, the amount of sucrose markedly exceeded that of glucose or fructose (Table 2). In most *A. chinensis* cultivars, total sugar contents were significantly higher than that in 'Hayward' fruit. Among them, 'Hongyang' fruit was highest in total sugar content.

According to the previous studies using an *A. arguta* genotype of unknown origin (Boyes *et al.*, 1996; Klages *et al.*, 1997), the predominant sugar of the fruit was sucrose. Our results confirmed the predominance of sucrose in *A. arguta* fruits using eight genotypes (Table 2). Sucrose contents in these fruits were 2–6-fold higher than the level of *A. deliciosa* fruit. The amounts of glucose and fructose were almost equal, but fructose content tended to exceed glucose content slightly.

Sugar alcohol For sugar alcohol components, *myo*-inositol was detected as a small peak with retention time of around 10.8 min (Fig. 1). Sorbitol or mannitol, which is another sugar alcohol that is commonly found in fruits of different kinds, was not detected in any *Actinidia* fruit tested in this study.

Table 2 shows the contents of *myo*-inositol in the fruit of various *Actinidia* genotypes. *Myo*-inositol content in the fruit of most common cultivar 'Hayward' was 0.116 g/100 g fresh weight (F.W.), which is roughly of the same level as values reported by Clements Jr. and Darnell (1980), Paterson *et al.* (1991) and Sanz *et al.* (2004). In *A. deliciosa*, *A. chinensis*, and *A. rufa* fruit, considerable variation was apparent in *myo*-inositol content, with concentrations ranging from trace amount to 0.177 g/100 g F.W. In these species, fruits of 'Bruno' contained the highest concentration of *myo*-inositol; fruits of 'Fuchu' contained the lowest. *Myo*-inositol contents in *A. chinensis* fruits in the present study are consistent with a previous report by Cheng *et al.* (2004), which found that the fruit of three *A. chinensis* genotypes contained 0.07–0.08 g/100 g F.W. *myo*-inositol.

Compared to kiwifruit, *A. arguta* fruit contained *myo*-inositol at much higher levels. *Myo*-inositol contents in those fruit were 0.575–0.982 g/100 g F.W. These *myo*-inositol contents were higher than those in cantaloupe (0.355 g/100 g F.W.) and orange (0.307 g/100 g F.W.), which are regarded as the highest levels among fresh vegetables and fruits of various kinds (Clements Jr. *et al.*, 1980). Moreover, the *myo*-inositol contents in *A. arguta* fruit are higher than those of 487 different foods, including meats, grains, and nuts, tested by Clements Jr. *et al.* (1980) with the sole exception of stone-

ground wheat (1.15 g/100 g F.W.).

Myo-inositol, a six-carbon cyclitol found ubiquitously in all biological systems, is classified as a member of the vitamin B complex. Although the nutritional importance of *myo*-inositol has not been fully confirmed, it is of potential importance as a component of inositol phosphates and phosphoinositide, which play important roles in signal transduction pathways in living cells, and consequently in numerous human diseases (Shi *et al.*, 2006). In addition, evidence increasingly suggests that dietary *myo*-inositol itself, or in combination with inositol hexaphosphate, has an anticancer function (Shi *et al.*, 2006; Vucenik and Shamsuddin, 2006).

Recently, *A. arguta* fruit entered the world market, and has come to be sold commercially as 'Babykiwi' (Williams *et al.*, 2003). These fruits are small and completely fuzzless, and can therefore be easily eaten whole without peeling. Our previous studies revealed that *A. arguta* fruit are a rich dietary sources of vitamin C and carotenoids such as β-carotene and lutein (Nishiyama *et al.*, 2004, 2005). In addition, results of the present study show that *A. arguta* fruits can be the richest dietary source of *myo*-inositol. The exceptionally high *myo*-inositol content might be another strength of *A. arguta* fruit.

Organic acids Organic acids are, along with sugars, the main elements determining the taste of fruits. Organic acids give fruits tartness and slow bacterial spoilage. Figure 1b shows a chromatographic profile of organic acids extracted from 'Hayward' fruit. The noticeable peaks 5, 6, 7, and 8 were revealed to represent quinic, malic, ascorbic, and citric acid, respectively, by their retention time and spiking of the standards. These four organic acids were detected without exception in all the *Actinidia* fruits tested in this study. Among these organic acids, ascorbic acid content in the *Actinidia* fruits was examined and reported previously (Nishiyama *et al.*, 2004). In the present study, contents of citric, quinic, and malic acids were quantified (Table 3).

'Hayward' fruit contained 1.10 g/100 g F.W. citric acid, 0.98 g/100 g F.W. quinic acid, and 0.22 g/100 g F.W. malic acid (Table 3). These results are essentially consistent with results of previous studies (MacRae *et al.*, 1989; Marsh *et al.*, 2003, 2004). The main organic acids in *A. deliciosa* and *A. chinensis* fruits were citric and quinic acid, although malic acid was present in much smaller amounts (Table 3). Among these genotypes, 'Abbott', 'Koryoku', and 'Sanryoku' fruits showed significantly lower citric acid contents; moreover, 'Hort16A' fruit showed significantly higher malic acid con-

Table 3. Concentration of organic acids in fruit of *Actinidia* genotypes.

Genotype	Concentration (g/100 g fresh weight)			
	Citric acid (C)	Quinic acid (Q)	Malic acid (M)	C+Q+M
Hayward	1.10 ± 0.13	0.98 ± 0.07	0.22 ± 0.03	2.30 ± 0.11
Bruno	1.20 ± 0.04	1.11 ± 0.05	0.21 ± 0.07	2.53 ± 0.10
Abbott	0.85 ± 0.10**	1.00 ± 0.22	0.23 ± 0.08	2.08 ± 0.37
Elmwood	1.22 ± 0.07	1.08 ± 0.09	0.27 ± 0.05	2.57 ± 0.10
Koryoku	0.84 ± 0.02**	1.05 ± 0.17	0.26 ± 0.09	2.16 ± 0.26
Sanryoku	0.90 ± 0.05*	1.01 ± 0.08	0.19 ± 0.03	2.11 ± 0.14
Jiangxi 79-1	1.26 ± 0.16	1.02 ± 0.10	0.14 ± 0.01	2.42 ± 0.10
Golden king	0.93 ± 0.02	1.01 ± 0.10	0.27 ± 0.04	2.22 ± 0.09
Kuimi	1.17 ± 0.02	1.12 ± 0.11	0.20 ± 0.02	2.48 ± 0.11
Sanuki gold	1.29 ± 0.13	0.88 ± 0.09	0.23 ± 0.06	2.39 ± 0.13
Hongyang	0.95 ± 0.09	0.96 ± 0.05	0.26 ± 0.04	2.16 ± 0.09
Kobayashi39	1.13 ± 0.07	0.97 ± 0.09	0.18 ± 0.04	2.27 ± 0.18
Hort16A	0.92 ± 0.08	1.12 ± 0.06	0.39 ± 0.07**	2.43 ± 0.10
Awaji	0.78 ± 0.14**	1.62 ± 0.15**	0.23 ± 0.07	2.64 ± 0.32*
Fuchu	0.62 ± 0.08**	0.90 ± 0.22	0.13 ± 0.08*	1.65 ± 0.38**
Hirano	0.60 ± 0.20**	0.70 ± 0.09**	0.22 ± 0.03	1.52 ± 0.16**
Gassan	0.85 ± 0.24**	0.54 ± 0.15**	0.18 ± 0.07	1.57 ± 0.46**
Issai	1.37 ± 0.30**	0.73 ± 0.12**	0.14 ± 0.07*	2.23 ± 0.21
Mitsuko	0.95 ± 0.16	0.62 ± 0.06**	0.25 ± 0.04	1.82 ± 0.21**
Kochi	0.70 ± 0.14**	0.63 ± 0.04**	0.10 ± 0.08**	1.44 ± 0.12**
Shimane	0.75 ± 0.04**	0.64 ± 0.20**	0.20 ± 0.11	1.58 ± 0.31**
Nagano	0.82 ± 0.05**	0.68 ± 0.19**	0.30 ± 0.14	1.80 ± 0.27**
Ananasnaya	0.54 ± 0.09**	0.51 ± 0.10**	0.18 ± 0.07	1.22 ± 0.17**
Kosui	1.00 ± 0.10	1.07 ± 0.17	0.17 ± 0.05	2.23 ± 0.30
Shinzan	1.13 ± 0.46	0.79 ± 0.09*	0.13 ± 0.04**	2.05 ± 0.46

Values are means ± SD of six experiments. *, **: Significantly different vs. 'Hayward' at $p < 0.05$ and $p < 0.01$, respectively.

tent than 'Hayward' fruit. The variation in organic acid composition was small among *A. deliciosa* and *A. chinensis* (Table 3).

In *A. rufa*, the proportion of citric acid was lower and the proportion of quinic acid was higher, than those of *A. deliciosa* and *A. chinensis* fruits. Notably, 'Awaji' fruit contained the highest amount of quinic acid among all the *Actinidia* genotypes tested (Table 3).

In *A. arguta* fruits, the amounts of total organic acids were lower than those in *A. deliciosa* and *A. chinensis* fruits, except for 'Issai' (Table 3). The amounts of individual organic acid tend to be lower than those in *A. deliciosa* and *A. chinensis* fruits. In particular, the amounts of quinic acid in fruits of all *A. arguta* genotypes were significantly lower than that in 'Hayward' fruit (Table 3).

According to sensory experiments using kiwifruit pulps by Marsh *et al.* (2003), citric, quinic, and malic acids cause different perceptions of acidity. Quinic acid has a greater impact on the perception of acidity than either citric or malic acid at equivalent molar concentrations. They also reported the importance of quinic acid as a characteristic 'Hayward' -like flavor. For those reasons, the difference in the proportion of organic acids found in the present study probably causes differences in the flavor of the flesh. *A. arguta* fruits are known for being sweeter than traditional kiwifruit (Nishiyama, 2007); the low acid content, especially low quinic acid content, of *A. arguta* fruit might be one reason for this perception.

The major organic acids found in the *Actinidia* fruit are citric, quinic, and malic acid. Among these, citric and malic acids are common organic acids frequently found in different kinds of commercially available fruits. After ingestion, citric and malic acids are expected to serve as important energy sources for the living cells via the Krebs cycle. *Actinidia* fruits are unusual in that they contain substantial amounts of quinic acid at levels similar to that of citric acid. Although the physiological and nutritional importance of quinic acid has not been established, it has attracted great interest. Quinic acid putatively serves as a precursor for the biosynthesis of polyphenols, such as chlorogenic acids and flavonoids, in plants (Weinstein *et al.*, 1961; Leuschner *et al.*, 1995). These dietary polyphenols act as a radical trapping antioxidant, which are widely perceived as contributing to prevention of various degenerative diseases including cardiovascular diseases and cancers (Scalbert *et al.*, 2005). Studies of the relationship between the amount of quinic acid and that of polypenols are now in progress in our laboratory.

Over the past decade, kiwifruit plantings have remained stable in many countries, but have declined in several others, including Japan (Ferguson and Huang, 2007). One probable reason for the stagnation of the kiwifruit industry is the lack of varietal diversity in the marketplace. Although various cultivars and selections exist in kiwifruit and related crops, the international world trade in kiwifruit remains dominated by 'Hayward' fruit, accounting for perhaps 95% of all traded kiwifruit (Ferguson and Huang, 2007). To stimulate the kiwifruit industry, new *Actinidia* cultivars with fruit of high eating quality must be released to the world market to offer greater choice to consumers. It is also necessary to develop convenient processed fruit products, such as beverages, to increase the consumption of kiwifruit, as kiwifruit are currently marketed mostly as fresh fruit. For this purpose, the selection of cultivars suitable for processing is required. The findings of the present study regarding sugar and organic acid components must be emphasized as fundamental data for both the selection of existing cultivars and for cultivar development.

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