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Changes in Fruit Physicochemical Characteristics by Fruit Clusters in June-bearing Strawberry Cultivars

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Abstract. Three Korean-bred strawberry cultivars ‘Maehyang’, ‘Seolhyang’, and ‘Keumhyang’, and a Japanese cultivar ‘Tochiotome’ were grown in a greenhouse and their physicochemical characteristics were investigated. Fruit weight of ‘Seolhyang’ and ‘Keumhyang’ in the first and second fruit clusters were greater than those of other cultivars and that of ‘Tochiotome’ was the greatest in the fifth fruit cluster. Fruit firmness generally decreased at later fruit clusters, and was the lowest in ‘Seolhyang’. The sugars/organic acids ratios in the first and third fruit clusters of ‘Maehyang’ were 4.9 and 8.0, respectively, representing the highest values among all cultivars. The ascorbic acid content was the greatest in the second fruit cluster for ‘Seolhyang’, ‘Keumhyang’, and ‘Tochiotome’ cultivars and that of ‘Maehyang’ was the greatest at the third fruit cluster. The anthocyanin content was higher in later fruit clusters and was the highest in ‘Keumhyang’ overall. Results indicate that Korean cultivars bred for the plastic protected culture, which are intended for very early harvest, showed more desirable physical characteristics in the first and second fruit clusters, while the content of anthocyanin was greater in the fruits from later fruit clusters.

***Additional key words*:** anthocyanin, ascorbic acid, organic acid, sugar

Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) fruits are a good source of natural antioxidants (Heinonen et al., 1998; Wang et al., 1996). Antioxidants can delay or inhibit the oxidation of lipids or other molecules by inhibiting oxidizing chain reactions and thereafter play an important role in health protection (Velioglu et al., 1998). Antioxidants in strawberry mainly include ascorbic acid and anthocyanin (Hannum, 2004). Ascorbic acid prevents or cures scurvy and maintains healthy skin, gums, and blood vessels (Harris, 1996). It is also known to have many biological functions including formation of collagen, absorption of inorganic iron, reduction of plasma cholesterol level, and reaction with singlet oxygen and other free radicals (Lee and Kader, 2000). Ascorbic acid was the most major contributor among other antioxidants to the electrochemical response in strawberries (Aaby et al., 2007). Anthocyanins were shown to protect cells against harmful free radicals and were associated with decreased incidence and mortality rates of cancer and heart disease (Velioglu et al., 1998).

The growth of strawberry plants is determinate, and terminal inflorescences develop at the top of the primary crowns (Guttridge, 1955). The axillary buds differentiate just below the inflorescences on the primary crown and develop into secondary crowns. After several leaves have formed on the secondary crowns, the secondary inflorescences differentiate at their tops (Kurokura et al., 2005). Thereafter, other axillary buds grow just below the second inflorescences and develop into the tertiary crowns and inflorescences likewise. The primary, secondary, and tertiary inflorescences are called the first, second, and third fruit clusters, respectively, when the fruits are borne in each cluster.

Morphological changes that occur as the strawberry plants develop have been studied (Jahn and Dana, 1970), but only a little is known about the difference in physicochemical

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characteristics of fruits between different fruit clusters. Moreover, the related information in the newly introduced Korean and Japanese cultivars has seldom been reported. In this study, physicochemical characteristics of fruits from three major Korean domestic ‘Maehyang’, ‘Seolhyang’, ‘Keumhyang’, and internationally well-known Japanese ‘Tochiotome’ were compared in different fruit clusters.

Materials and Methods

Production of Strawberry Fruit

On September 15, 2006, three Korean ‘Maehyang’, ‘Seolhyang’, and ‘Keumhyang’ and a Japanese ‘Tochiotome’ were transplanted on a commercial greenhouse located in Nonsan (36°11'12"N/127°05'58"E/and elevation 18 m), Chungnam Province, Korea. The strawberry plants were cultivated under soil using hydroponic culture methods in a greenhouse. The plant density was 24 plants/m^2. The plants were fertilized based on the results of soil tests that were performed during spring following regional recommendations (9.6 kg·10 a^{-1} for N, 4.9 kg·10 a^{-1} for P_2O_5, and 7.4 kg·10 a^{-1} for K_2O). Fruits were harvested at the optimal fruit maturity, when about 90% of the fruit surface had reached full red color. The ripe strawberry fruits were harvested five times (at January 10, February 12, March 13, April 11, and May 17, 2007) between the first and fifth fruit clusters. The first fruit cluster fruits were harvested on January when the mean air temperature was 0.4℃, with a range of -7.0 to 11.3℃. The second and third cluster fruits were harvested during February and March when the mean air temperature was 5.6℃, with a range of -8.3 to 21.1℃. Lastly, the fourth and fifth cluster fruits were harvested during April and May when the mean air temperature was 15.2℃, with a range of -0.8 to 28.7℃. The minimum night temperature of inside the greenhouse was maintained above 10℃.

Measurement of Physical Characteristics

The harvested fruits were transported to the Vegetable Science Laboratory at Seoul National University within three hours for the measurements of physical and biochemical characteristics and all the measurements were replicated three times. Fruit firmness was measured using a texture analyzer (TA-XT2, Arrow Scientific, Lane Cove, Australia) and the penetration speed and depth were 10 mm·s^{-1} and 5 mm, respectively. A 3 mm diameter, needle-type probe was used to measure firmness in newton (N). Fruit color was measured at the surface using a color meter (CR-400, Minolta Co., Tokyo, Japan). The color of fruit was recorded using the CIE (L*, a*, and b*) from uniform color space. Numerical values of a* and b* were converted into the hue angle (H = $\tan^{-1}$ b*/a*) and chroma (chroma = $(a^{*2} + b^{*2})^{1/2}$), which quantify the intensity or purity of the hue (Francis, 1980).

Extraction and Analysis Sugars and Organic Acids

Fruit sample (5 g) was homogenized with 20 mL of distilled water, filtered using No. 2 filter paper and filtered again through a 0.45 μm syringe filter. The filtrate was diluted and injected into a chromatography system (Dionex 2500, Dionex Co., New York, NY, USA).For sugar analysis, the solvent was 18 mM sodium hydroxide at a flow rate of 1 mL·min^{-1}. CarboPac PA10 column (4 × 250 mm; Dionex Co., New York, NY, USA) and anamperonmetry detector with Au electrode wereused. Fructose and glucose content were calculated by using external standards. Total sugar content was calculated by summing the contents of fructose and glucose. The same extract used in the sugar analysis was used in organic acid analysis. IonPac ICE-AS6 column (9 × 250 mm; Dionex Co., New York, NY, USA) was used for separation of acids and 0.4 mM heptafluorobutyric acid was used as an eluent at a flow rate 1 mL·min^{-1}. A suppressed detector, with an anion-ICE micromembrane suppressor and 5 mN tetrabutylammonium hydroxide was used. External standard was used to calculate organic acid content. Since citric and malic acids were the major found in the strawberry extract, total organic acid content was calculated by summing contents of those two acids.

Extraction and Analysis of Ascorbic Acid

Fruit sample (10 g) was homogenized with 50 mL of buffer solution (0.1 M citric acid, 0.05% EDTA, and 5% MeOH) and filtered through a No. 2 filter paper. After adjusting its pH with 1 M HCl, the mixture was passed through a Sep-pak C18 cartridge. The cartridge was preconditioned with 7 mL methanol, followed by 10 mL water. The residual water in the cartridge was flushed with air. The first 1 mL was discarded and the next 3 mL was passed through the cartridge and mixed with 1 mL of freshly prepared 1, 2-phenylenediamine dihydrochloride (OPDA) solution. The final pH values were between 2.20-2.45 after adding the OPDA solution. L-ascorbic was analyzed by HPLC (Spectra System P2000, Thermo Separation Products Co., Herts, UK) with a flow rate of 1.5 mL·min^{-1} as suggested by Zapata and Durour (1992). The L-ascorbic acid was detected at 254 nm. A C18 reverse phase column (4.6 × 250 mm, 5 μm; Zorbax, Agilent Co., New York, USA) was used for analysis and the solvent was 5% MeOH and 50 mM potassium dihydrogen phosphate, with a flow rate of 1.5 mL·min^{-1}.

Extraction and Analysis of Anthocyanin

Anthocyanin was extracted from the epidermal tissue of fruit (2 g), less than 2 mm thick, by homogenizing with 5 mL HCl (1%)-methanol solution. The extraction was filtered through No. 2 filter paper and measured through a spectrophotometer at 520 nm (UV-2550, Shimadzu, Kyoto, Japan). Total anthocyanin content was expressed as mg pelargonidin-3-glucoside (ε = 36,000 $L \cdot mol^{-1} \cdot cm^{-1}) \cdot g^{-1}$ FW (Ferreyra et al., 2007).

Statistical Analysis

Statistical analysis was conducted to evaluate the significant differences among the fruit from the strawberry cultivars within the same fruit cluster. ANOVA was tested to assess physical characteristics (fruit weight, length, width, shape index, and color parameters) and bioactive compounds (sugars, organic acids, anthocyanin, and ascorbic acid content). Significant difference was determined at $P \leq 0.05$.

Results and Discussion

Fruit Physical Characteristics

For the first, second, third, and fourth fruit clusters, fruit weights of ‘Seolhyang’ and ‘Keumhyang’ were greater than those from the other cultivars. The first fruit cluster of ‘Keumhyang’ had the greatest fruit weight among all tested cultivars. However, they became similar to other cultivars in the fifth fruit cluster, while those of ‘Maehyang’ and ‘Tochiotome’ were consistent over the harvest period (Table 1). Significant variations in fruit number, fruit weight, and weight per fruit among the cultivars were expected based on previously reported harvest (Hortyński et al., 1991; Santos et al., 2009). Our results indicate that ‘Seolhyang’ and ‘Keumhyang’ would be adequate as the main cultivars for forced culture, which could be complemented during low production periods. The fruit shape of ‘Maehyang’ was conical, resulting in the index of length to width of about 1.5, whereas that of ‘Seolhyang’ and ‘Tochiotome’ was cordate with an index of length to width that was approximately 1.3. There was no change in fruit shape as the fruit cluster progressed (Table 1). Fruit shape dose not easily change and is not affected by the environmental factors, and therefore is used as a major characteristic for the classification of cultivars (Kim et al.,

Table 1. Changes in weight, length, width, shape index, and firmness of fruits by fruit clusters in four strawberry cultivars.

Cultivar	Weight (g)	Length (mm)	Width (mm)	Shape index[z]	Firmness (N)
The first fruit cluster (Harvesting at January 10, 2007)					
Maehyang	16.0 c[y]	46.4 b	29.1 d	1.6 a	0.39 ab
Seolhyang	26.8 b	48.3 b	36.3 b	1.3 b	0.34 b
Keumhyang	44.7 a	55.5 a	48.0 a	1.2 c	0.36 ab
Tochiotome	15.5 c	41.3 c	31.4 c	1.3 b	0.44 a
The second fruit cluster (Harvesting at February 12, 2007)					
Maehyang	16.4 c	47.6 ab	29.3 c	1.6 a	0.54 a
Seolhyang	30.3 a	49.9 a	38.2 a	1.3 c	0.38 c
Keumhyang	18.4 bc	47.0 ab	32.3 b	1.5 b	0.47 b
Tochiotome	20.4 b	46.1 b	33.8 b	1.4 bc	0.56 a
The third fruit cluster (Harvesting at March 13, 2007)					
Maehyang	15.5 d	45.5 bc	28.3 c	1.6 a	0.47 a
Seolhyang	25.3 b	47.9 b	35.0 b	1.4 c	0.31 c
Keumhyang	34.9 a	59.0 a	39.8 a	1.5 b	0.37 b
Tochiotome	21.7 c	43.7 c	34.8 b	1.3 d	0.43 a
The fourth fruit cluster (Harvesting at April 11, 2007)					
Maehyang	16.5 c	43.3 b	30.4 b	1.4 a	0.34 a
Seolhyang	18.8 ab	41.5 c	33.0 a	1.3 b	0.24 b
Keumhyang	19.7 a	47.5 a	32.9 a	1.4 a	0.35 a
Tochiotome	18.1 b	41.3 c	33.1 a	1.2 b	0.35 a
The fifth fruit cluster (Harvesting at May 17, 2007)					
Maehyang	17.9 b	45.6 a	30.8 c	1.5 a	0.33 a
Seolhyang	17.1 b	38.9 b	33.2 b	1.2 c	0.24 c
Keumhyang	17.6 b	46.9 a	31.8 bc	1.5 a	0.28 bc
Tochiotome	24.9 a	47.3 a	37.2 a	1.3 b	0.31 ab

[z]Shape index: Fruit length/width.
[y]Mean separation within columns by Duncan’s multiple range test at 5% significance level.

Table 2. Changes in external color of fruits by fruit clusters in four strawberry cultivars.

Cultivar	L*	a*	b*	Hue (°)	Chroma
The first fruit cluster (Harvesting at January 10, 2007)					
Maehyang	37.3 b[a]	40.1 ab	23.7 c	30.6 c	46.6 a
Seolhyang	42.4 a	38.4 c	29.1 a	37.1 a	48.2 a
Keumhyang	32.9 c	41.4 a	21.1 d	26.9 d	46.4 a
Tochiotome	38.3 b	38.9 bc	25.8 b	33.6 b	46.7 a
The second fruit cluster (Harvesting at February 12, 2007)					
Maehyang	36.7 bc	39.9 ab	23.9 b	30.8 b	46.5 b
Seolhyang	41.7 a	40.7 a	29.7 a	36.0 a	50.3 a
Keumhyang	36.5 c	41.1 a	25.5 ab	31.7 ab	48.5 ab
Tochiotome	39.4 ab	38.6 b	26.3 ab	34.1 ab	46.7 b
The third fruit cluster (Harvesting at March 13, 2007)					
Maehyang	40.3 a	40.5 ab	27.3 a	33.9 a	48.9 a
Seolhyang	40.6 a	39.7 b	29.8 a	36.8 a	49.6 a
Keumhyang	35.5 b	41.4 a	22.1 b	27.9 b	46.9 a
Tochiotome	40.4 a	39.2 b	28.8 a	36.2 a	48.7 a
The fourth fruit cluster (Harvesting at April 11, 2007)					
Maehyang	36.1 b	40.7 ab	23.3 b	29.7 b	46.9 b
Seolhyang	40.6 a	40.6 ab	29.7 a	36.0 a	50.3 a
Keumhyang	36.3 b	39.3 b	24.7 b	32.2 b	46.5 b
Tochiotome	39.5 a	41.7 a	27.1 ab	32.9 ab	49.7 a
The fifth fruit cluster (Harvesting at May 17, 2007)					
Maehyang	36.4 b	40.3 a	23.2 b	29.8 b	46.5 a
Seolhyang	40.2 a	36.9 b	28.9 a	37.9 a	46.9 a
Keumhyang	35.9 b	39.2 a	23.2 b	30.4 b	45.5 a
Tochiotome	38.1 ab	39.5 a	24.5 b	31.5 b	46.6 a

[z]Mean separation within columns by Duncan's multiple range test at 5% significance level.

2009).The firmness of fruit from all cultivars decreased in the later fruit clusters meaning that the fruit was softer at later harvest periods (Table 1). Fruit firmness is generally an important characteristic, and is one of the most important characteristics that strawberry breeders look for in their breeding programs. Strawberries with tough skin and firm flesh tolerate handling and transportation damage better, and have a longer shelf life and more attractive appearance than soft fruits (Hietaranta and Linna, 1999). Hue values of fruits at the fourth and fifth fruit clusters were significantly smaller than those at the first, second, and third fruit clusters (Table 2). Previous investigations have revealed that the color of strawberries is conditioned by genetic, climatic, and agronomic factors, and the postharvest color changes associated with biosynthetic changes of anthocyanins can occur (Matsumoto et al., 2008; Skupień and Oszmiański, 2004). High temperature, one of the climatic factors, caused more rapid development of color depending upon the cultivar (Wang and Camp, 2000). In later fruit clusters, strawberry fruit surface colors became darker (L* value decreased) and redder (b* value decreased) as the day or night temperature increased.

Sugars and Organic Acids Contents

Sugars contents of 'Seolhyang', 'Keumhyang', and 'Tochiotome' cultivars at the fourth fruit cluster (harvesting at April 11, 2007) were the greatest among different fruit clusters. At the fourth fruit cluster, a total sugar content of 'Keumhyang' was 71.3 mg $\cdot g^{-1}$ FW, the highest value among all cultivars. The total sugars content at the fifth fruit cluster (harvesting at May 17, 2007) of 'Maehyang' was 53.8 mg $\cdot g^{-1}$ FW, the highest value among all cultivars (Table 3). The environmental conditions in which late fruit clusters grew and developed were warmer and had an increased light level, which resulted in higher sugar contents. The total sugar content can change during the harvesting period but the proportion of each sugar remains constant, regardless of the growing conditions and cultivars (Forney and Breen, 1986; Woodward, 1972). Shaw (1990) also found that the sugars and acids contents of strawberry fruit were dependent upon the environmental conditions. Plant shading treatment was also shown to significantly reduce the sugar/acid ratio in strawberry fruit (Watson et al., 2002). The mechanisms by which high light levels incident on the crop improve the level of sugars in the fruit remain to be determined. Glucose and fructose were dominant in all the tested cultivars, but the

Table 3. Changes in the sugars and organic acids contents of fruits by fruit clusters in four strawberry cultivars.

Cultivar	Sugars content (mg·g^{-1}FW)			Organic acids content (mg·g^{-1}FW)			TS/TO[z]
	Glucose	Fructose	Total	Citric acid	Malic acid	Total	
The first fruit cluster (Harvesting at January 10, 2007)							
Maehyang	17.8 b[y]	34.4 a	52.2 a	7.1 b	3.7 a	10.8 a	4.9 a
Seolhyang	17.5 b	27.1 b	44.6 ab	7.8 b	3.0 ab	10.8 a	4.2 a
Keumhyang	13.6 c	25.6 b	39.2 b	10.6 a	1.8 b	12.4 a	3.2 b
Tochiotome	22.1 a	26.9 b	49.0 ab	8.0 b	2.5 ab	10.5 a	4.6 a
The second fruit cluster (Harvesting at February 12, 2007)							
Maehyang	17.1 b	18.9 c	35.9 b	3.1 c	1.4 a	4.4 b	8.2 a
Seolhyang	26.0 a	26.4 a	52.3 a	4.7 b	1.4 a	6.2 a	8.5 a
Keumhyang	18.3 b	19.9 c	38.2 b	6.1 ac	0.9 b	7.0 a	5.5 b
Tochiotome	12.5 c	23.2 b	35.6 b	3.4 c	0.7 b	4.1 b	8.8 a
The third fruit cluster (Harvesting at March 13, 2007)							
Maehyang	22.1 a	20.9 b	43.1 b	8.8 c	4.1 a	12.9 b	3.4 a
Seolhyang	20.2 a	21.4 b	41.7 b	15.9 a	3.9 a	19.7 a	2.1 b
Keumhyang	26.5 a	29.3 a	55.7 a	13.7 ab	1.8 c	15.4 b	3.6 a
Tochiotome	23.5 a	23.5 b	46.9 ab	11.0 bc	2.9 b	13.8 b	3.4 a
The fourth fruit cluster (Harvesting at April 11, 2007)							
Maehyang	24.8 b	26.4 b	51.2 b	10.2 a	4.7 a	14.9 a	3.7 a
Seolhyang	31.8 a	32.7 ab	64.5 b	10.4 a	2.6 b	13.0 a	5.0 a
Keumhyang	33.3 a	38.0 a	71.3 a	11.7 a	1.4 b	13.2 a	6.4 a
Tochiotome	27.9 ab	27.3 b	55.2 b	14.4 a	2.6 b	17.0 a	3.3 a
The fifth fruit cluster (Harvesting at May 17, 2007)							
Maehyang	24.0 a	29.8 a	53.8 a	5.5 ab	1.8 a	7.3 a	8.0 a
Seolhyang	18.0 b	27.1 a	45.0 b	4.9 b	1.5 a	6.4 a	7.0 ab
Keumhyang	17.8 b	21.4 b	39.2 c	5.9 ab	1.0 a	7.0 a	5.7 ab
Tochiotome	17.8 b	21.9 b	39.7 bc	6.9 a	1.1 a	8.0 a	5.0 b

[z]TS/TO: Total sugars/organic acids.
[y]Mean separation within columns by Duncan's multiple range test at 5% significance level.

sucrose level was negligible (date not shown). Sugars are the main soluble components in ripe strawberry fruits, with glucose and fructose accounting for almost 99% of the total sugar content (Olsson et al., 2004). Even though those sugars are found in almost equal amounts (Mass et al., 1996), the sucrose level is generally much lower (Forney and Breen, 1986). The proportion of fructose and glucose is important to the perception of fruit quality because fructose is 1.8 times sweeter than sucrose (Doty, 1976), while glucose is only 0.8 times sweeter (Pangborn, 1953; Yamaguchi et al., 1970). Therefore, a higher porportion of fructose would make fruits taste sweeter than those with low fructose content. The sweetness of those cultivars is generally regarded as the best among the cultivars, and is likely one of the reasons fruit from 'Maehyang' and 'Keumhyang' are highly favored as gift items in luxury department stores during the early harvest period. Organic acids content of all tested cultivars at the third (harvesting at March 13, 2007) and the fourth (harvesting at April 11, 2007) fruit clusters was higher than in the first fruit clusters. The citric acid content at the third fruit cluster of 'Seolhyang' was 15.9 mg · g^{-1} FW and this was the highest among all cultivars. However, the malic acid content at the fourth fruit cluster of 'Maehyang' was 4.7 mg · g^{-1} FW, which was the highest among all cultivars. The total sugars/organic acids ratio at the first and fifth fruit clusters of 'Maehyang' were 4.9 and 8.0, respectively, representing the highest value among all cultivars (Table 3). Organic acids are minor components of a strawberry fruit, but in combination with sugars, they play an important role in flavor, and thus have an impact on the quality of the strawberry fruit (Wang et al., 2002).

Ascorbic Acid Content

Significant differences were found in ascorbic acid contents among cultivars and fruit cluster. The ascorbic acid content of 'Maehyang' ranged between 0.52 and 1.06 mg · g^{-1} FW, which was the highest among cultivars. There was up to a 1.5-fold difference in the ascorbic acid content between cultivars within the same fruit cluster. The ascorbic acid content was the greatest in the second fruit cluster for 'Seolhyang', 'Keumhyang', and 'Tochiotome' cultivars. The ascorbic acid content at the third fruit cluster (harvesting at March 13, 2007) of 'Maehyang' was 1.06 mg · g^{-1} FW, the highest value among all cultivars (Fig. 1).

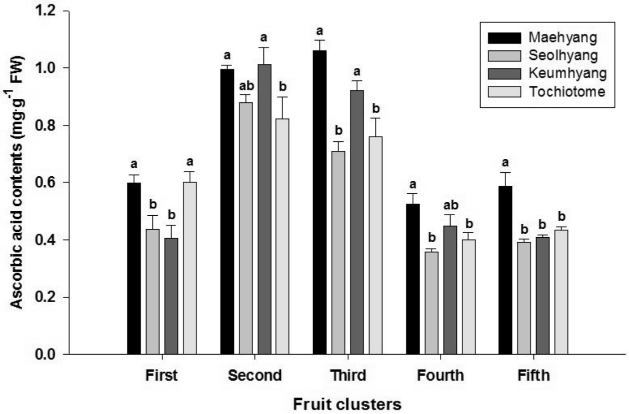

Fig. 1. Changes in the ascorbic acid content of fruits by fruit clusters in four strawberry cultivars. Vertical bars show standard deviation (n = 3). Small letters inside the figure indicate mean separation by Duncan's multiple range test at $p \leq 0.05$.

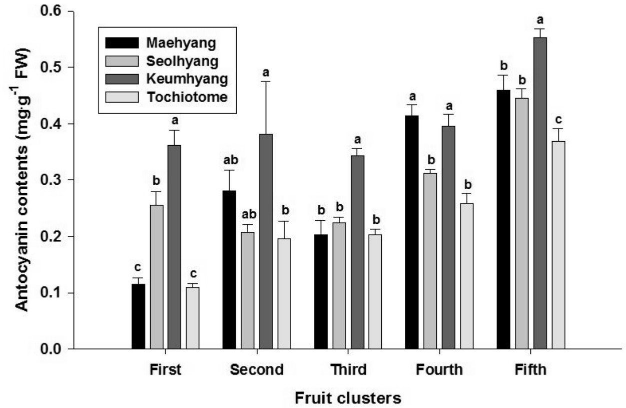

Fig. 2. Changes in the anthocyanin content of fruits by fruit clusters in four strawberry cultivars. Vertical bars show standard deviation (n = 3). Small letters inside the figure indicate mean separation by Duncan's multiple range test at $p \leq 0.05$.

Lee and Kader (2000) have indicated that the ascorbic acid content can be modified by several preharvest factors. For example, higher light intensity would promote the sugar production and ascorbic acid synthesis. However, the ascorbic acid contents of all the tested cultivars at the fourth and fifth fruit clusters were lower than those at the second and third clusters. As reported by Wang and Camp (2000), temperature caused a negative effect, so that the higher temperatures in day and night at the third fruit cluster might decline the syntheses of sugar and ascorbic acid.

Anthocyanin Content

There were significant differences in the anthocyanin content among cultivars and fruit clusters. The anthocyanin content of 'Keumhyang' at the fifth cluster (harvesting at May 17, 2007) was 0.55 $mg \cdot g^{-1}$ FW, which was the highest among all the tested cultivars. The anthocyanin content increased at the later fruit clusters. There was up to a 3.3-fold difference in the anthocyanin content among cultivars within the same fruit cluster (Fig. 2). When the day/night temperature increased the fruit surface and flesh colors became darker and redder, and their antioxidants content significantly increased (Wang and Zheng, 2001). Nunes et al. (1995) indicated that a* value was highly correlated with the anthocyanin concentration in strawberries. Our results also indicated that a higher anthocyanin content, and that a* color was also higher than the other cultivars.

The anthocyanin contents were higher in the fruit of later fruit clusters, however, the ascorbic acid contents were higher in the fruit of the second and third fruit clusters. Fruit weights of 'Seolhyang' and 'Keumhyang' were greater than those of the other cultivars in the first and second fruit clusters, and ascorbic acid and anthocyanin contents of 'Maehyang' and 'Keumhyang' were greater than other cultivars. In conclusion, the physicochemical characteristics of fruits from the Korean strawberry cultivars tested in this study are comparable to or better than the Japanese cultivar that is widely grown in East Asian countries. Domestic market consumers also accept these cultivars as equal or better than Japanese cultivars.

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