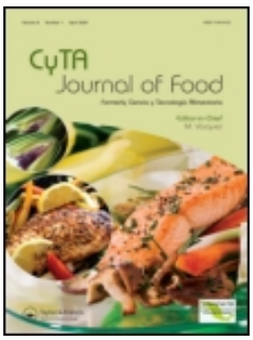

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Effect of long-term cold storage on physicochemical attributes and bioactive components of kiwi fruit cultivars

Efecto del almacenamiento en frío a largo plazo en los atributos fisicoquímicos y en los componentes bioactivos de diferentes variedades de kiwi

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Various kiwi fruit cultivars, bred in Korea, were kept in cold storage for 8–24 weeks for possible increase of their quality. Firmness significantly decreased at initial time in all cultivars. The rate of softening was the slowest in "Hayward", followed by "Hort 16A", "Haenam", "Daheung", "Bidan", "Hwamei", and "SKK 12". Sensory value increased with decreasing of firmness. Soluble solids content increased with storage time while acidity gradually decreased. Reducing sugar content significantly increased at early stage of storage with decreasing of starch content. There was no difference of these indices among cultivars. Respiration rate increased with time and then decreased during cold storage. Peaks time was different between cultivars, therefore we represented trend of respiration changes in all cultivars. All kiwi fruit cultivars showed climacteric patterns in respiration. The rate of softening was closely related to the degree and peak time of ethylene production. The highest shelf life was in "Hayward" and "Hort 16 A" (24 weeks) and the lowest in "SKK-12" (8 weeks). All investigated cultivars bred in Korea showed much lower shelf life than "Hayward" and "Hort 16 A". Radical scavenging assays and chemometrical processing were used for the determination of bioactive kiwi fruits' compounds. Polyphenols in water extracts were the highest in "SKK-12" and the lowest in "Hayward" [16.34 ± 1.11 and 5.30 ± 0.45 mg gallic acid equivalents (GAE)/g dry weight (DW)]. The values of β-carotene activities (27.61 ± 2.44% and 8.33 ± 0.74%) and Ferric-reducing/antioxidant power [(FRAP, Trolox equivalent (TE)/g DW) 24.55 ± 2.01 and 7.12 ± 0.41] were the highest in "SKK-12". The lowest results were estimated in "Hayward". All kiwi fruit cultivars showed a high level of correlation between the contents of phenolic compounds (polyphenols, tannins, and flavonoids) and their antioxidant values. We presented for the first time the results of shelf life of new cultivars bred in Korea and their comparison with the widely studied ones, such as "Hayward" and "Hort 16A". Cold storage extended shelf life in kiwi fruit without any chilling injury or color change. According to the antioxidant properties of different cultivars, the highest was in "SKK-12" with the lowest shelf life and the lowest was in "Hayward" with the highest shelf life.

Keywords: new cultivars; firmness; reducing sugar; respiration; ethylene; bioactivity

Con el objetivo de comprobar un posible mejoramiento de la calidad de diferentes variedades de kiwi cultivadas en Corea, las mismas se almacenaron en frío durante 8 a 24 semanas. Se constató que la dureza de todas las variedades almacenadas, disminuyó significativamente en el primer momento. En este sentido, la variedad "Hayward" mostró la tasa de ablandamiento más baja, siguiéndole "Hort 16A", "Haenam", "Daheung", "Bidan", Hwamei" y "SKK-12". A medida que disminuyó la dureza se elevó el valor sensorial. A mayor tiempo de almacenamiento, se evidenció un aumento en el contenido de sólidos solubles, disminuyendo paulatinamente la acidez. Durante la primera etapa de almacenamiento, se aceleró significativamente la reducción en el contenido de azúcar conjuntamente con la disminución del contenido de almidón, no presentándose diferencias en estos índices entre las distintas variedades. La tasa de respiración se elevó con el tiempo, disminuyendo luego durante el almacenamiento en frío. Debido a que el tiempo pico mostrado por las distintas variedades fue diferente, los autores registraron la tendencia de cambio de respiración para cada una de ellas. Todas las variedades de kiwi mostraron patrones climatéricos de respiración. La tasa de ablandamiento se relacionó estrechamente con el grado y el tiempo pico de producción de etileno. Las variedades "Hayward" y "Hort 16A" registraron una vida útil más larga (24 semanas), mientras que "SKK-12" mostró la vida útil más corta (8 semanas). El resto de las variedades sembradas en Corea que fueron investigadas en este estudio, registró vidas útiles más cortas que "Hayward" y "Hort 16A". Para la determinación de los compuestos bioactivos del kiwi se utilizaron valoraciones de captación de radicales y procesamiento quimiométrico. A partir de ello se evidenció que "SKK-12" presentó los polifenoles extraídos con agua más elevados mientras que "Hayward" mostró los más bajos (16,34 ± 1,11 y 5,30 ± 0,45 mg equivalentes de ácido gálico (GAE)/g peso seco, DW). En lo que respecta a los valores de las actividades de β-caroteno (27,61 ± 2,44% y 8,33 ± 0,74%) y al poder de reducción de férrico/antioxidante [(FRAP, Trolox equivalente (TE)/g dw) 24,55 ± 2,01 y 7,12 ± 0,41] los más elevados se constataron en "SKK-12", mientras que los más bajos se evidenciaron en "Hayward". Todas las variedades de kiwi reportaron altos niveles de correlación entre los contenidos de compuestos fenólicos (polifenólicos, taninos y flavonoides) y sus valores antioxidantes. Este estudio constituye el primero en el que se reportan resultados de vida útil de nuevas variedades cultivadas en Corea y la comparación entre éstas y las variedades que han sido más estudiadas, por ejemplo la "Hayward" y la "Hort 16A". El almacenamiento en frío extendió la vida útil de kiwi sin que se produjeran daños atribuibles al frío ni tampoco cambios de color. En cuanto a las propiedades antioxidantes de las distintas variedades, "SKK-12" mostró los valores más elevados aunque exhibiendo la vida útil más corta; en cambio, "Hayward" presentó los menores valores de dichas propiedades mostrando la vida útil más larga.

Palabras claves: nuevas variedades; reducción de azúcar; respiración; bioactividad

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†This article was written in memory of my dear brother Prof. Simon Trakhtenberg, who died in November 2011, who encouraged me and our research group during all his life.

Introduction

Kiwi fruit supports its position as a highly nutritious and low-calorie fruit with the potential to deliver a range of health benefits (Drummond, 2013). Consuming gold kiwi fruit with iron-rich meals improves poor iron status, and green kiwi fruit aids digestion and laxation. As a rich source of antioxidants, they may protect the body from endogenous oxidative damage (Stonehouse et al., 2013). Research into their health benefits has focused on the cultivars *Actinidia deliciosa* "Hayward" (green kiwi fruit) and *Actinidia chinensis* "Hort 16A" (gold kiwi fruit). While many research gaps remain, kiwi fruit with their multiple health benefits have the potential to become part of our "daily prescription for health" (Burdon et al., 2004; Stonehouse et al., 2013). Comparison of the antioxidant effects *in vitro* demonstrated that kiwi fruit had stronger antioxidant effects than orange and grapefruit, which are rich in vitamin C; gold kiwi had the strongest antioxidant effects (Iwasawa, Morita, Yui, & Yamazaki, 2011). Different treatments for the prolonged shelf life of fruits were ethylene treatment with combination of cold storage or room temperature (Mworia et al., 2012). Other results were obtained by Koutsoflini, Gerasopoulos, and Vasilakakis (2013), where harvested kiwi fruits during fruit maturation or after delayed storage (DS) at 20°C for 0, 1, 2, 3 and 4 weeks and 1 µl L^{-1} of ethylene treatment for 24 hours were stored at –0.5°C for 24 weeks and additional ripening at 20°C for 5 days. Changes in biochemical parameters of fruits and vegetables, ripening during cold storage and storage duration were widely studied in the last years (Ferguson, 2013; Fiorentino et al., 2009; Kovač et al., 2010; Massolo, Concellón, Chaves, & Vicente, 2013; Mworia et al., 2012; Téllez, Saucedo, Arévalo, & Valle, 2009). There are numerous reports about "Hayward" and "Hort 16A" cultivars, their properties, cold-storage treatments, and health benefits (Burdon et al., 2004; Fiorentino et al., 2009; Gorinstein et al., 2009; Koutsoflini et al., 2013; Pranamornkith, East, & Heyes, 2012). Whereas very little information is found about the shelf life of new kiwi fruit cultivars bred in Korea and changes in their quality during 24 weeks of cold storage. So, in the present study we compared the effect of long-term cold storage on physicochemical properties and bioactive components of five new cultivars with the known ones such as "Hayward" and "Hort16A". For this purpose texture and sensory analyses, total soluble phenols, antioxidant activity (AA) and quality parameters were determined. In order to receive the reliable results of total antioxidant capacities two generally accepted assays (FRAP and β-carotene) were used. As far as we know no results of such investigations were published.

Materials and methods

Fruit samples

Kiwi fruits of seven cultivars were harvested at the optimal stage in orchard, located in Haenam county (longitude 126° 15″ and latitude 34° 18″), Jeonnam province, Korea, in 2011. All cultivars, except "Hort 16A", were bred in Korea. "Hort 16A" is a New Zealand gold kiwi fruit and was purchased in 2011 from a farmer, located in Jeju Island. "Hwaemi" and "SKK-12" are green kiwi fruit cultivars of 100-g size as "Hayward". "Bidan" has a smaller size of 20 g and its skin is white (flesh is green). Defect fruits were discarded and then, the healthy ones were stored in cold room (0°C, 90% RH) for 24 weeks. The samples were treated with liquid nitrogen in order to prevent oxidation of phenolic compounds and then lyophilized as described earlier (Gorinstein et al., 2009; Park et al., 2012).

Chemicals and reagents

6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), Folin–Ciocalteu reagent (FCR); β-carotene, linoleic acid and Tween-40 (polyoxyethylene sorbitan monopalmitate) and $FeCl_3 \times 6H_2O$ were purchased from Sigma Chemical Co., St Louis, MO, USA. 2, 4, 6-Tripyridyl-*s*-triazine (TPTZ) was purchased from Fluka Chemie, Buchs, Switzerland. All reagents were of analytical grade.

Texture analysis

The fruits were analyzed for firmness by measuring penetration force in kilogram using a fruit-firmness tester (Model KM, Fruit Test Tech, and Japan). Firmness tester has cylinder-style shape, the tip diameter is 0.5 mm, the bottom diameter is 10 mm and the length is 20 mm. After peeling, the tester penetrates (punches) the flesh with hand pressing. The mean values of the firmness were expressed as Newton (N). 1 N is 9.8 kg.

Determination of total soluble solids (TSS), pH, total acidity (TA), and dry matter

The peeled fruits were homogenized and filtered through a cheesecloth in order to obtain a clear juice for determination of TSS (Brix), pH, TA, and dry matter. The TSS was measured using a refractometer (Atago Com. Ltd., Tokyo, Japan), pH was estimated with a pH meter. The TA was measured in 4 mL of juice, diluted to 20 mL of distilled water and titrated with 0.1 N NaOH. The TA was expressed as a percentage of citric acid.

Starch and reducing sugar contents, carbon dioxide, and ethylene productions

Starch was determined in 10 g of flesh kiwi fruit extracted with 20 mL of 90% ethanol and filtered through Whatman No. 4 filter paper (110 mm pore size). The extract solution was evaporated and then 5 mL of 90% ethanol were added. Starch concentration was obtained from values of absorbance (calibration curve), measured at 525 nm on a spectrophotometer (Hewlett-Packard, model 8452A, Rockville, USA). Reducing sugar was extracted from juice and analyzed with the modified method of 3.5-dinitrosalicylic acid (Park & Park, 1997).

For measurement of carbon dioxide and ethylene production, five fruits were sealed in a 1.8-L glass jar for 24 hours and head space gas was sampled with a 1-mL syringe. Ethylene and respiration contents were determined using gas chromatography (GC) (Hewlett Packard, USA) according to modified method of Park and Kim (2002). The amount was calculated as following: CO_2/ethylene content(GC) × g(fruit weight)/kg × 1(hour)/24 hour, that means that if the amount of CO_2 from the GC analysis using the standard calibration curve is 15 mL, then multiple by 0.5 fruit weight (if gas was extracted from 500 g, and the used units are kg), then divide on 24 hours (1 hour unit/24 hours of extraction time) and the result is 0.31 mL $hour^{-1}$ kg^{-1}. The contents were expressed for CO_2 in mL kg^{-1} $hour^{-1}$ and for C_2H_4 in µL kg^{-1} $hour^{-1}$.

Total soluble phenols

Total soluble polyphenols were extracted with water at room temperature and extracted during 1 hour at concentration 25 mg mL^{-1}. The polyphenols were determined by Folin–Ciocalteu method (Singleton, Orthofer, & Lamuela-Raventós, 1999) with absorbance measurement at 750 nm (Spectrophotometer, Hewlett-Packard, model 8452A, Rockville, USA). The results were expressed as mg of GAE per g DW. Total flavonoid content was determined by an aluminum chloride colorimetric method with some modifications. The absorbance was measured immediately against the blank at 510 nm. The extracts of condensed tannins (procyanidins) with 4% methanol vanillin solution were measured at 500 nm. (+)-Catechin served as a standard for flavonoids and tannins (Park et al., 2012), and the results were expressed as catechin equivalents (CE).

Antioxidant assay/activity

Ferric-reducing/antioxidant power (FRAP) assay measures the ability of the antioxidants in the investigated samples to reduce ferric-tripiridyltriazine (Fe^{3+} TPTZ) to a ferrous form (Fe^{2+}). FRAP reagent (2.5 mL of a 10 mmol ferric-tripiridyltriazine solution in 40 mmol HCl plus 2.5 mL of 20 mmol $FeCl_3$ xH_2O and 25 mL of 0.3 mol L^{-1} acetate buffer, pH 3.6) of 900 µL was mixed with 90 µL of distilled water and 30 µL of kiwi fruit extract samples as the appropriate reagent blank. The absorbance was measured at 595 nm (Benzie & Strain, 1996).

Antioxidant assay, using β-carotene linoleate model system (β-carotene): β-Carotene (0.2 mg) in 0.2 mL of chloroform, linoleic acid (20 mg), and Tween-40 (polyoxyethylene sorbitan monopalmitate) (200 mg) were mixed (Jayaprakasha & Rao, 2000). Chloroform was removed at 40°C under vacuum, and the resulting mixture was diluted with 10 mL of water and mixed well. To this emulsion was added 40 mL of oxygenated water. Four milliliter aliquots of the emulsion were pipetted into different test tubes containing 0.2 mL of fruit extracts (50 and 100 ppm) and Butylated hydroxyanisole (BHA) (25 and 50 ppm) in ethanol. BHA was used for comparative purposes. A control containing 0.2 mL of ethanol and 4 mL of the above emulsion was prepared. The tubes were placed at 50°C in a water bath, and the absorbance at 470 nm was taken at zero time (t = 0). Measurement of absorbance was continued until the color of β-carotene disappeared in the control tubes (t = 180 min) at an interval of 15 min. A mixture prepared as mentioned above without β-carotene served as blank. The AA of the extracts was evaluated in terms of bleaching of the β-carotene using the following formula, AA = 100 $[1–(A_0 – A_t) / (A°_0 – A°_t)]$, where A_0 and $A°_0$ are the absorbance values measured at zero time of the incubation for test sample and control, respectively, and A_t and $A°_t$ are the absorbance measured in the test sample and control, respectively, after incubation for 180 min.

Sensory analysis

Sensory quality was carried out in a sensory laboratory by 12 qualified panelists. Taste quality was evaluated by affective test of appearance, taste (sweetness, sourness, flavor, texture) and total acceptation in Hedonic scale method which was 1–5 rating scale (1 = severely bad, 2 = bad, 3 = moderate, 4 = good, 5 = excellent). We did not use phenolics and AA in sensory evaluation.

Statistical analysis

Simple comparisons of mean values were performed by Student's t-test and level of significance was accepted at $p \leq 0.05$. Stepwise and canonical discriminant analysis (CDA) was used to investigate and select the best physicochemical indices to monitor changes and differences between kiwi fruit cultivars during cold treatment. CDA recognition ability test was calculated as the percentage of correctly classified samples in the a priori defined categories. Statistical evaluation of the experimental data was performed by statistical package Unistat v. 6.0 (Unistat, London, United Kingdom).

Results and discussion

Texture analysis

The physicochemical properties of kiwi fruit cultivars (Table 1) changed during cold storage for 8–24 weeks and the most extreme ones between them were in "SKK-12" and "Hayward". The firmness (N) of "SKK-12" during 8 weeks of cold storage was changed from 37.81 ± 0.30 to 5.14 ± 0.04 and

Table 1. Changes in quality of seven kiwi fruit cultivars grown in Korea during 24 weeks of cold storage.

Tabla 1. Cambios detectados en la calidad de siete variedades de kiwi cultivadas en Corea a partir de su almacenamiento en frío durante 24 semanas.

Cultivars	Time storage (weeks)	Firmness (N)	Sensory
Bidan	0	38.52^{a} ± 0.30	1.35 ± 0.01
	4	25.01^{b} ± 0.20	1.70^{b} ± 0.01
	8	18.34 ± 0.14	2.1^{c} ± 0.02
	12	7.42 ± 0.06	2.30^{d} ± 0.02
	16	4.53 ± 0.03	2.50 ± 0.02
SKK-12	0	37.81 ± 0.30	1.60 ± 0.01
	4	22.12 ± 0.18	2.25 ± 0.02
	8	5.14^{c} ± 0.04	2.60 ± 0.02
Daheung	0	40.25^{d} ± 0.32	1.25 ± 0.01
	4	22.76 ± 0.18	1.70^{b} ± 0.01
	8	15.32 ± 0.12	2.10^{c} ± 0.02
	12	5.50^{e} ± 0.04	2.70 ± 0.02
Haenam	0	38.75^{a} ± 0.30	1.40^{a} ± 0.01
	4	25.13^{b} ± 0.21	1.62 ± 0.02
	8	16.50 ± 0.13	2.83^{f} ± 0.05
	12	4.61 ± 0.04	2.85^{f} ± 0.04
Hort16A	0	43.11 ± 0.34	1.05 ± 0.06
	4	27.71 ± 0.22	1.40^{a} ± 0.06
	8	20.78 ± 0.16	1.70^{b} ± 0.01
	12	15.02 ± 0.12	2.10^{c} ± 0.08
	16	10.50 ± 0.08	2.92^{g} ± 0.02
	20	5.51^{e} ± 0.04	2.95^{h} ± 0.03
	24	5.59 ± 0.04	2.96^{h} ± 0.03
Hwamei	0	36.18 ± 0.29	1.52 ± 0.01
	4	21.42 ± 0.17	2.32^{d} ± 0.02
	8	9.88^{f} ± 0.08	3.10^{j} ± 0.03
	12	9.91^{f} ± 0.08	3.01^{i} ± 0.03
Hayward	0	40.32^{d} ± 0.32	1.23 ± 0.01
	4	33.01 ± 0.26	1.75 ± 0.01
	8	22.36 ± 0.18	2.16^{c} ± 0.02
	12	16.21 ± 0.13	2.35^{d} ± 0.07
	16	11.50 ± 0.09	2.45 ± 0.02
	20	9.75 ± 0.07	2.76^{e} ± 0.02
	24	5.15^{e} ± 0.04	2.78^{ef} ± 0.05

Note: Values are means ± SD of 10 measurements; means within a column with the same superscripts are not statistically different, all without superscript are different ($p < 0.05$; Student's t-test).

Nota: Los valores son las medias ± DE de 10 mediciones; Las medias dentro de una columna, con el mismo superíndice no son estadísticamente diferentes, todas aquellas sin superíndice son diferentes ($p < 0,05$; prueba t de Student).

for "Hayward" during 24 weeks changed from 40.32 ± 0.32 to 5.15 ± 0.04. Dry matter (%) for the same cultivars at 8 week for "SKK-12" and for "Hayward" at 12th week was similar. Texture is usually used in sensory evaluation for fruits, but we measured firmness with as an index of softening. Shelf life in kiwi fruit is determined by the degree of softening, Kiwi fruits are softened when the firmness reached below 5 N. In a recent report (Korsak & Park, 2010), "Hayward" kiwi fruits (*A. deliciosa*) were treated with 100 ppm ethylene at 20°C for 24 hours and then immediately ripened at 20°C for 10 days. Flesh firmness significantly decreased at initial time in fruits treated with ethylene, while sensory value increased with the progress of ripening. Treatment of ethylene was not used in the present experiment. The evaluation of softening characteristics (White, Nihal de Silva, Requejo-Tapia, & Harker, 2005) was similar to our results. In contrast to fruit maturation, postharvest (after harvest and before storage) of DS at non-chilling temperature and ethylene treatment advanced the ripening of "Hayward" and resulted in increased low-temperature breakdown incidence (Koutsoflini et al., 2013). Significant fruit softening and decreased TA were observed without ethylene production in intact fruit stored at low temperature for 1 month, but not in fruit stored at room temperature. Repeated 1-methylcyclopropene (1-MCP) treatments (twice a week) failed to inhibit the changes that occurred in low-temperature storage. These observations indicate that low temperature modulates the ripening of kiwi fruit in an ethylene-independent manner, suggesting that kiwi fruit ripening is inducible by either ethylene or low-temperature signals (Mworia et al., 2012). Kiwi fruits were stored at 0°C for 12 weeks, followed by 6 days of shelf life at 20°C. Fruit ripened and softened slowly during storage at 0°C, and no ethylene was detectable at the end of storage or during the shelf life. Five ethylene receptor genes showed different changes in expression during low-temperature storage (Yin et al., 2009).

Determination of TSS, pH, TA, and dry matter

The TSS (Brix) before the treatment were from 7.02 ± 0.06 to 13.72 ± 0.10 and from 7.83 ± 0.06 to 14.97 ± 0.12 for "SKK-12" during 8 weeks and "Hayward" for 24 weeks, respectively (Table 2). Dry matter (%) before the treatment was from 15.75 ± 0.13 to 15.42 ± 0.11 and from 16.68 ± 0.14 to 15.14 ± 0.12 for "SKK-12" during 8 weeks and "Hayward" for 24 weeks, respectively (Table 2). The pH and TA (%) during the cold storage changed from 3.23 ± 0.03 to 3.33 ± 0.01 and 1.44 ± 0.08 to 0.91 ± 0.03 for "SKK-12", respectively. For "Hayward", pH values were from 3.22 ± 0.02 to 3.52 ± 0.01 and TA was from 1.49 ± 0.10 to 0.84 ± 0.10. Fruit firmness rapidly decreased and TSS increased

Table 2. Changes in physicochemical properties of seven kiwi fruit cultivars grown in Korea during 24 weeks of cold storage.

Tabla 2. Cambios detectados en las propiedades fisicoquímicas de siete variedades de kiwi cultivadas en Corea a partir de su almacenamiento en frío durante 24 semanas.

Cultivars	Time storage (weeks)	TSS (Brix)	Acidity (%)	pH	Dry matter (%)
Bidan	0	7.41 ± 0.06	1.42^{d} ± 0.12	3.21^{g} ± 0.01	16.21^{a} ± 0.10
	4	11.03 ± 0.09	1.11^{c} ± 0.09	3.25^{a} ± 0.01	16.26^{a} ± 0.11
	8	12.82^{d} ± 0.10	0.90^{b} ± 0.05	3.40 ± 0.01	16.82^{b} ± 0.13
	12	13.35^{e} ± 0.11	0.79^{a} ± 0.02	3.42 ± 0.02	16.73^{b} ± 0.13
	16	14.01^{g} ± 0.11	0.83^{b} ± 0.03	3.35^{b} ± 0.03	16.64^{b} ± 0.09
SKK-12	0	7.02 ± 0.06	1.44^{d} ± 0.08	3.23^{a} ± 0.03	15.75^{c} ± 0.13
	4	10.83 ± 0.09	1.08^{c} ± 0.07	3.25^{a} ± 0.01	15.31^{d} ± 0.12
	8	13.72 ± 0.10	0.91^{b} ± 0.03	3.33^{c} ± 0.01	15.42^{d} ± 0.11
Daheung	0	6.85 ± 0.05	1.45^{d} ± 0.16	3.22 ± 0.01	15.55^{e} ± 0.08
	4	11.81 ± 0.09	1.22^{c} ± 0.10	3.35^{b} ± 0.02	15.47^{e} ± 0.12
	8	12.83^{d} ± 0.10	0.94^{b} ± 0.06	3.35^{b} ± 0.01	15.28^{f} ± 0.10
	12	13.52 ± 0.11	0.82^{a} ± 0.04	3.55 ± 0.03	15.37^{d} ± 0.14
Haenam	0	7.74 ± 0.06	1.41^{d} ± 0.02	3.25^{a} ± 0.01	15.89^{c} ± 0.17
	4	11.14^{b} ± 0.09	1.11^{c} ± 0.03	3.31^{b} ± 0.03	15.46^{e} ± 0.12
	8	13.11 ± 0.10	0.93^{b} ± 0.03	3.30^{b} ± 0.01	16.56^{b} ± 0.13
	12	13.95^{fg} ± 0.11	0.83^{b} ± 0.04	3.45 ± 0.02	15.84^{c} ± 0.15
Hort16A	0	7.53 ± 0.06	1.46^{d} ± 0.28	3.33^{c} ± 0.02	16.32^{a} ± 0.13
	4	11.11^{b} ± 0.09	1.12^{c} ± 0.16	3.31^{b} ± 0.01	16.25^{a} ± 0.16
	8	12.21^{c} ± 0.10	0.97^{b} ± 0.14	3.25^{a} ± 0.01	16.33^{a} ± 0.10
	12	13.34^{e} ± 0.11	0.93^{b} ± 0.10	3.38 ± 0.01	16.41^{a} ± 0.11
	16	14.51 ± 0.11	0.85^{b} ± 0.26	3.45^{f} ± 0.01	16.12^{a} ± 0.12
	20	14.22^{h} ± 0.11	0.85^{b} ± 0.20	3.55^{d} ± 0.01	16.13^{a} ± 0.17
	24	14.25^{h} ± 0.11	0.85^{b} ± 0.14	3.55^{d} ± 0.01	16.42^{b} ± 0.14
Hwamei	0	6.21 ± 0.05	1.48^{d} ± 0.19	3.11 ± 0.02	15.50^{e} ± 0.10
	4	10.56^{a} ± 0.08	1.12^{c} ± 0.12	3.22^{e} ± 0.01	15.41^{d} ± 0.12
	8	12.17^{c} ± 0.10	0.92^{b} ± 0.18	3.26^{a} ± 0.01	15.33^{d} ± 0.11
	12	12.18^{c} ± 0.10	0.92^{b} ± 0.15	3.26^{a} ± 0.01	15.37^{d} ± 0.13
Hayward	0	7.83 ± 0.06	1.49^{d} ± 0.10	3.22^{e} ± 0.02	16.68^{b} ± 0.14
	4	10.63^{a} ± 0.08	1.22^{c} ± 0.21	3.33^{c} ± 0.02	16.29^{a} ± 0.09
	8	12.24^{c} ± 0.10	0.95^{b} ± 0.12	3.44^{f} ± 0.02	16.71^{c} ± 0.10
	12	13.34^{e} ± 0.10	0.85^{b} ± 0.09	3.31^{b} ± 0.01	15.35^{d} ± 0.12
	16	13.86^{f} ± 0.11	0.84^{b} ± 0.08	3.22^{g} ± 0.01	15.26^{f} ± 0.15
	20	14.15^{h} ± 0.11	0.85^{b} ± 0.07	3.51^{h} ± 0.01	15.32^{d} ± 0.14
	24	14.97 ± 0.12	0.84^{b} ± 0.10	3.52^{h} ± 0.01	15.14^{f} ± 0.12

Note: Values are means ± SD of 10 measurements; means within a column with the different superscripts or without superscript are statistically different ($p < 0.05$; Student's *t*-test).

Nota: Los valores son las medias ± DE de 10 mediciones; las medias dentro de una columna con diferente o sin superíndice son estadísticamente diferentes ($p < 0,05$; prueba *t* de Student).

for all cultivars during the first 14 days of storage at 1°C, according to Krupa, Latocha, and Liwińska (2011). The polyphenols in vine ripe fruits were similar to the fruits of storage harvest maturity (8–10% TSS). Our results are in line with Krupa et al. (2011), that firmness rapidly decreased and the TSS increased for all cultivars during the first 14 days of storage at 1°C. Physicochemical properties of samples of "Abbot", "Alison", "Bruno", "Monty", and "Hayward" cultivars of kiwi fruit were studied during cold storage at 0-, 9-, and 18-week intervals. The mean chemical composition of the fruits was as follows: starch = 0.3–7.0%, °Brix = 6.5–14.8%, and acidity = 1.8–2.5% of the studied cultivars. "Hayward" had the best overall quality particularly with regard to its resistance to softening. This study confirms that long-term cold storage at 1 ± 1°C and 80 ± 5% RH is suitable for maintaining the highest quality of Iranian grown cultivars of kiwi fruit (Zolfaghari, Sahari, Barzegar, & Samadloiy, 2010). "Hayward" cultivar was similar to the one grown in Italy (Castaldo, Lo Voi, Trifiro, & Gherardi, 1992). The physicochemical indices of "Hayward" grown in Iran differ from the present results shown in Tables 1–2. Brix changed from 7.83 ± 0.06 to 14.97 ± 0.12 in comparison with Iranian of 8.13 ± 0.15 to 17.70 ± 0.26 during 18 weeks. pH changed from 3.22 ± 0.02 to 3.52 ± 0.01 in comparison with 3.10 ± 0.01 to 2.93 ± 0.02 for the same cultivar, grown in Italy. These results are in line with our obtained data. Fruit firmness, content of starch, TSS, dry matter, and total acids content were decreased in apples after 14 weeks of storage in a controlled atmosphere (2°C, 95% relative air moisture, 2% CO_2, and 1% O_2) in each harvest time (Kovač et al., 2010). Harvested fruit [(*Cucurbita maxima* var. Zapallito (Carr.) Millan] was treated with the inhibitor of ethylene action 1-MCP (1 μL L^{-1}) and stored at 10 or 0°C for 14 or 19 days. Firmness, respiration rate, acidity, sugars, and antioxidants were determined. At 10°C, 1-MCP treated fruit showed lower deterioration and weight loss (Massolo et al., 2013).

Starch and reducing sugar contents, carbon dioxide, and ethylene productions

Reducing sugar content (Table 3) significantly increased at early stage of storage (from 35.20 ± 0.30 to 47.32 ± 0.40% for "Hayward") with decreasing of starch content (11.12 ± 0.09 to 7.21 ± 0.06% for "Hayward"). There was no difference of these indices among cultivars. Respiration rate increased with time and then decreased during cold storage (from 38.18 ± 0.31 to 17.12 ± 0.14 μL kg^{-1} $hour^{-1}$ for C_2H_4, and from 4.22 ± 0.04 to 2.13 ± 0.02 mL kg^{-1} $hour^{-1}$ for CO_2). Peaks time was different between cultivars, therefore we represented trend of respiration changes in all cultivars. During cold storage the significant effectiveness

Table 3. Changes in reducing sugar, starch, and ethylene and CO_2 production of seven kiwi fruit cultivars grown in Korea during 24 weeks of cold storage.

Tabla 3. Cambios detectados en la disminución de azúcar, almidón y etileno, y en la producción de CO_2 en siete variedades de kiwi cultivadas en Corea a partir de su almacenamiento en frío durante 24 semanas.

Cultivars	Time storage (weeks)	Reducing sugar	Starch	Ethylene production	CO_2 production
Bidan	0	12.11 ± 0.10	35.15 ± 0.30	20.12^{c} ± 0.17	2.10 ± 0.02
	4	22.31 ± 0.19	16.80 ± 0.14	23.20 ± 0.20	2.40 ± 0.02
	8	35.20^{b} ± 0.30	11.12 ± 0.09	38.18 ± 0.31	4.22^{a} ± 0.04
	12	47.32 ± 0.40	7.21^{c} ± 0.06	29.16^{a} ± 0.25	2.23^{e} ± 0.03
	16	45.15 ± 0.38	5.62 ± 0.05	25.50 ± 0.22	2.53 ± 0.04
SKK-12	0	11.12^{a} ± 0.09	38.53 ± 0.32	18.21 ± 0.15	2.05^{f} ± 0.05
	4	38.17 ± 0.32	17.16 ± 0.14	29.32^{a} ± 0.25	3.42 ± 0.03
	8	44.32^{c} ± 0.37	7.14^{c} ± 0.06	27.18^{b} ± 0.23	4.21^{a} ± 0.04
Daheung	0	11.22^{a} ± 0.10	32.22^{a} ± 0.27	17.12 ± 0.14	2.13^{f} ± 0.02
	4	21.12 ± 0.18	19.15 ± 0.16	23.52 ± 0.20	3.11 ± 0.03
	8	35.15^{b} ± 0.30	10.20 ± 0.09	36.16 ± 0.31	3.52^{c} ± 0.03
	12	41.32^{d} ± 0.35	8.08^{b} ± 0.09	27.31^{b} ± 0.23	2.91^{d} ± 0.06
Haenam	0	11.52 ± 0.10	33.13 ± 0.28	18.50 ± 0.16	2.01^{f} ± 0.03
	4	23.13 ± 0.20	16.22 ± 0.14	30.12 ± 0.26	3.33 ± 0.03
	8	33.50 ± 0.28	8.03^{b} ± 0.07	34.13 ± 0.29	3.75^{b} ± 0.05
	12	40.45 ± 0.34	6.41 ± 0.05	27.15^{b} ± 0.23	2.53 ± 0.01
Hort16A	0	12.53 ± 0.10	36.15 ± 0.31	20.21^{c} ± 0.17	2.13^{f} ± 0.06
	4	21.58 ± 0.18	21.12 ± 0.18	24.23 ± 0.20	2.85^{d} ± 0.07
	8	35.25^{b} ± 0.30	12.21 ± 0.10	33.13 ± 0.28	4.12 ± 0.09
	12	42.20 ± 0.36	7.50 ± 0.06	41.14 ± 0.35	3.72^{b} ± 0.08
	16	44.16^{c} ± 0.37	5.50 ± 0.05	32.02 ± 0.27	3.21 ± 0.03
	20	43.12 ± 0.37	6.25 ± 0.04	26.06 ± 0.22	2.68 ± 0.04
	24	41.15^{d} ± 0.35	4.51 ± 0.06	25.21 ± 0.21	2.21^{e} ± 0.06
Hwamei	0	11.21^{a} ± 0.09	32.50^{a} ± 0.28	21.32 ± 0.18	2.21^{e} ± 0.08
	4	30.20 ± 0.26	18.16 ± 0.15	27.20^{b} ± 0.23	3.52^{c} ± 0.06
	8	12.11 ± 0.10	35.15 ± 0.30	20.12^{c} ± 0.17	2.10 ± 0.02
	12	22.31 ± 0.19	16.80 ± 0.14	23.20 ± 0.20	2.40 ± 0.02
Hayward	0	35.20^{b} ± 0.30	11.12 ± 0.09	38.18 ± 0.31	4.22^{a} ± 0.04
	4	47.32 ± 0.40	7.21^{c} ± 0.06	29.16^{a} ± 0.25	2.23^{e} ± 0.03
	8	45.15 ± 0.38	5.62 ± 0.05	25.50 ± 0.22	2.53 ± 0.04
	12	11.12^{a} ± 0.09	38.53 ± 0.32	18.21 ± 0.15	2.05^{f} ± 0.05
	16	38.17 ± 0.32	17.16 ± 0.14	29.32^{a} ± 0.25	3.42 ± 0.03
	20	44.32^{c} ± 0.37	7.14^{c} ± 0.06	27.18^{b} ± 0.23	4.21^{a} ± 0.04
	24	11.22^{a} ± 0.10	32.22^{a} ± 0.27	17.12 ± 0.14	2.13^{f} ± 0.02

Note: Values are means ± SD of 10 measurements; means within a column with the same superscripts are not statistically different, all without superscript are different ($p < 0.05$; Student"s *t*-test). The contents were expressed for CO_2 in mL kg^{-1} $hour^{-1}$ and for C_2H_4 in μL kg^{-1} $hour^{-1}$; reducing sugar and starch, %.

Nota: Los datos son la medias ± DE de 10 mediciones; las medias dentro de una misma columna con el mismo superíndice no son diferentes estadísticamente, todas aquellas sin presencia de superíndice son diferentes ($p < 0,05$; prueba *t* de Student). Los contenidos fueron expresados para CO_2 en mL kg^{-1} $hora^{-1}$ y para C_2H_4 en μL kg^{-1} $hora^{-1}$; azúcares reductores y almidón, %.

of shelf life in kiwi fruit is characterized by respiration and ethylene production. Therefore, we analyzed these contents rather than gas composition (Table 3).

Total soluble phenols

Polyphenols in water extracts (Table 4) were the highest in "SKK-12" and the lowest in "Hayward" (16.34 ± 1.11 and 5.30 ± 0.45 mg GAE/g DW). Flavonoids and tannins were for SKK-12 and for Hayward differ but not always significantly. Park (2009) showed changes during cold storage for 24 weeks during 2008 season collection from the same orchard. Our present results slightly differ from the previous data, but the two-season collection showed similar relationship between the same cultivars. Relatively high content of bioactive compounds and antioxidant properties of kiwi fruit determined by the advanced analytical methods justify its use as a source of valuable antioxidants (Park et al., 2012). The bioactive compounds in kiwi fruit as an indication of quality after extraction using different solvents were studied in the recent publications (Park et al., 2012). The methanol extracts of kiwi fruit showed significantly higher amounts of bioactive compounds than ethyl acetate extracts. The cultivar "Bidan", in comparison with the classic "Hayward", showed significantly higher bioactivity (Park et al., 2012). Our previous data slightly differ from the final results shown in Table 4. The obtained results of kiwi fruit bioactivity correspond with the reported data of Mikulic-Petkovsek, Schmitzer, Slatnar, Stampar, and Veberic (2012); Nunes-Damaceno, Muñoz-Ferreiro, Romero-Rodríguez, and Vázquez-Odériz (2013); and Pranamornkith et al. (2012). Our results *in vitro* were similar to Lee et al. (2010), where the effects of the two main kiwi fruit cultivars (gold and green kiwi fruits) and their active phenolic compounds were evaluated.

Antioxidant activities

Radical scavenging assays and chemometrical processing were used for the determination of bioactive kiwi fruits' compounds (Table 4). The values of β-carotene activities (27.61 ± 2.44% and 8.33 ± 0.74%) and Ferric-reducing/antioxidant power [(FRAP, μM Trolox equivalent (TE)/g DW) 24.55 ± 2.01 and 7.12 ± 0.41] were the highest in "SKK-12". The lowest results were estimated in "Hayward". All kiwi fruit cultivars showed a high level of correlation between the contents of phenolic compounds and their antioxidant values.

Table 4. Changes in phenolic compounds and antioxidant activities of the seven kiwi fruit cultivars grown in Korea during 24 weeks of cold storage.

Tabla 4. Cambios detectados en los compuestos fenólicos y en las actividades antioxidantes de siete variedades de kiwi cultivadas en Corea a partir de su almacenamiento en frío durante 24 semanas.

Cultivars	Time storage (weeks)	Polyphen (mgGAE/g)	Flavon (mg CE/g)	Tannins (mg CE/g)	FRAP (μMTE/g)	β-carotene (% AA)
Bidan	0	$11.56^{i} \pm 1.12$	$0.75^{d} \pm 0.06$	$2.16^{gh} \pm 0.22$	$19.41^{k} \pm 1.71$	$20.19^{fg} \pm 2.11$
	4	$12.01^{i} \pm 1.21$	$0.81^{de} \pm 0.09$	$2.41^{hm} \pm 0.29$	$19.56^{kl} \pm 1.81$	$20.87^{fgh} \pm 2.20$
	8	$12.43^{jk} \pm 1.13$	$0.89^{e} \pm 0.09$	$2.65^{mn} \pm 0.25$	$19.96^{kl} \pm 1.83$	$21.89^{ghi} \pm 2.18$
	12	$13.41^{kl} \pm 1.23$	$0.95^{ef} \pm 0.11$	$2.89^{n\circ} \pm 0.22$	$20.85^{l} \pm 0.02$	$23.89^{ij} \pm 2.26$
	16	$13.97^{l} \pm 1.32$	$1.00^{f} \pm 0.11$	$3.04^{\circ} \pm 0.33$	$21.32^{m} \pm 0.03$	$24.15^{hij} \pm 2.13$
SKK-12	0	$15.75^{m} \pm 1.13$	$0.43^{a} \pm 0.06$	$1.44^{jk} \pm 0.08$	$23.23^{mn\circ} \pm 2.03$	$25.81^{jk} \pm 2.33$
	4	$16.31^{m} \pm 1.12$	$0.51^{b} \pm 0.07$	$1.58^{k} \pm 0.07$	$23.85^{n\circ} \pm 2.01$	$26.12^{jk} \pm 2.68$
	8	$16.34^{m} \pm 1.11$	$0.62^{c} \pm 0.07$	$1.60^{l} \pm 0.03$	$24.55^{\circ} \pm 2.01$	$27.61^{k} \pm 2.44$
Daheung	0	$4.56^{b} \pm 0.48$	$0.36^{j} \pm 0.05$	$1.23^{d} \pm 0.13$	$6.22^{c} \pm 0.61$	$7.34^{abc} \pm 0.72$
	4	$4.89^{bc} \pm 0.42$	$0.43^{a} \pm 0.05$	$1.33^{dj} \pm 0.13$	$6.76^{cde} \pm 0.62$	$8.16^{cd} \pm 0.88$
	8	$5.21^{cd} \pm 0.51$	$0.51^{b} \pm 0.06$	$1.44^{jk} \pm 0.14$	$7.35^{e} \pm 0.71$	$8.82^{de} \pm 0.82$
	12	$5.59^{d} \pm 0.54$	$0.55^{b} \pm 0.06$	$1.57^{k} \pm 0.14$	$7.88^{e} \pm 0.61$	$9.08^{e} \pm 0.84$
Haenam	0	6.23 ± 0.61	$0.44^{a} \pm 0.06$	$0.86^{a} \pm 0.08$	8.56 ± 0.65	38.75 ± 0.30
	4	$6.98^{e} \pm 0.62$	$0.54^{b} \pm 0.06$	$0.96^{c} \pm 0.08$	9.71 ± 0.86	$25.13^{j} \pm 0.22$
	8	$7.23^{ef} \pm 0.64$	$0.61^{c} \pm 0.07$	$1.07^{d} \pm 0.09$	$10.80^{f} \pm 1.01$	16.50 ± 0.13
	12	$7.69^{f} \pm 0.69$	$0.70^{d} \pm 0.09$	$1.17^{d} \pm 0.11$	$11.38^{fgh} \pm 1.02$	13.84 ± 0.04
Hort16A	0	$9.22^{g} \pm 0.73$	$0.94^{e} \pm 0.07$	$1.76^{e} \pm 0.14$	$11.02^{fg} \pm 0.82$	$19.11^{f} \pm 1.14$
	4	$9.65^{gh} \pm 0.76$	$0.99^{e} \pm 0.07$	$1.82^{e} \pm 0.16$	$11.34^{fgh} \pm 0.81$	$19.51^{f} \pm 1.12$
	8	$9.83^{gh} \pm 0.78$	$1.11^{f} \pm 0.08$	$1.95^{ef} \pm 0.17$	$11.87^{ghi} \pm 0.91$	$20.18^{fg} \pm 1.16$
	12	$10.21^{hi} \pm 0.81$	$1.18^{fg} \pm 0.09$	$2.03^{fg} \pm 0.21$	$12.21^{hij} \pm 0.93$	$20.42^{fg} \pm 1.42$
	16	$10.42^{hi} \pm 0.82$	$1.22^{gh} \pm 0.11$	$2.15^{gh} \pm 0.21$	$12.76^{ij} \pm 1.11$	$21.20^{gh} \pm 1.58$
	20	$10.63^{hi} \pm 1.11$	$1.31^{hi} \pm 0.12$	$2.25^{gh} \pm 0.22$	$12.89^{ij} \pm 1.21$	$21.51^{gh} \pm 1.64$
	24	$11.08^{i} \pm 1.14$	$1.37^{i} \pm 0.13$	$2.37^{h} \pm 0.24$	$13.12^{j} \pm 1.31$	$22.07^{hi} \pm 1.74$
Hwamei	0	$12.65^{j} \pm 1.21$	$0.46^{a} \pm 0.05$	$1.89^{e} \pm 0.11$	$21.21^{m} \pm 2.02$	$22.78^{hi} \pm 1.29$
	4	$12.91^{jk} \pm 1.32$	$0.56^{b} \pm 0.08$	$2.12^{g} \pm 0.12$	$22.12^{mn} \pm 2.04$	$22.42^{hi} \pm 1.47$
	8	$13.63^{jk} \pm 1.36$	$0.67^{c} \pm 0.10$	$2.32^{h} \pm 0.18$	$22.87^{mn\circ} \pm 2.11$	$22.88^{hi} \pm 1.58$
	12	$14.23^{k} \pm 1.39$	$0.75^{d} \pm 0.10$	$2.50^{i} \pm 0.15$	$23.11^{mn\circ} \pm 2.21$	$23.32^{i} \pm 1.68$
Hayward	0	$4.18^{a} \pm 0.28$	$0.36^{j} \pm 0.06$	$0.82^{a} \pm 0.07$	$5.22^{a} \pm 0.22$	$6.87^{a} \pm 0.42$
	4	$4.29^{a} \pm 0.28$	$0.39^{ja} \pm 0.08$	$0.89^{ab} \pm 0.09$	$5.45^{a} \pm 0.26$	$6.95^{a} \pm 0.46$
	8	$4.61^{b} \pm 0.31$	$0.42^{a} \pm 0.09$	$0.93^{b} \pm 0.09$	$5.87^{b} \pm 0.28$	$7.26^{ab} \pm 0.58$
	12	$4.85^{bc} \pm 0.41$	$0.49^{b} \pm 0.10$	$0.98^{bc} \pm 0.11$	$6.36^{cd} \pm 0.31$	$7.65^{bc} \pm 0.61$
	16	$4.95^{bc} \pm 0.41$	$0.51^{b} \pm 0.11$	$1.07^{cd} \pm 0.13$	$6.65^{cd} \pm 0.34$	$7.98^{cd} \pm 0.67$
	20	$5.12^{c} \pm 0.42$	$0.53^{b} \pm 0.11$	$1.11^{d} \pm 0.13$	$6.89^{de} \pm 0.35$	$8.12^{cd} \pm 0.71$
	24	$5.30^{c} \pm 0.45$	$0.57^{b} \pm 0.12$	$1.17^{d} \pm 0.14$	$7.12^{e} \pm 0.41$	$8.33^{cd} \pm 0.74$

Note: Values are means ± SD of 10 measurements; per g dry weight. Abbreviations: Polyphen, polyphenols; CE, catechin equivalent; GAE, gallic acid equivalent; FLAVON, flavonoids. TE, Trolox equivalent, β-carotene, β-carotene linoleate assay; AA, antioxidant activity. FRAP, Ferric-reducing/antioxidant power; Means within a column with different superscripts are statistically different ($p < 0.05$; Students *t*-test).

Nota: Los datos son las medias ± DE de 10 mediciones; por g de peso seco. Abreviaturas: Polyphen, polifenoles; CE, equivalentes de catequina; GAE, equivalentes de ácido gálico; FLAVON, flavonoides. TE, equivalentes de Trolox, β- carotene, Prueba del linoleato β- caroteno; AA, actividad antioxidante; FRAP, Método del poder reductor del ión férrico; Las medias dentro de una misma columna con diferente superíndice son estadísticamente diferentes ($p < 0,05$; prueba *t* de Student).

Our recent results differed from the ones showed by Park et al. (2008), where the antioxidant capacities were determined by 2, 2-Azino-bis (3-ethyl-benzothiazoline-6-sulfonic acid) diammonium salt (ABTS), 2,2-diphenyl-1-picrylhydrazyl (DPPH), and cupric reducing antioxidant capacity (CUPRAC). Our results are in full correspondence with Krupa et al. (2011), where a strong correlation between polyphenol contents (TPC) and AA was in hardy kiwi fruits. TPC in ripe fruits were similar to the ones of the of storage harvest maturity (8–10% SSC). There was an increase in TPC after 7 days at the temperature 1°C, but a longer period of storage caused a decrease. The AA slightly decreased during storage. That means that phenolics affect the AA of hardy kiwi fruits (Krupa et al., 2011). The fresh-cut mangoes retained their bioactive compound content during cold storage and their antioxidant and nutritional properties make them a good source of these compounds (Robles-Sánchez et al., 2009).

Sensory analysis

The sensory value (score) at the beginning was from 1.60 ± 0.01 to 2.60 ± 0.02 for "SKK-12" and from 1.23 ± 0.01 to 2.78 ± 0.05 for "Hayward" (Table 1). Duration of cold storage changed the quality of fruits. The results showed that Mamey fruits treated with 600 and 900 nL L^{-1} and stored for 7 days, delayed their ripening for 3 and 6 days, respectively, but the fruits stored for 14 days, reached ripeness with an acceptable quality after 17 and 19 days (Téllez et al., 2009).

Shelf life of kiwi fruit cultivars were 8, 10, 12, 12, 14, 20, 24 weeks in "SKK 12", "Hwamei", "Haenam", "Daheung", "Bidan", "Hort 16 A", and "Hayward" cultivars, respectively. Shelf life of new cultivars bred in Korea such as "SKK 12", "Hwamei", "Daheung", and "Bidan" considerably reduced compared to "Hort 16A" or "Hayward" cultivars.

Statistical analysis

Stepwise discriminant analysis was applied to select the best discriminating parameters for distinguishing and differentiation of kiwi fruit cultivars (Table 5). From 10 examined parameters 6 were recognized as highly significant ($p < 0.001$). According to the highest F-ratio and the smallest Wilks' Lambda value, flavonoids and beta-carotene were found as the variables with the highest discriminating power. CDA showed a canonical correlation 0.9 for the discriminant function 1, which explained 88.6% of total variation. The second and third functions together explained only 11.3% of total variation, indicating that the maximum possible variation between kiwi fruit cultivars was explained by the first discriminant function. Canonical scores revealed clear discrimination between kiwi fruit cultivars, as shown by the clustering data in Figure 1. FRAP value, content of polyphenols and flavonoids were selected by canonical

Table 5. Summary table of stepwise discriminant analysis – selection of the best discriminating variables for differentiation of seven kiwi fruit cultivars (Tolerance: 0.001; F-to-Enter: 3.8416 (5.0%); F-to-Remove: 2.7056 (10.0%).

Tabla 5. Tabla resumen del análisis discriminante por pasos – selección de las mejores variables discriminantes para la diferenciación de las siete variedades de kiwi (tolerancia: 0,001; F-to-Enter: 3,8416 (5,0%); F-to-Remove: 2,7056 (10,0%).

Variable	Entered at Step	F-to-Enter	Probability	Wilks' Lambda
FRAP	1	58.8579	0.0000	0.0710
Polyphenols	2	61.9242	0.0000	0.0046
Tannins	3	56.2213	0.0000	0.0003
Flavon	4	199.8017	0.0000	6.29×10^{-6}
Sensory	5	54.0130	0.0000	4.16×10^{-7}
beta-carotene	6	10.6427	0.0000	1.06×10^{-7}

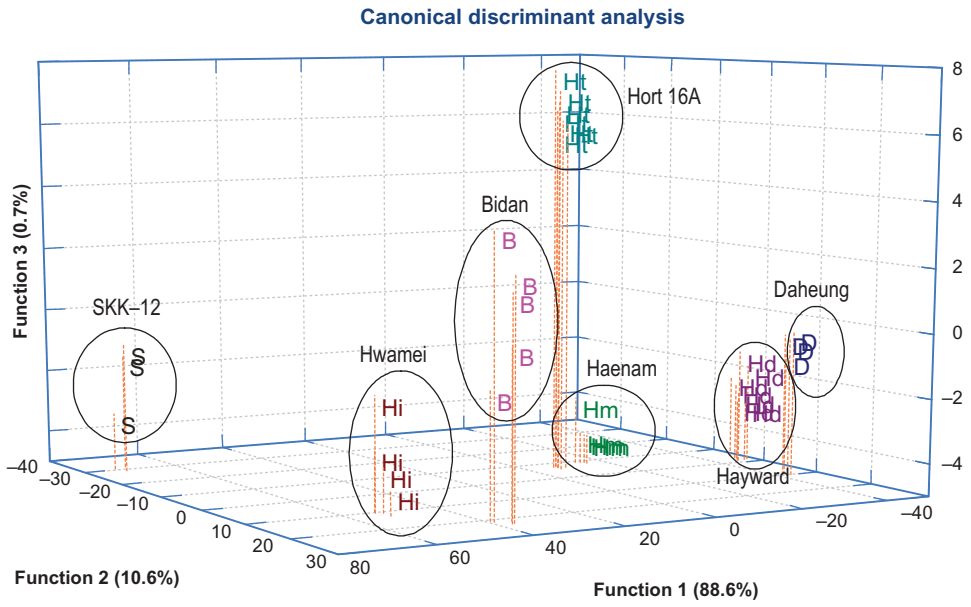

Figure 1. Canonical scores of the first three canonical discriminant functions during cold treatment of kiwi fruit cultivars (B, Bidan; S, SKK-12; D, Daheung; Hm, Haenam; Ht, Hort 16A; Hi, Hwamei; Hd, Hayward) categorized by10 descriptors (reducing sugar, starch, ethylene production, CO_2 production, sensory, polyphenols, flavonoids, tannins, FRAP value, β-carotene).

Figura 1. Puntaje canónico de las primeras tres funciones discriminantes canónicas obtenidas durante el almacenamiento en frío de variedades de kiwi (B- Bidan, s- skk-12, D- Daheung, Hm- Haenam, Ht- Hort 16A, Hi- Hwamei, Hd- Hayward), categorizadas por 10 descriptores (reducción de azúcar, almidón, producción de etileno, producción de CO_2, sensorial, polifenólidos, flavonoides, taninos, valor frap, β-caroteno).

discrimination as the best variables for categorization of kiwi fruit according to their genotype. Classification of kiwi fruit samples in the recognition ability conditions using the CDA procedure resulted with 100% of correctly categorized samples according to their affiliation to kiwi fruit cultivars.

Conclusions

We presented for the first time the results of shelf life of new cultivars bred in Korea and their comparison with the widely studied ones such as "Hayward" and "Hort 16A". Cold storage had a significant effect on physicochemical and nutritional properties of kiwi fruit and improved their quality and AA. Cold storage enhanced the firmness, starch, and TSS due to lower respiration and ethylene production. Cold storage extended shelf life in kiwi fruit without any chilling injury or color change in green kiwi fruit such as "Hayward" and other similar cultivars, but gold kiwi fruit slightly changed the color. The suggested methods for the quality of kiwi fruit can be applied for any fruit. High amount of natural antioxidants such as phenolic compounds in all cultivars makes kiwi fruit even more important for daily consumption.

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References

Benzie, I. F. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Analytical Biochemistry, 239*, 70–76. doi:10.1006/abio.1996.0292

Burdon, J., McLeod, D., Lallu, N., Gamble, J., Petley, M., & Gunson, A. (2004). Consumer evaluation of "Hayward" kiwifruit of different at-harvest dry matter contents. *Postharvest Biology and Technology, 34*, 245–255. doi:10.1016/j.postharvbio.2004.04.009

Castaldo, D., Lo Voi, A., Trifiro, A., & Gherardi, S. (1992). Composition of Italian kiwi (*Actinidia chinensis*) puree. *Journal of Agricultural and Food Chemistry, 40*, 594–598. doi:10.1021/jf00016a013

Drummond, L. (2013). The composition and nutritional value of kiwi fruit. *Advances in Food* and *Nutrition Research, 68*, 33–57. doi:10.1016/B978-0-12-394294-4.00003-1

Ferguson, A. R. (2013). Kiwi fruit: the wild and the cultivated plants. *Advances in Food* and *Nutrition Research, 68*, 15–32. doi:10.1016/B978-0-12-394294-4.00002-X

Fiorentino, A., D'Abrosca, B., Pacifico, S., Mastellone, C., Scognamiglio, M., & Monaco, P. (2009). Identification and assessment of antioxidant capacity of phytochemicals from kiwi fruits. *Journal of Agricultural and Food Chemistry, 57*, 4148–4155. doi:10.1021/jf900210z

Gorinstein, S., Haruenkit, R., Poovarodom, S., Park, Y. S., Vearasilp, S., Suhaj, M. … Jang, H.-G. (2009). The comparative characteristics of snake and kiwifruits. *Food and Chemical Toxicology, 47*, 1884–1891. doi:10.1016/j.fct.2009.04.047

Iwasawa, H., Morita, E., Yui, S., & Yamazaki, M. (2011). Antioxidant effects of kiwi fruit *in vitro* and *in vivo*. *Biological and Pharmaceutical Bulletin, 34*, 128–134. doi:10.1248/bpb.34.128

Jayaprakasha, G. K., & Rao, L. J. (2000). Phenolic constituents from lichen *Parmotrema stuppeum* (Nyl.). Hale and their antioxidant activity. *Zeitschrift Für Naturforschung B, 55C*, 1018–1022.

Korsak, T., & Park, Y. S. (2010). Ethylene metabolism and bioactive compounds in ethylene-treated 'Hayward' kiwifruit during ripening. *Horticulture Environment Biotechnology, 51*, 89–94.

Koutsoflini, A., Gerasopoulos, D., & Vasilakakis, M. (2013). The effects of fruit maturation, delayed storage and ethylene treatment on the incidence of low-temperature breakdown of 'Hayward' kiwifruit. *Journal of the Science of Food and Agriculture, 93*, 410–414. doi:10.1002/jsfa.5776

Kovač, A., Skendrović Babojelić, M., Pavičić, N., Voća, S. N., Voća, N., Dobričević, N. … Šindrak, Z. (2010). Influence of harvest time and storage duration on "Cripps Pink" apple cultivar (Malus × domestica Borkh) quality parameters. *Cyta – Journal of Food, 8*, 1–6. doi:10.1080/11358120902989632

Krupa, T., Latocha, P., & Liwińska, A. (2011). Changes of physicochemical quality, phenolics and vitamin C content in hardy kiwifruit (*Actinidia arguta* and its hybrid) during storage. *Scientia Horticulturae, 130*, 410–417. doi:10.1016/j.scienta.2011.06.044

Lee, D. E., Shin, B. J., Hur, H. J., Kim, J. H., Kim, J., Kang, N. J. … Lee, H. J. (2010). Quercetin, the active phenolic component in kiwifruit, prevents hydrogen peroxide-induced inhibition of gap-junction intercellular communication. *British Journal of Nutrition, 104*, 164–170. doi:10.1017/S0007114510000346

Massolo, J. F., Concellón, A., Chaves, A. R., & Vicente, A. R. (2013). Use of 1-methylcyclopropene to complement refrigeration and ameliorate chilling injury symptoms in summer squash. *Cyta - Journal of Food, 11*, 19–26. doi:10.1080/19476337.2012.676069

Mikulic-Petkovsek, M., Schmitzer, V., Slatnar, A., Stampar, F., & Veberic, R. (2012). Composition of sugars, organic acids, and total phenolics in 25 wild or cultivated berry species. *Journal of Food Science, 77*, C1064–C1070. doi:10.1111/j.1750-3841.2012.02896.x

Mworia, E. G., Yoshikawa, T., Salikon, N., Oda, C., Asiche, W. O., Yokotani, N., Abe, D., Ushijima, K., Nakano, R., Kubo, Y. (2012). Low-temperature-modulated fruit ripening is independent of ethylene in 'Sanuki Gold' kiwifruit. *Journal of Experimental Botany, 63*, 963–971. doi:10.1093/jxb/err324

Nunes-Damaceno, M., Muñoz-Ferreiro, N., Romero-Rodríguez, M. A., & Vázquez-Odériz, M. L. (2013). A comparison of kiwi fruit from conventional, integrated and organic production systems. *LWT – Food Science and Technology, 54*, 291–297. doi:10.1016/j.lwt.2013.05.002

Park, Y. S. (2009). Storability of new kiwi fruit cultivar bred in Korea. *Korean Journal of Horticultural Science and Technology, 27*, 123–127.

Park, Y. S., Heo, B. G., Ham, K. S., Kang, S. G., Park, Y. K., Nemirovski, A. … Leontowicz, M. (2012). Analytical determination of bioactive compounds as an indication of fruit quality. *Journal of AOAC International, 95*, 1725–1732. doi:10.5740/jaoacint.12-130

Park, Y. S., Jung, S. T., Kang, S. G., Heo, B. G., Arancibia Avila, P., Toledo, F. … Gorinstein, S. (2008). Antioxidants and proteins in ethylene-treated kiwi fruits. *Food Chemistry, 107*, 640–648. doi:10.1016/j.foodchem.2007.08.070

Park, Y. S., & Kim, S. Y. (2002). Effects of prestorage conditioning and hot water dip on fruit quality of non-astringent 'Fuyu' persimmon fruit during storage. *Journal of Korean Society of Horticultural Science, 43*, 58–63.

Park, Y. S., & Park, M. Y. (1997). Effects of time and degree of fruit thinning on the fruit quality, yield and return bloom in kiwi fruit. *Journal of Korean Society of Horticultural Science, 38*, 60–65.

Pranamornkith, T., East, A., & Heyes, J. (2012). Influence of exogenous ethylene during refrigerated storage on storability and quality of *Actinidia chinensis* (cv. Hort16A). *Postharvest Biology and Technology, 64*, 1–8. doi:10.1016/j.postharvbio.2011.09.011

Robles-Sánchez, R. M., Islas-Osuna, M. A., Astiazarán-García, H., Vázquez-Ortiz, F. A., Martín-Belloso, O., Gorinstein, S., & González-Aguilar, G. A. (2009). Quality index, consumer acceptability, bioactive compounds, and antioxidant activity of fresh-cut "ataulfo" mangoes (*Mangifera indica* L.) as affected by low-temperature storage. *Journal of Food Science, 74*, SS126–S134. doi:10.1111/j.1750-3841.2009.01104.x

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. *Methods of Enzymology, 299*, 152–178. doi:10.1016/S0076-6879(99)99017-1

Stonehouse, W., Gammon, C. S., Beck, K. L., Conlon, C. A., von Hurst, P. R., & Kruger, R. (2013). Kiwifruit: our daily prescription for health. *Canadian Journal of Physiology and Pharmacology, 91*, 442–447. doi:10.1139/cjpp-2012-0303

Téllez, P. P., Saucedo, V. C., Arévalo, G. M. L., & Valle, G. S. (2009). Ripening of mamey fruits (*Pouteria sapota*Jacq.) treated with 1-methylcyclopropene and refrigerated storage. *Cyta – Journal of Food, 7*, 45–51. doi:10.1080/11358120902850750

White, A., Nihal de Silva, H., Requejo-Tapia, C., & Harker, F. R. (2005). Evaluation of softening characteristics of fruit from 14 species of *Actinidia*. *Postharvest Biology and Technology, 35*, 143–151. doi:10.1016/j.postharvbio.2004.08.004

Yin, X.-R., Allan, A. C., Zhang, B., Wu, R.-M., Burdon, J., Wang, P. … Chen, K. (2009). Ethylene-related genes show a differential response to low temperature during 'Hayward' kiwi fruit ripening. *Postharvest Biology and Technology, 52*, 9–15. doi:10.1016/j.postharvbio.2008.09.016

Zolfaghari, M., Sahari, M. A., Barzegar, M., & Samadloiy, H. (2010). Physicochemical and enzymatic properties of five kiwi fruit cultivars during cold storage. *Food Bioprocess and Technology, 3*, 239–246. doi:10.1007/s11947-008-0114-6