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The effects of ethylene treatment on the bioactivity of conventional and organic growing 'Hayward' kiwi fruit

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

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ABSTRACT

Conventional (CG) and organically grown (OG) 'Hayward' kiwi fruits were submitted to ethylene treatment for 24 h, followed by storage at 20 °C for 10 days. Radical scavenging assays, UV spectrometry, fluorometry and chemometrical processing were used to determine the main kiwi fruits' compounds. Firmness gradually decreased the longer they were stored, regardless of cultivation type. The rate of softening was slightly higher in OG than in CG fruits. The sensory value of kiwi fruit increased with reduced firmness and did not vary among cultivation types. Soluble solids content increased with the storage time, while acidity decreased in all fruits. Significant differences were found in polyphenols (189.98 ± 12.75 and 219.43 ± 15.73 mg gallic acid equivalents (GAE)/100 g fresh weight, FW) in the last day of treatment between treated conventional and organic kiwi fruits. The values of angiotensin-converting enzyme (ACE, %) – inhibiting activity (85.35 ± 5.97 and 92.33 ± 6.46) and electron donating abilities (EDA, %), using 1-diphenyl-2-picrylhydrazyl (56.80 ± 5.87 and 70.63 ± 6.67) showed significant differences between treated conventional and organic kiwi fruit. The antioxidant capacities by 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)diammonium salt (ABTS + μM TE/g DW) for conventional and organic kiwi fruits were 24.1 ± 3.18 and 27.6 ± 3.85 and by nitrite oxide scavenging assay (NSE, %) as 56.35 ± 3.94 and 59.87 ± 4.19 for conventional and organic kiwi fruits, respectively, but not always significant. The observed peaks by 3-D fluorescence showed differences in the position of the main peaks and their fluorescence intensity for conventional and organic kiwi fruits in comparison with non-ethylene-treated samples. In conclusion, ethylene treatment increased the bioactivity of organic and conventional kiwi fruits. The antioxidant values for organic fruits were significantly higher than for conventional and higher than in those not treated with ethylene. All fruits showed a high level of correlation between the contents of phenolic compounds and their antioxidant values. According to the bioactivity of kiwi fruits from two cultivation systems, a combination of these fruits has to be included in the diet.

1. Introduction

Kiwi fruits are popular and have several compounds with antioxidant properties, including ascorbic acid, carotenoids and polyphenols (Gammon et al., 2012; Gorinstein et al., 2009; Lee et al., 2010; Krupa et al., 2011). Increased consumption of these fruits protects cardiovascular diseases, because of the unique composition of green kiwi fruit, which has the potential to lower the risk of cardiovascular disease (Gammon et al., 2012; Mikulic-Petkovsek et al., 2012). 'Hayward' kiwi fruit (*Actinidia deliciosa*), grown under a variety of conditions, is one of the best-known cultivars. Recently there have been some reports showing the differences between plants grown under specific conditions (Chen et al., 2010; Leccese et al., 2010). The effects of cultivation systems and the fruit's-post harvest management on the antioxidant properties of fruits and vegetables were recently investigated (Jensen et al., 2012; Lester and Saftner, 2011; Migliori et al., 2012). 'Hayward' kiwi fruit treated with ethylene or 1-methylcyclopropene (1-MCP) was compared with non-treated fruit in a number of reports (Park et al., 2005, 2006, 2007; Jhalegar et al., 2011). The

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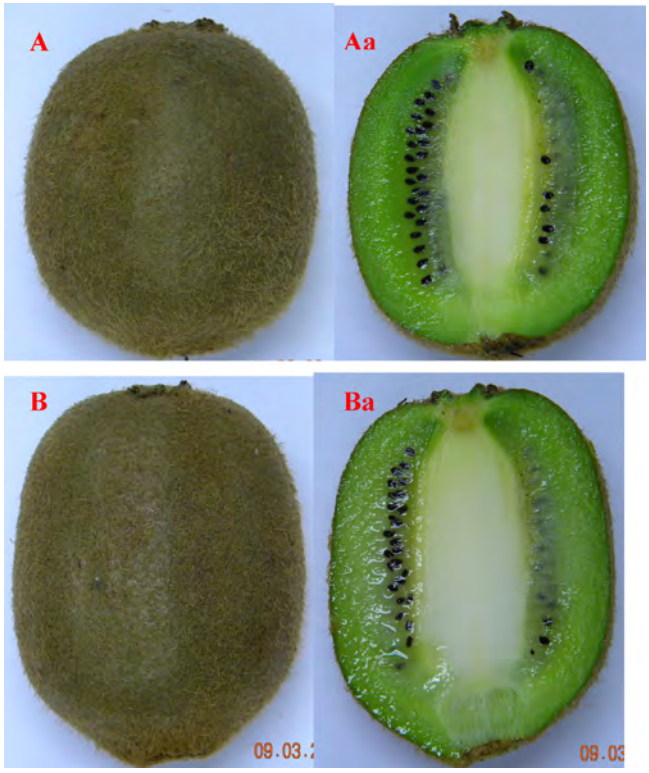

Fig. 1. (A, Aa) Conventional and (B, Ba) Organic kiwi fruits.

differences in the bioactivity between 'Hayward' kiwis grown in conventional and organic conditions were less studied (Park et al., 2012a,b). Therefore, it was decided to compare the nutritional properties of organic and conventional kiwi fruits after ethylene treatment. In order to receive the reliable results of total antioxidant capacities, four generally accepted assays (ABTS, NSE, ACE and DPPH) were used (Brand-Williams et al., 1995; Re et al., 1999; Pandey and Tripathi, 2010; Patten et al., 2012). Three-dimensional fluorescence was applied for comparison of organic and conventional ethylene treated and non-treated kiwi fruits (Gorinstein et al., 2009; Park et al., 2012b). As far as we know, no results of such investigations were published.

2. Materials and methods

2.1. Fruit samples

'Hayward' kiwi fruit cultivar was grown under conventional and organic conditions in an orchard at Heanam County (longitude 126°15″ and latitude 34°18″), Jeonnam province in South Korea. The harvest dates were October 30, 2011 and October 18, 2012 (Fig. 1). Average data were taken into account from two harvest seasons. Mean temperature was about 13–14 °C, rainfall – 1300 mm, and soil was loam. In fertilization of organic kiwi fruit manure was applied (30 ton per 1 ha). During the dormant season, we sprayed them with lime–sulphur mixture to control pests and diseases. In growing season, we sprayed two or three times with Bordeaux mixture [liquid] and four or five times with bio-control agent (Seva stop, Poex, white killer, produced in Korea). No pesticides or herbicides were applied during the growing process. Drip irrigation (300 ton per week per 1 ha) was usually used. Fruits with defects were discarded and 50 good fruits (80–100 g) were placed in five glass jars of the same type. These healthy fruits were divided into two groups; one was treated with 100 ppm ethylene for 6, 12, 18 and 24 h at 20 °C, the others were not treated (control). For these two treatments, the fruits were put into an 18 L glass jar and ventilated with humidified flow of air or air mixed with ethylene of 300 mL mL^{-1}. Thereafter, the ethylene treated fruits were ripened separately at 20 °C growth chamber (Percival, USA) for 10 days. Control fruits were immediately ripened at 20 °C in the same growth chamber as above. The samples were treated with liquid nitrogen in order to prevent oxidation of phenolic compounds and then lyophilized as previously described (Gorinstein et al., 2009; Park et al., 2012a).

2.2. Chemicals and reagents

Trolox; phenolic standards; Tris, tris(hydroxymethy1) aminomethane; ABTS; Folin-Ciocalteu reagent; DPPH; Griess reagent; rabbit-lung acetone powder and hippuryl–histidine–leucine synthetic peptide mixture were purchased from Sigma Chemical Co., St Louis, MO, USA. Sodium nitrite, acetic acid and hydrochloric acid were purchased from Samchun Chemical Co., Korea.

2.3. Analytical methods

The fruits were analyzed for firmness by measuring penetration force in kilograms, using a fruit-firmness tester (Model KM, Fruit Test Tech, and Japan). The mean values of firmness were expressed as newtons (N). The peeled fruits were homogenized and filtered through a cheese cloth to obtain a clear juice for determination of soluble solid content (SSC, Brix, %), pH and acidity. The SSC was measured using a refractometer (Atago Com. Ltd., Tokyo, Japan), pH with a pH meter. The acidity was measured in a 4 mL of juice, diluted to 20 mL of distilled water and titrated with 0.1 N NaOH. The acidity was expressed as a percentage of citric acid. 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 and flavor) and total acceptance in Hedonic scale method, which had a 1–5 rating scale (1, very bad; 2, bad; 3, moderate; 4, good; 5, excellent). Ascorbic acid (mg/100 g FW) was determined in the sample extract, which was filtered through Sepak C_{18} Cartridge with HPLC solvent. 5 mM of hexadecyltrimethylammonium bromide and 5 mM KH_2PO_4 (pH around 4.6) were added to the sample. The standard and extracted samples were analyzed using HPLC pump system (Waters, Model 510, USA), connected with a UV detector (Waters, USA) set at 365 nm. The Waters Symmetry C_{18} column (0.5 μm, 4.6 mm × 250 mm) was pre-equilibrated with a mobile phase consisting of methanol: water (5:95, v/v) at a flow rate of 1.5 mL min^{-1} on the 25 °C column temperature (Jhalegar et al., 2011; Korsak and Park, 2010; Koutsoflini et al., 2013).

2.3.1. Determination of bioactive compounds and total antioxidant capacities

The extracts were phenols extracted with ethanol (concentration 20 mg/mL) during 1 h in a cooled ultrasonic bath (Mikulic-Petkovsek et al., 2012). Total polyphenols (TP, mg gallic acid equivalents (GAE)/100 g FW) were determined by Folin-Ciocalteu method (Singleton et al., 1999) with absorbance measurements at 750 nm using spectrophotometer (Hewlett-Packard, model 8452A, Rockvile, USA). Antioxidant capacity (AC) was determined by (1) ABTS (μM trolox equivalent) TE/g DW: $ABTS^{\bullet+}$ radical cation was generated by the interaction of ABTS (7 mmol/L) and $K_2S_2O_8$ (2.45 mmol/L). Absorbancy measurements were carried out at 734 nm (Re et al., 1999). (2) Electron Donating Ability (EDA, %) by the 1,1-diphenyl-2-picrylhydrazyl radical, DPPH): in the assay 100 μL of kiwi fruit samples were added to 2 mL of a 0.1 M solution of DPPH in ethanol. The reaction was kept in the dark for 30 min. Then the reaction mixtures were measured

at 517 nm (Brand-Williams et al., 1995). (3) In nitrite oxide scavenging activity (NSE, %) assay: 1 mL kiwi fruit extract was mixed with 10 mL 0.1 N HCl and 2 mL 0.1 mM $NaNO_2$ and then reacted at 37 °C water bath for 60 min. To 1 mL of reaction solution 0.4 mL Griess reagent [sulfanilamide-N-(1-naphtyl)ethylenediamine] and 2 mL of 2% acetic acid were added and placed an ambient temperature for 15 min. The absorbances of the extracts were measured at 520 nm (Pandey and Tripathi, 2010). Angiotensin-converting enzyme (ACE)-inhibiting activity: To 36 mL of rabbit-lung acetone powder 10 mL distilled water were added and centrifuged (4 °C, 12,000 × *g*) for 10 min. The upper extract reacted with the reaction solution; containing 100 μL of 100 mM sodium borate buffer, 50 μL distilled water (blank) or kiwi fruit extract, 50 μL of 5 mM hippuryl–histidine–leucine solution. Solution of 100 μL of rabbit-lung acetone powder were added to reaction solution and kept at 37 °C for 1 h. Then the reaction was stopped by adding 200 μL of 1 N HCL. Reaction solution reacted with 2 mL of ethyl acetate and then centrifuged (0 °C, 2000 × *g*) for 5 min. To the extract, 0.1 mL of 1 N NaCL was added and then measured at 228 nm (Patten et al., 2012).

2.3.2. Fluorometric measurements

Two-dimensional (2D-FL) fluorescence measurements for kiwi fruit extracts at a concentration of 0.01 mg/mL were recorded on a model FP-6500, Jasco spectrofluorometer, serial N261332, Japan, equipped with 1.0 cm quartz cells and a thermostat bath. The 2D-FL was taken at emission wavelengths from 300 to 750 nm; and at excitation of 280 nm. The three-dimensional spectra (3D-FL) were collected with subsequent scanning emission spectra from 200 to 795 nm at 1.0 nm increments by varying the excitation wavelength from 200 to 500 nm at 10 nm increments (Gorinstein et al., 2009).

2.3.3. Statistical analyses

To verify the statistical significance, mean ± SD of ten independent measurements were calculated. After Shapiro–Wilk normality test for distribution of data ($n = 10$) obtained for each sample, Student's *t*-test was applied for simple statistical comparisons of counterpart data means. The *t* values were calculated and compared to t_{krit} value for $n = 10$ at significance level of <0.05. Differences between groups were tested by ANOVA. Pattern recognition techniques for differentiation of conventionally and organically produced 'Hayward' kiwi fruit using the principal component analysis and factoring, was realized by statistical program Unistat® (Unistat Ltd., 4 Shirland Mews, London W9 3DY, England).

3. Results

The following changes appeared in conventional and organic kiwi fruits during the treatment of ethylene for 24 h and storage of 10 days. The firmness (N) of non-treated fruit and 10 days of storage was from 30.51 ± 3.38 to 6.08 ± 0.42 and from 29.68 ± 2.38 to 5.08 ± 1.20 for conventional and organic kiwi fruits, respectively. The sensory value (score) at the beginning was from 2.03 ± 0.5 to 3.17 ± 0.7 for conventional kiwi fruit, and for organic estimated from 2.37 ± 0.12 to 3.4 ± 0.17. After the treatment and storage the values were from 2.67 ± 0.29 to 4.87 ± 0.17 and from 3.33 ± 0.29 to 4.77 ± 0.25 for conventional and organic fruits, respectively. The soluble solid contents (Brix) before the treatment were from 11.1 ± 0.36 to 12.3 ± 0.12 and from 11.9 ± 0.15 to 12.9 ± 0.05, but after the treatment the values changed and were from 12.5 ± 0.5 to 13.5 ± 0.18 and from 12.8± to 15.0 ± 0.15 for conventional and organic fruits. The pH and total acidity (%) during the storage were from 3.17 ± 0.07 to 3.59 ± 0.08 and from 2.08 ± 0.07 to 1.64 ± 0.42, respectively. For organic kiwi fruit the values for pH and total acidity were the following: from 3.25 ± 0.11 to 3.69 ± 0.15 and from 1.78 ± 0.09 to 1.05 ± 0.06. After treatment and storage the pH and acidity for conventional kiwi fruit changed from 3.36 ± 0.18 to 3.72 ± 0.12 and from 1.59 ± 0.17 to 1.01 ± 0.14, respectively. For organic kiwi fruit after the treatment the pH and acidity have changed from 3.4 ± 0.22 to 4.17 ± 0.19 and from 1.21 ± 0.01 to 0.76 ± 0.06, respectively. The vitamin C (mg/100 g FW) level of conventional samples was from 3.17 ± 0.07 to 3.49 ± 0.08 and after treatment changed from 3.35 ± 0.18 to 3.72 ± 0.12. For organic untreated fruit the data estimated from 3.25 ± 0.11 to 3.59 ± 0.15 and after treatment vitamin C was from 3.40 ± 0.22 to 4.17 ± 0.19. The change in the main bioactive compounds is shown in Tables 1–3. The final results of total phenolics (mg GAE/100 g FW) were different for conventional and organic kiwi fruit (Table 1). All organic kiwi fruits samples significantly differ from conventional associates, only in the 6 and 8 days of storage some insignificant differences were found. The antioxidant activities by ABTS (μM TE/g DW), EDA, NSE and ACE were significantly higher in organic kiwi fruit than in conventional (Tables 2 and 3). As it was shown above the fresh 'Hayward' kiwi fruit samples cultivated by conventional and organic methods (treated with ethylene 0–24 h) and stored (0–10 days) at 20 °C were examined for quality parameters: firmness, sensorial parameters, soluble solid content, total phenolics, pH, TA, vitamin C, antioxidant activities by ABTS, EDA, NSE, and ACE values. In the case of changes caused by ethylene treatment two-ways ANOVA denoted some significant differences ($P < 0.05$) between fresh kiwi fruit samples in parameters of soluble solid content, TA, and antioxidant activities by ABTS, NSE and ACE values. These differences still remained after 10 days of kiwi fruit storage at 20 °C. When fresh and stored kiwi fruit samples were compared according to their affiliation to organic or conventional production systems significant differences ($P < 0.05$) were found in following parameters: firmness, soluble solid content, TA, vitamin C, ACE. No differences were noted according to sensorial attribute and total phenolic content. The Box and Dot plot (Fig. 2) demonstrates the variation of all the examined variables characterizing the 'Hayward' kiwi fruit produced by organic and conventional systems. Multivariate plotting procedure was used to inspect and to discover the relationships inherent within the data matrix, because of too many variables examined for 'Hayward' kiwi fruit produced by organic and conventional systems. In sun-ray icon plot (Fig. 3A) a star-like shape is drawn for each case. Each ray represents a different variable; the middle of the ray is the mean value of the variable. Values for each parameter are connected by a cord. This plot clearly demonstrates the found differences between organic and conventional kiwi fruits (Fig. 3A and B). These distinctions between compared 'Hayward' kiwi fruit retained even some days of storage at room temperature (20 °C) as seen on Fig. 3B. The most significant change occurred on the 6th day of storage (Tables 1–3).

The 2-D fluorescence spectra showed the results described below. At emission of the wavelengths of 336 nm and 341 nm the recording of the peak in the fluorescence spectra for conventional and organic ethylene-treated kiwi fruit was with fluorescence intensity (FI) 236.58 and 289.50 (Fig. 4A) in comparison with untreated of 193.54 and 225.67. The changes in the fluorescence intensity of treated and untreated samples corresponded with the changes of polyphenol compounds (Table 1). The second peaks were at 443 nm and 451 nm for conventional and organic kiwi fruit with fluorescence of 72.70 and 100.25 in comparison with untreated conventional and organic kiwi fruits of 62.67 and 81.88. The next peak was at 622 nm and 651 nm with fluorescence of 39.27 and 43.73 for conventional and organic kiwi fruit (Fig. 4A) in comparison with 34.14 and 35.84 for untreated conventional and organic kiwi fruits. Three-dimensional fluorescence of conventional and organic kiwi fruits shows the differences in the main peaks and their fluorescence intensities (Fig. 4B and C).

Table 1
Total phenolics (mg gallic acid equivalent (GAE)/100 g FW) of 'Hayward' conventional and organic kiwifruits during ethylene treatment of 24 h and storage for 10 days at 20 °C.

Cultivars	Ethylene treatment, h	Total phenolics					
		Days of storage at 20 °C					
		0	2	4	6	8	10
Conventional 'Hayward'	0	141.18 ± 6.62ac	143.12 ± 6.65ac	144.15 ± 6.93ac	145.25 ± 7.55ac	148.24 ± 8.74ac	149.44 ± 8.95bc
	6	143.28 ± 6.83ac	148.25 ± 8.42ac	154.43 ± 9.15bc	170.24 ± 11.05bc	172.11 ± 11.14bc	176.23 ± 11.92bc
	12	145.16 ± 7.15ac	150.32 ± 8.82bc	156.12 ± 10.21bc	174.18 ± 11.65bc	176.14 ± 11.82bc	178.55 ± 12.08bc
	18	148.24 ± 8.71ac	153.65 ± 9.02bc	160.35 ± 10.43bc	180.15 ± 12.32bc	181.25 ± 12.15bc	182.34 ± 12.43bc
	24	154.45 ± 9.09bc	160.21 ± 10.81bc	166.25 ± 10.91bc	186.41 ± 12.76bc	187.24 ± 12.85bc	189.98 ± 12.75bc
Organic 'Hayward'	0	156.70 ± 10.43ad	157.25 ± 10.61ad	158.24 ± 10.15ad	160.15 ± 10.82ad	151.31 ± 11.3ac	163.25 ± 11.45ad
	6	160.28 ± 10.73ad	167.40 ± 10.11ad	179.14 ± 12.08bd	197.17 ± 13.17bd	172.32 ± 2.43bc	205.16 ± 14.15bd
	12	162.13 ± 11.08ad	171.20 ± 11.85bd	182.22 ± 12.14bd	174.27 ± 14.3bc	183.67 ± 13.7bc	207.53 ± 14.43bd
	18	164.65 ± 11.64ad	175.40 ± 11.45bd	185.40 ± 12.41bd	185.00 ± 15.9bc	190.00 ± 16.8bc	210.62 ± 15.11bd
	24	171.43 ± 11.92bd	178.23 ± 12.25bd	187.25 ± 11.25bd	189.00 ± 16.4bc	188.00 ± 20.0bc	219.43 ± 15.73bd

Each observation is a mean ± SD; for two growing seasons; $n = 10$; values with different letters are significantly different at $p < 0.05$; first letters "a" and "b" explain significances caused by storage or ethylene treatment time. Conventional samples are compared to conventional reference zero time sample and organic samples compared to organic reference; second letters "c" and "d" explain significances between counterparts of organic and conventional kiwi fruits.

4. Discussion

In the recent years, there has been growing interest in the influence of sustainable cultivation systems on the biochemical quality of vegetables and fruits. Changes in biochemical parameters of fruits and vegetables were widely studied the last years (Migliori et al., 2012; Mworia et al., 2010; Vieira et al., 2010).

Organic food is perceived as being of better quality and healthier than conventional foods, although the scientific research on organic foodstuffs is highly contradictory (Jensen et al., 2012; Park et al., 2012a,b). This well-controlled field study demonstrated no clear influence of cultivation methods or harvest year on the nutritional quality of carrots or effect of cultivation methods on health-related biomarkers in a sensitive rat model (Jensen et al., 2012). Our present results differed from the ones reported previously where the antioxidant capacities were determined by ABTS, DPPH, and CUPRAC. (Park et al., 2005, 2006, 2007). In a recent study, 'Hayward' kiwi fruits were treated with 100 ppm ethylene at 20 °C for 24 h and then immediately ripened at 20 °C for 10 days (Korsak and Park, 2010). Flesh firmness significantly decreased at initial time in fruits treated with ethylene, while sensory value increased with the progress of ripening. Similar results were obtained in both conventional and organic 'Hayward' kiwi in the present study, where an average of two seasons is discussed. Polyphenols and antioxidants were significantly higher in ethylene treated samples that in non-treated fruit, and in organic samples were significantly higher than in conventional, except for some data of the 6 and 8 days of treatment (Table 1). The amounts of polyphenols were similar to the information given by Mikulic-Petkovsek et al. (2012). Other results were obtained by Koutsoflini et al. (2013), where harvested kiwi

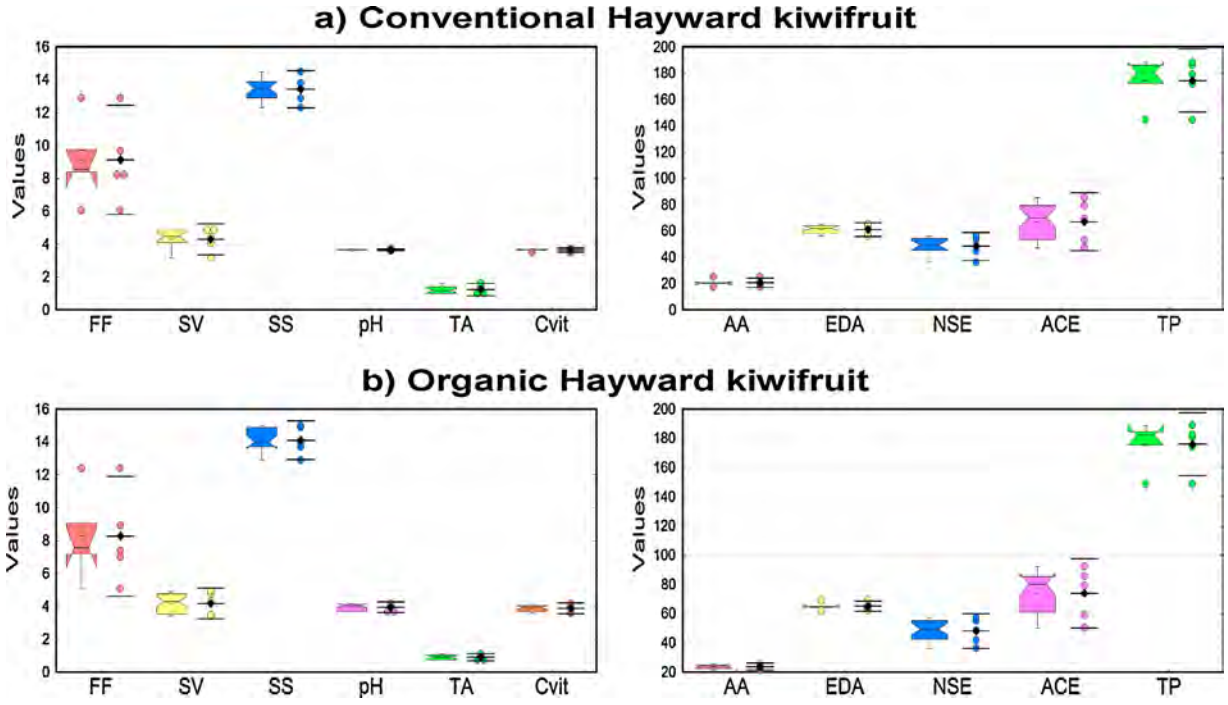

Fig. 2. Box/whisker and dot plots showing examined variables variation of organic and conventional Hayward kiwi fruits treated with ethylene (0–24 h) and stored 10 days at 20 °C. Abbreviations: FF, fruit firmness; SV, sensory value; SS, soluble solid content; pH, TA, total acidity; Cvit, vitamin C; AA, antioxidant activity; EDA, electron donating ability; NSE, nitrite scavenging activity; ACE, angiotensin converting enzyme; TP, total phenolics.

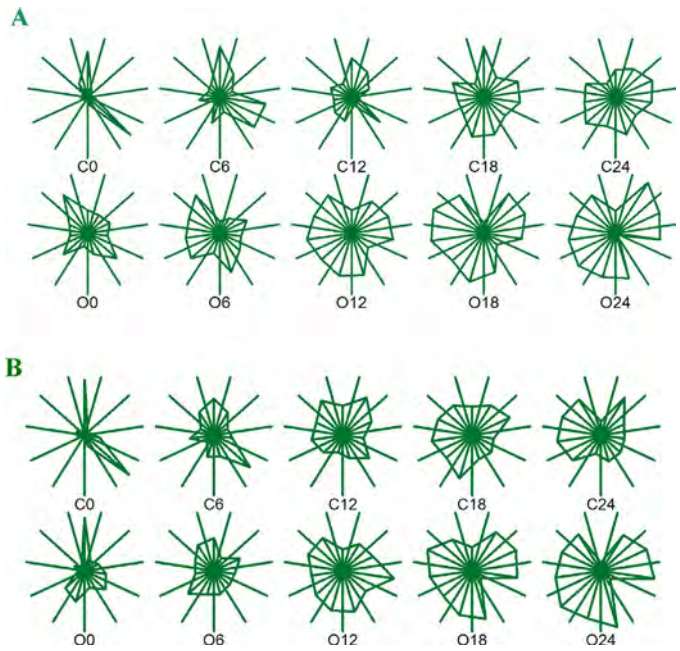

Fig. 3. Sun Ray Icon Plot of organically (O) and conventionally (C) produced fresh Hayward kiwi fruits (A) treated with ethylene (0, 6, 12, 18, 24 h) and (B) stored (10 days at 20 °C) compared according to the 11 examined variables (FF, fruit firmness; SV, sensory value; SSC, soluble solid content; pH, TA, total acidity; Cvit, vitamin C; AA, antioxidant activity; EDA, electron donating ability; NSE, nitrite scavenging activity; ACE, angiotensin converting enzyme; TP, total phenolics).

fruits during fruit maturation or after delayed storage (DS) at 20 °C for 0, 1, 2, 3 and 4 weeks and 1 μL/L of ethylene treatment for 24 h were stored at −0.5 °C for 24 weeks and additional ripening at 20 °C for 5 days. Ethylene-treated fruits showed a comparable increase in low-temperature breakdown (LTB), to that corresponding to 2–3 weeks of DS. In contrast to fruit maturation, postharvest (after harvest and before storage) DS at non-chilling temperature and ethylene treatment advanced the ripening of 'Hayward' kiwi fruit and resulted in increased LTB incidence. Our results are in accordance with others, where results of principal component analysis demonstrated that, for both systems, the chemical patterns were different as a function of farming mode (conventional vs organic). Similar conclusions were reported by Chen et al. (2010) where was analyzed the growing year and time of harvest in Rio Red grapefruit. Our recent and previous results about the organic and conventional kiwi fruits are in agreement with Lester and Saftner (2011), that there are too many variables in a comparison of these two products.

In spite of many variables studied in this report, the data on bioactivity of organic kiwi fruit during two seasons was significantly higher than in conventional (Tables 2 and 3).

Some variables such as the physical, biological, and chemical/nutritional attributes of soils, the irrigation sources and amounts, crop varieties, crop maturities and harvest dates – pre- and postharvest processing, handling, and/or storage methods, individually and collectively – provide greater clarity on how inputs unique to organic and conventional systems affect produce quality. Therefore it is difficult to measure the differences in all variables even during two collection seasons. It was shown in our study (Park et al., 2012a,b) that organic crops have higher amounts of dry matter, ascorbic acid, phenolics and antioxidants than conventionally grown crops. Recent investigations of nutritional quality in organic

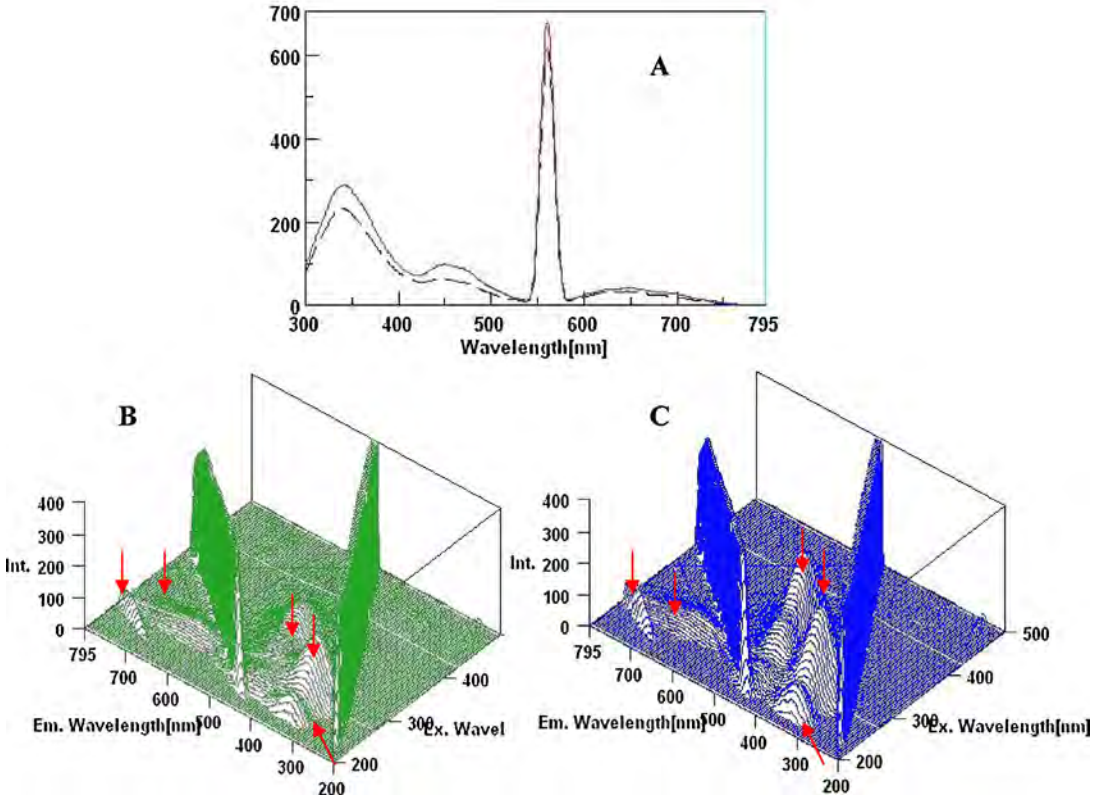

Fig. 4. (A) Two-dimensional fluorescence spectra of 0.01 mg/mL of extracts of organic (upper line), and conventional (lower line), excitation at 280 nm and emission (*x*-axis from 300–795 nm), *y* axis is the fluorescence intensity; (B) three dimensional fluorescence (3D-FL) of conventional and (C) organic kiwi fruits. 3D-FL spectra used emission wavelengths from 200 to 750 nm and excitation wavelengths from 200 to 500 nm; scanning speed was 1000 nm/min, emission mode and fluorescence intensity up to 400. Abbreviations: *z*-axis – Int, fluorescence intensity; on *y*-axis – Em. Wavelength, emission wavelength; on *x*-axis – Ex. Wavel, excitation wavelength; Arrows show the area of the location of the peaks.

Table 2
Antioxidant activity by 2,2-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid)diammonium salt (ABTS) and electron donating ability (EDA, % of inhibition) of 'Hayward' conventional and organic kiwifruits during ethylene treatment of 24 h and storage for 10 days at 20 °C.

Cultivars	Ethylene treatment, h	Antioxidant activity by ABTS, μM TE/g DW						EDA, %					
		Days of storage at 20 °C						Days of storage at 20 °C					
		0	2	4	6	8	10	0	2	4	6	8	10
Conventional 'Hayward'	0	17.4 ± 0.48ac	17.9 ± 1.25ac	18.3 ± 1.25ac	18.9 ± 1.42bc	19.0 ± 1.42bc	19.1 ± 1.15bc	31.25 ± 2.19ac	31.85 ± 2.23ac	32.24 ± 2.32ac	34.98 ± 2.46bc	35.31 ± 2.91bc	35.66 ± 3.94bc
	6	18.1 ± 1.14ac	19.2 ± 1.41bc	19.2 ± 1.44bc	21.0 ± 2.65bc	21.3 ± 2.61bc	21.7 ± 2.65bc	33.18 ± 2.26ac	34.25 ± 2.91bc	35.18 ± 2.56bc	38.93 ± 2.65bc	39.51 ± 2.75bc	40.84 ± 4.07bc
	12	18.8 ± 1.22bc	20.1 ± 2.18bc	20.1 ± 2.18bc	22.8 ± 2.93bc	23.1 ± 2.82bc	23.2 ± 2.81bc	41.65 ± 2.83bc	42.39 ± 3.08bc	43.65 ± 3.82bc	48.15 ± 4.34bc	49.32 ± 4.54bc	51.25 ± 5.11bc
	18	19.0 ± 1.43bc	20.3 ± 2.23bc	20.3 ± 2.23bc	23.0 ± 2.96bc	23.2 ± 2.71bc	23.5 ± 2.78bc	43.14 ± 2.96bc	44.19 ± 3.85bc	45.31 ± 3.89bc	51.48 ± 4.65bc	52.14 ± 4.72bc	53.06 ± 5.42bc
	24	19.1 ± 1.65bc	20.8 ± 2.45bc	20.8 ± 2.45bc	23.7 ± 2.91bc	24.0 ± 3.02bc	24.1 ± 3.18bc	46.18 ± 3.08bc	45.31 ± 3.91bc	46.27 ± 4.12bc	53.68 ± 4.97bc	54.11 ± 5.32bc	56.80 ± 5.87bc
Organic 'Hayward'	0	18.3 ± 1.15ac	18.6 ± 1.14ac	18.9 ± 1.22ac	19.7 ± 1.39bc	20.0 ± 2.23ac	20.1 ± 2.31ac	46.28 ± 3.17ad	47.39 ± 3.79ad	48.25 ± 3.76ad	51.43 ± 5.18bd	52.65 ± 5.01bd	53.24 ± 4.36bd
	6	18.9 ± 1.42ac	19.7 ± 1.65ac	20.1 ± 2.18ac	22.9 ± 2.48bc	23.1 ± 2.68bc	23.6 ± 2.71bc	49.16 ± 3.68ad	51.31 ± 3.88bd	53.18 ± 4.11bd	59.23 ± 5.15bd	61.42 ± 6.18bd	62.95 ± 4.18bd
	12	19.7 ± 1.64ac	20.5 ± 2.23bc	21.1 ± 2.75bc	23.8 ± 2.75bc	24.3 ± 2.75bc	21.9 ± 2.85bc	50.22 ± 3.65bd	52.64 ± 3.94bd	54.89 ± 4.87bd	62.81 ± 6.16bd	63.94 ± 6.14bd	64.28 ± 4.84bd
	18	20.8 ± 2.17bc	21.7 ± 2.83bc	22.6 ± 2.83bc	25.6 ± 3.03bc	26.1 ± 3.18bc	26.3 ± 3.43bc	52.23 ± 3.72bd	54.43 ± 4.18bd	56.91 ± 4.99bd	64.83 ± 6.23bd	65.71 ± 6.28bd	66.89 ± 4.69bd
	24	21.6 ± 2.61bd	22.7 ± 2.95bc	23.8 ± 2.68bd	26.9 ± 3.24bd	27.3 ± 3.63bc	27.6 ± 3.85bc	55.18 ± 3.88bd	57.18 ± 5.01bd	59.23 ± 5.88bd	68.14 ± 6.34bd	69.15 ± 6.43bd	70.73 ± 6.67bd

Each observation is a mean ± SD; for two growing seasons; $n = 10$; values with different letters are significantly different at $p < 0.05$; first letters "a" and "b" explain significances caused by storage or ethylene treatment time. Conventional samples are compared to conventional reference zero time sample and organic samples to organic reference; second letters "c" and "d" explain significances between counterparts of organic and conventional kiwi fruits.

Table 3
Antioxidant activity by nitrite oxide scavenging assay (NSE, % of inhibition) and angiotensin converting enzyme inhibiting activity (ACE, % of inhibition) of conventional and organic 'Hayward' kiwifruits during ethylene treatment of 24 h and storage for 10 days at 20 °C.

Cultivars	Ethylene treatment	NSE, %						ACE, %					
		Days of storage at 20 °C						Days of storage at 20 °C					
		0	2	4	6	8	10	0	2	4	6	8	10
Conventional 'Hayward'	0	15.32 ± 1.07ac	16.21 ± 1.13ac	22.86 ± 1.67bc	29.35 ± 2.05bc	31.56 ± 2.21bc	36.32 ± 2.54bc	30.53 ± 2.14ac	35.68 ± 2.51bc	39.16 ± 2.74bc	45.35 ± 3.17bc	46.34 ± 3.24bc	47.35 ± 3.31bc
	6	19.32 ± 1.35bc	21.16 ± 1.45bc	29.78 ± 2.08bc	32.26 ± 2.26bc	41.91 ± 2.93bc	45.33 ± 3.17bc	35.35 ± 2.47bc	42.12 ± 2.95bc	45.35 ± 3.17bc	52.43 ± 3.67bc	53.35 ± 3.73bc	58.75 ± 4.08bc
	12	20.35 ± 1.42bc	22.35 ± 1.56bc	36.99 ± 2.59bc	40.33 ± 2.96bc	44.14 ± 3.22bc	49.35 ± 3.45bc	42.35 ± 2.96bc	46.14 ± 2.18bc	54.96 ± 3.85bc	64.32 ± 4.51bc	68.68 ± 4.81bc	70.32 ± 4.92bc
	18	22.35 ± 1.56bc	25.35 ± 1.77bc	38.25 ± 2.68bc	43.18 ± 3.23bc	46.31 ± 3.45bc	54.35 ± 3.81bc	45.84 ± 3.21bc	54.35 ± 3.45bc	63.28 ± 4.25bc	72.98 ± 5.11bc	73.21 ± 5.12bc	79.35 ± 5.55bc
	24	24.32 ± 1.70bc	29.23 ± 2.05bc	40.15 ± 2.71bc	46.18 ± 3.52bc	53.12 ± 3.72bc	56.35 ± 3.94bc	50.35 ± 3.52bc	60.21 ± 4.21bc	72.56 ± 5.08bc	75.34 ± 5.27bc	77.58 ± 5.43bc	85.35 ± 5.97bc
Organic 'Hayward'	0	17.38 ± 1.22ad	19.35 ± 1.35bd	25.32 ± 1.77bd	30.23 ± 2.12bc	33.44 ± 2.34bc	39.32 ± 2.54bd	31.16 ± 2.18ac	40.35 ± 2.82bd	42.56 ± 2.98bd	46.12 ± 3.23bc	50.32 ± 3.52bd	58.55 ± 4.11bd
	6	25.35 ± 1.77bd	26.54 ± 1.86bd	30.35 ± 2.12bc	42.23 ± 2.96bd	45.35 ± 3.17bd	47.35 ± 3.17bc	40.35 ± 3.52bd	50.32 ± 3.22bd	54.32 ± 3.88bd	57.35 ± 4.15bd	60.85 ± 4.26bd	66.21 ± 4.26bd
	12	29.48 ± 2.06bd	32.56 ± 2.28bd	40.12 ± 2.81bd	44.56 ± 2.98bd	46.12 ± 3.23bc	51.18 ± 4.36bc	53.35 ± 3.87bd	62.74 ± 4.38bd	67.44 ± 5.32bd	75.98 ± 5.32bd	80.33 ± 5.62bd	81.96 ± 5.74bd
	18	30.35 ± 2.12bd	35.14 ± 2.46bd	44.15 ± 3.09bd	46.18 ± 3.41bc	49.35 ± 3.45bc	55.35 ± 3.87bc	56.32 ± 3.94bd	68.35 ± 4.70bd	75.61 ± 5.29bd	79.35 ± 5.55bd	83.21 ± 5.82bd	89.24 ± 6.25bd
	24	32.35 ± 2.26bd	40.23 ± 2.82bd	45.25 ± 3.17bd	48.65 ± 3.41bc	57.35 ± 4.01bd	59.87 ± 4.19bc	65.35 ± 4.57bd	74.44 ± 5.71bd	77.42 ± 4.12bd	81.84 ± 4.78bd	85.76 ± 6.91bd	92.33 ± 6.46bd

Each observation is a mean ± SD; for two growing seasons; $n = 10$; values with different letters are significantly different at $p < 0.05$; first letter pair "a" and "b" mark significances caused by storage and ethylene treatment. All conventional kiwi fruits are compared to conventional reference zero time sample and organic samples to organic reference kiwi fruit; second letter pair "c and d" mark significant differences between organic and conventional counterpart samples.

versus conventional produce also indicate that soil nitrogen delivery rates strongly affect nutritional quality. Nitrogen profiling is a promising new approach to improving the nutritional quality of both organic and conventional produce.

The polyphenols are highly correlated with all values of ABTS, EDA, NSE and ACE (Tables 1–3). Our results fully correspond to the technique used by to Krupa et al. (2011), where it was shown that it was a strong correlation between polyphenols and antioxidant activity in hardy kiwi fruits. Fruit firmness rapidly decreased, and SSC increased for all cultivars during the first 14 days of storage at 1 °C. The ascorbic acid and polyphenols in vine-ripe fruits were similar to the ones of the fruits of storage harvest maturity (8–10% SSC). White et al. (2005) found that the spectrum of softening behavior was broader than occurs in current commercial cultivars. In particular, fruit from some small-fruited genotypes tended to remain relatively firm even toward the end of the ripening process at 20 °C that corresponds with our results.

5. Conclusions

Ethylene treatment and then ripening improved the quality and bioactivity of both types of kiwi fruits. The bioactivity of organic kiwi fruit was significantly higher than of conventional. Still the scientific reports and our present and previous results are contradictory about organic and conventional fruits and many variables are included in such comparison. The suggested methods for the quality of kiwi fruit can be applied for any fruit. High quality of bioactive compounds in both cultivation systems makes kiwi fruit even more important for daily consumption.

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