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A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits

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Abstract: Postharvest performance of organic and conventional 'Hayward' kiwifruits grown on the same farm in Marysville, California, and harvested at the same maturity stage were compared in this study. Quality parameters monitored included morphological (shape index) and physical (peel characteristics) attributes of the initial samples. Maturity indices (CO_2 and C_2H_4 production, firmness, color, soluble solids content and acidity) and content of compounds associated with flavor and nutritional quality (minerals, sugars and organic acids, ascorbic acid, total phenolics, and antioxidant activity) were determined at 0, 35, 72, 90 and 120 days of storage at 0 °C, and after 1 week of shelf-life simulation at 20 °C, after each storage duration. Organically and conventionally grown kiwifruits had similar soluble solids content at harvest, but conventional kiwifruits had a higher firmness and L^* value, and a lower hue angle and chromaticity, resulting in a lighter green color when compared with the organic kiwifruits. These differences were maintained for all the storage durations, with the soluble solids content increasing more in conventionally grown kiwifruits. The two production systems resulted in different morphological attributes since organic kiwifruits exhibited a larger total and columella area, smaller flesh area, more spherical shape, and thicker skin compared to conventional kiwifruits. All the main mineral constituents were more concentrated in organic kiwifruits, which also had higher levels of ascorbic acid and total phenol content, resulting in a higher antioxidant activity. Sugars and organic acids composition was not affected by the production system.

Keywords: *Actinidia deliciosa*; antioxidant activity; ascorbic acid; minerals; organic acids; phenolic compounds; sugars

INTRODUCTION

The world market for certified organic foods was estimated to be worth US $23–25 billion in 2003 and is growing at roughly 19% per year.[1] Although organic products make up a minor share of the world market, soaring sales particularly in the United States and Europe have made organics the fastest-growing segment of the global food industry.[2] Around the world people buy organic food because they see it as safer for themselves, for farmers, and for the environment.[3]

Proponents of organic agriculture often claim that organically produced plant foods promote human health more than products from conventional production systems. Others claim the opposite, and many doubt if there is any difference at all.[4]

Postharvest handling of these commodities raises a number of issues both in terms of allowed procedures and of their effectiveness in maintaining quality of the produce. On the other hand, the postharvest performance of the produce obtained from specific sustainable procedures may be somewhat affected by preharvest conditions.

In organic systems many methods are used to maintain soil fertility, including addition of organic matter to the soil, that slowly release soil nutrients, in contrast to chemical fertilizers.[5] In addition, conventional agriculture practices utilize levels of pesticides that can result in a disruption of phenolic metabolites in the plant, which have a protective role in plant defense mechanisms.[6] These differences may result in differences in plant composition and nutritional quality, which in turn influence storage performance of products.

Very few comparative studies addressed the issue of qualitative difference between fruits, nuts, and oil seeds for organic and conventional cultivations, and the spectrum of the observed species is also very limited.[7] Some of these studies are focused only on the antioxidant activity and reported higher total phenol content of organically grown products, such as peaches and pears,[8] strawberry and marionberry,[9] wine grapes,[10] and plums.[11] Even fewer studies monitored

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the postharvest life and quality of organically *versus* conventionally grown fresh fruits, and among these apples received the greatest attention,[12–14] showing some difference in terms of incidence of physiological disorders, soluble solids, firmness, and mineral content. For organic strawberries Cayuela *et al.*[15] reported better organoleptic characteristics, and higher resistance to deterioration during simulated marketing conditions. In a comparison of ripening behavior of organic and non-organic banana after treatment with Etherel, Nyanjage *et al.*[16] found that the organic banana ripened faster, as measured by peel color changes, and had lower gravimetric pulp:peel ratio and impedance than non-organic banana. Hasey *et al.*,[17] comparing a kiwifruit vineyard system converted to organic procedures, found organically grown kiwifruits as firm or firmer than conventionally grown fruits. In a comparison of New Zealand kiwifruits, Benge *et al.*[18] reported that conventional kiwifruits at harvest, even with the same firmness average as organic fruits, had a higher soluble solids content, while firmness, softening behavior, and decay incidence did not differ between the two systems. Soft patches incidence, measured after 10 weeks of storage, was higher in conventional fruits, showing a negative correlation with levels of calcium in the fruit tissue.

The objective of this work was to compare quality attributes, including morphological, physical, and nutritional characteristics, at harvest, and during cold storage, of organic and conventional kiwifruits grown in the same soil type and environmental conditions.

EXPERIMENTAL

Plant material

Organically and conventionally grown kiwifruits (*Actinidia deliciosa,* cv. Hayward), cultivated at Chase National Kiwi Farms (Marysville, CA, USA) in the year 2004 were used in this study. All vines were on a pergola trellis system and spaced 5.5 m apart down the row line and 4.6 m between rows. The organic fruit was harvested from a 9.3 ha block and the conventional fruit was harvested from a 10.9 ha block located about 1.6 km east of the organic block. All blocks used in the trial were planted in 1981. All blocks were grafted seedlings from the nursery. The same male pollenizers were used and specifically Tomuri and, for the last three seasons, Chieftains, so both were still present in the year of the experiment.

Treatments made to the organic production system were in compliance with the US National Organic Program[19] and were certified organic. Organic kiwifruit production averaged 22.5 tons ha^{-1} and the conventionally grown fruit averaged 26.9 tons ha^{-1}.

For scale insect control on conventional vines, Volck Supreme Spray was applied at 56 L ha^{-1} during the dormant winter season. Organic vines were sprayed with Omni Supreme Oil (organically approved) at 56 L ha- at the same timing. Because of concerns of inadequate winter chilling, Dormex (hydrogen cyanamide) was applied to conventional vines in February 2004 at 37 L ha^{-1}.

In both production systems, grass, weeds, and pruning were mowed in the row centers every few weeks when needed during the spring and summer months. In the conventional system, glyphosate [*N*-(phosphonomethyl)glycine] at a 2% rate per 378.5 L of water was sprayed twice down each row during the growing season. A propane burner that burned a 1.5 m wide strip down each row was used in the organic system.

Plants were irrigated using an under vine impact solid set sprinkler system at 514 L min^{-1} ha^{-1} in 10 h sets when needed in both production systems. Leaf analysis was done in summer to achieve the required level of mineral content. In the conventional system, vines were fertilized with 4484 kg ha^{-1} of calcium sulfate (gypsum) in February and 560.5 kg ha^{-1} ammonium sulfate in March. Organic vines received more fertilizer treatments in order to achieve the same productivity as conventionally grown kiwifruit. The applications were 4484 kg ha^{-1} of calcium sulfate (gypsum) in February, 9.35 L ha^{-1} of Amino 21 (a humic acid extract) before budbreak, two 468 L ha^{-1} Agrolizer (organic blend of 6-2-0 fertilizer) in March, 9.35 L ha^{-1} Omega K (biological source of potassium 0-0-25) in March, 1.12 kg ha^{-1} TAP Organic powder (1% soluble nitrogen and 17% soluble potash) in April, and 37.4 L ha^{-1} Cal-Mate (6% humic acid and 2% carboxylic acid) during the growing season.

Experimental design

'Hayward' kiwifruits harvested at the same maturity stage in October (at 9.5% soluble solids content, which is well above the minimum requirement of 7%) were transported to the Postharvest Pomology Laboratory at the University of California at Davis (UCDavis), where they were sorted to eliminate defective fruits and divided into 15 samples of 40 kiwifruits for each treatment (with 3 replicates ×5 storage times, including initial time), while another 60 kiwifruits for each treatment were used for determination of fruit characteristics.

Groups of four samples (one for each evaluation time) were placed in three 296 L tanks (one for each replicate) for each treatment, in a 0 °C storage room and ventilated with a continuous flow of humidified air scrubbed with potassium permanganate to remove ethylene.

Monitored quality parameters included morphological and physical characteristics of the initial samples, maturity indices, and components associated with nutritional quality, performed at 0, 35, 72, 90 and 120 days of cold storage at 0 °C, and after shelf-life simulation (7 days at 20 °C) following each storage duration.

Morphological and physical attributes

At the time of harvest on 60 fruits for each production system, the following attributes were measured:

- peel and flesh color measured on each side of the fruit, using a Minolta colorimeter (Model CR-200, Minolta, Ramsey, NJ, USA) in the CIE $L^*a^*b^*$ mode, and then calculating hue angle and chromaticity as follows:

$$\text{Hue angle} = \arctan\frac{b^*}{a^*}$$

$$\text{Chromaticity} = \sqrt{a^{*2} + b^{*2}}$$

- peel thickness, removing peel from each of two sides and then measuring thickness as the average of four pieces of skin, using a micrometer;
- shape indices, calculated by elaborating images of the central longitudinal section acquired by scanner (Canonscan LD50, Lake Success, NY, USA), with a Matlab (Mathworks Inc. Natick, MA, USA) algorithm to calculate the following shape indices:

– area (in number of pixels) on the whole section and on the columella; the area of the flesh was calculated as difference of previous determinations;

– the equivalent diameter (ED), meaning the diameter of a sphere with the same area, were $\text{ED} = \sqrt{\frac{4 \times A}{\pi}}$, with A as the surface of the longitudinal section;

– eccentricity $E = \frac{F2 - F1}{a}$, where $F2 - F1$ is the distance between the two foci and a is the length of the major axis, ranging from 0 (for a circumference) to 1 (for the most elongated ellipse).

Maturity and quality indices

Initially and after each storage duration, 20 kiwifruits of each replicate were used for analytical determinations and the remaining 20 were kept at 20 °C in air for 7 days to simulate marketing conditions before evaluation.

Regarding maturity and quality indices the following attributes were monitored:

- flesh color using a colorimeter as described for peel color;
- flesh firmness with a fruit texture analyzer (model GS-14, Güss, Strand, South Africa) by measuring force required for an 8 mm probe to penetrate in two opposite locations the mesocarp tissue to a depth to 8.9 mm;
- columella firmness of each fruit central slice of about 15 mm of thickness, as described above for flesh firmness;
- titratable acidity on 4 g of fruit juice for each replicate, using an automatic titrator (Radiometer, Copenhagen, Denmark) with 0.1 mol L^{-1} NaOH solution to pH 8.1 and reported as percentage of citric acid;
- soluble solids content (SSC) using a refractometer (Abbe model 10450, American Optical Corp, Buffalo, NY, USA);
- weight loss as percentage of initial weight.

For metabolic activity measures, four organic and four conventional kiwifruits were kept in eight individual 0.5 L jars at 0 °C connected to a continuous flow of humidified air scrubbed from ethylene for the entire duration of the experiment, in the same conditions in which all the fruits were kept in the tanks. After each storage duration an additional 4 + 4 kiwifruits were kept in individual 0.5 L jars for 7 days at 20 °C in order to monitor metabolic activity of the kiwifruits kept at 20 °C, simulating shelf-life conditions. Periodically, two samples of 10 mL of gas were collected from each jar to measure respiration rate (as ml CO_2 kg^{-1} h^{-1}) with an infrared gas analyzer (Model PIR-2000 R, Horiba Instruments, Irvine, CA, USA) and C_2H_4 production (as μL C_2H_4 kg^{-1} h^{-1}) with a Carle 211 gas chromatograph (Hach Carle, Loveland, CO, USA) equipped with a flame ionization detector.

Constituents associated with nutritional quality

After the previous determinations, kiwifruits were cut in half, separately cut into small cubes and quickly frozen in liquid nitrogen for one half or dried at 60 °C until constant weight for the other half.

The following determinations were performed on the frozen samples:

- organic acid and sugar composition by high-performance liquid chromatography (HPLC) (Hewlett-Packard 1050 pump, Roseville, CA, USA) coupled with a photodiode array detector (DAD) (Series 1040M, Series II) and refractometric detector;[20]
- reduced ascorbic acid and dehydroascorbic acid concentrations using the HPLC procedure described by Zapata and Dufour;[21]
- total phenolics by the Folin–Ciocalteu reagent;[22] dilutions were carried out in duplicate and calculated using a calibration curve obtained with *p*-coumaric acid, reading the absorbance at 575 nm;
- antioxidant activity by spectrophotometer using the DPPH (2,2 diphenyl1-1-picrylhydrazil) method.[23]

Dried samples were used for mineral and nitrate composition performed at the UC-DANR Analytical Laboratory at UC Davis. K and Na were determined by atomic absorption spectrometry (AAS), while for Ca, P, B, and Mg inductively coupled plasma atomic emission spectrometry (ICP-AES) was used.[24]

Total nitrogen was measured using a nitrogen gas analyzer in helium and oxygen environment in a quartz combustion tube and thermal conductivity (LECO FP-528).[25]

Total extractable nitrate and ammonium were measured using a spectrophotometric method.[26]

Statistical analysis

The statistical design was a completely random design (CRD) organized in a split plot with the production system as main factor and the time of storage as second factor, resulting in a two-way ANOVA. Additionally, for each storage evaluation a one-way ANOVA was performed for production system.

RESULTS AND DISCUSSION

Morphological and physical characteristics

Morphological characteristics are reported in Table 1. Organic kiwifruits showed statistically higher values of total and columella area and lower values of flesh area than conventional kiwifruits. As a consequence, the equivalent diameter (ED) was higher in organic samples either for the whole kiwifruits or for their columella. Eccentricity (E) was not different for whole kiwifruits, while for the columella it presented a higher value in conventional kiwifruits, indicating a less spherical shape than the organic kiwifruits, with values of 0.94 and 0.91 respectively. Differences in morphological attributes were not monitored in previously published reports.

Differences in peel color consisted of a higher peel chromaticity and hue angle (79.2°) for conventional kiwifruits compared to organic kiwifruits (78.4°), indicating a color more on the yellow side of the first quarter as confirmed by the b^* value, significantly higher in conventional than in organic kiwifruits.

Peel thickness was 35% higher in organic than in conventional kiwifruits. This can be explained as a defense mechanism developed in organic kiwifruits which are not protected by chemical treatments against pests and pathogens. There are some reports correlating the thickness of the grape berry cuticle and skin to the resistance of fruits to the *Botrytis* fungus.[27,28] A higher gravimetric pulp:peel ratio for conventional compared to organic bananas was reported, highlighting also in this case the higher weight of the peel for organic bananas.[16] One other factor involved in increasing the thickness of the skin of the fruits is supplied with fertilization, which in our study was higher for organic than for conventional fruits, as reported for peaches[29] or grapes,[30] where the increasing nitrogen availability caused a decrease of the weight of grape skins and of the skin:berry ratio.

Table 1. Morphological attributes of organic and conventional kiwifruits

Morphological attributes	Treatment	
	Organic	Conventional
Shape attributes		
Fruit area	287.6a	278.2b
Columella area	61.9a	38.8b
Flesh area	225.7b	239.3a
Fruit eccentricity	0.57 ns	0.54 ns
Columella eccentricity	0.91b	0.94a
Fruit equivalent diameter	604.7a	594.9b
Columella equivalent diameter	275.9a	218.1b
Peel attributes		
Thickness (mm)	0.27a	0.20b
L^*	50.3 ns	49.7 ns
a^*	5.2 ns	5.0 ns
b^*	25.3b	27.7a
Chroma	25.9b	27.2a
Hue angle (°)	78.4b	79.2a
Flesh attributes		
L^*	63.0b	66.6a
a^*	−15.7b	−13.9a
b^*	33.8a	31.3b
Chromaticity	37.3a	34.3b
Hue angle (°)	114.9a	114.0b

Values for each parameter followed by a different letter within each row are significantly different, $P < 0.05$.

Flesh color, which exhibited more differences than skin color, was lighter in conventional than in organic kiwifruits, as indicated by a higher L^* value, lower a^* and b^* values, lower chromaticity and hue angle (Table 1).

Maturity and quality indices

Although kiwifruits were harvested at the same stage of maturity in terms of soluble solids content (about 9.5%), conventionally grown kiwifruits were about 20% firmer than organic fruits, with an initial firmness, respectively, of 52 N and 43 N.

Metabolic activity, measured as CO_2 and C_2H_4 production rates, did not show significant differences during storage at 0 °C. The pattern was almost the same, with a slight increase at 35 days resulting in a CO_2 production of 2.3 mL kg^{-1} h^{-1} for conventional kiwifruits and 1.9 mL kg^{-1} h^{-1} for organic kiwifruits (Fig. 1). These values increased after 1 week at 20 °C to about to 7 (for organic kiwifruits) and 8 mL CO_2 kg^{-1} h^{-1} (for conventional kiwifruits), reaching a peak during the second shelf-life period, after 35 days of storage, when organic kiwifruits reached almost 12 mL CO_2 kg^{-1} h^{-1} *versus* 10 mL CO_2 kg^{-1} h^{-1} CO_2 for conventional kiwifruits. After 72 days of storage, the respiration rate during shelf-life conditions decreased to about 5 mL for the organically grown kiwifruits and to 7 for the conventional ones, showing a significant difference after 3 months of storage, when the respiration rate of the organically grown kiwifruits kept for 1 week at 20 °C was significantly lower than that of the conventional kiwifruits.

No differences were observed in the ethylene production rates during storage at 0 °C and after the shelf-life simulation (Table 2).

Conventionally grown kiwifruits were firmer than organic ones and remained significantly firmer until 35 days of storage. This is in contrast to what was observed by Hasey *et al.*,[17] who found organic kiwifruits as firm or firmer than conventional kiwifruits, and by Benge *et al.*,[18] who did not find any differences in firmness between organic and conventional kiwifruits after harvesting, but observed a higher incidence of soft patches in conventional kiwifruits after 10 days of storage. Firmness can be affected by several agricultural practices, such as sunlight exposure[31] and fertilization.[32] Calcium is the plant nutrient most frequently associated with

Table 2. Maturity and quality indices of organic and conventional kiwifruits, after storage at 0 °C for 4 months and after shelf-life simulation at 20 °C

	Storage at 0 °C		Storage at 0 °C + 7 d of shelf-life at 20 °C	
Quality indices	Organic	Conventional	Organic	Conventional
Respiration rate (mL CO$_2$ kg^{-1} h^{-1})	1.6 ns	1.8 ns	7.5 ns	8.5 ns
Ethylene production (μg kg^{-1} h^{-1})	0.02 ns	0.02 ns	1.6 ns	0.4 ns
Weight loss (%)	1.1 ns	1.1 ns	4.8 ns	4.0 ns
Flesh firmness (N)	18.2b	22.4a	6.3b	10.2a
Columella firmness (N)	38.7b	55.9a	14.6b	34.7a
L^*	59.8a	62.7a	55.8b	60.1a
a^*	−13.7b	−12.4a	−11.9ns	−10.9ns
b^*	29.7a	28.7b	26.4 ns	26.4 ns
Chromaticity	32.7a	31.3b	29.0 ns	28.6 ns
Hue angle (°)	114.8a	113.2b	114.2a	112.3b
Soluble solids (%)	12.5b	13.2a	13.7b	14.7b
Citric acid (%)	1.42 ns	1.35 ns	1.1 ns	1.1 ns

Values for each parameter followed by the same letter within each row are significantly different, $P < 0.05$.

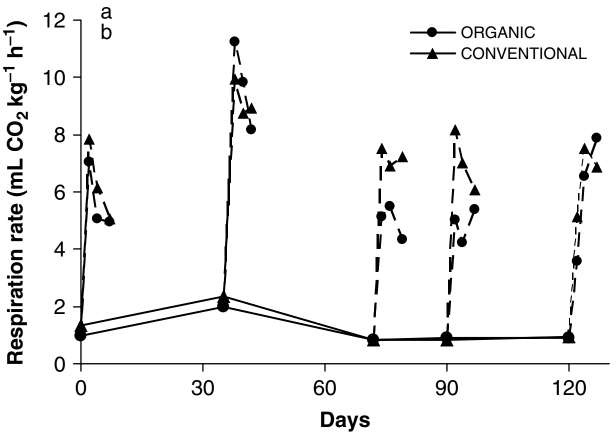

Figure 1. Respiration rate of organic and conventional kiwifruits, after storage at 0 °C for 4 months (solid line) and shelf-life simulation (broken line) at 20 °C. Values for each storage time marked by different letters are significantly different, $P < 0.05$.

fruit quality in general and firmness in particular, and its effects on fruit-softening processes has been studied by several authors, as reviewed by Poovaiah.[33] Organic kiwifruits in this study received a higher amount of minerals than that received by conventional kiwifruits, including calcium, nitrogen, and potassium. It could be that the effect of calcium on firmness of kiwifruits was counteracted by the large amounts of nitrogen and potassium that are known to decrease fruit firmness.[34,35]

As shown in Table 2, the firmness average for all the storage durations was 22.4 N for conventional *versus* 18.2 N for organic kiwifruits. The average firmness values declined after storage at 20 °C to 10.2 N for conventional and to 6.3 N for organic kiwifruits.

Columella firmness was also higher in conventional than in organic kiwifruits (Fig. 2), and this difference was also maintained after shelf-life conditions. The mean value for this parameter was 55.9 N for conventional kiwifruits *versus* 38.7 N for organic kiwifruits. After the shelf-life simulation, the mean values decreased to 34.7 N for conventional and to 14.6 N for organic kiwifruits.

The differences observed for firmness were reflected in the color determinations; firmer fruits were lighter in color than softer fruits. Conventional kiwifruits, in fact, had a higher L^* value and a lower hue angle and chromaticity, resulting in a lighter green color when compared to the organic kiwifruits. These differences remained significant after all storage durations (Fig. 2). Results on color and firmness indicated a faster ripening process in organic kiwifruits, as also observed during the ripening process of organic bananas.[16]

No differences were observed for acidity (around 1.4% of citric acid) between conventional and organic kiwifruits (Table 2).

The soluble solids content was higher in conventional kiwifruits, with 13.2% versus 12.5% in organic kiwifruits, increasing after the shelf-life to 14.7% versus 13.7%. In both organic and conventional kiwifruits SSC increased during the first 35 days of storage at 0 °C from 9.5% to about 13.5%; it then continued to increase slowly during the following months for conventional kiwifruits, while it remained quite stable for the organic kiwifruits. In addition, conventional kiwifruits kept for 1 week at 20 °C after 35 days of storage showed an increase in SSC of about 1%, while no increase in SSC was observed in organic kiwifruits.

Despite the different skin thickness between kiwifruits from the two production systems, no significant differences were detected on weight loss, which reached about 1% during 4 months of storage at 0 °C, increasing to 4% for conventional and 4.8% for the organic fruits, after the shelf-life simulation.

Constituents related to nutritional quality

Organic and conventional kiwifruits presented almost the same contents of organic acids and sugars, despite the difference in soluble solid contents, without any significant differences, except for quinic acid content, which was higher in organic than in conventional kiwifruits (Table 3). Sugar composition during storage

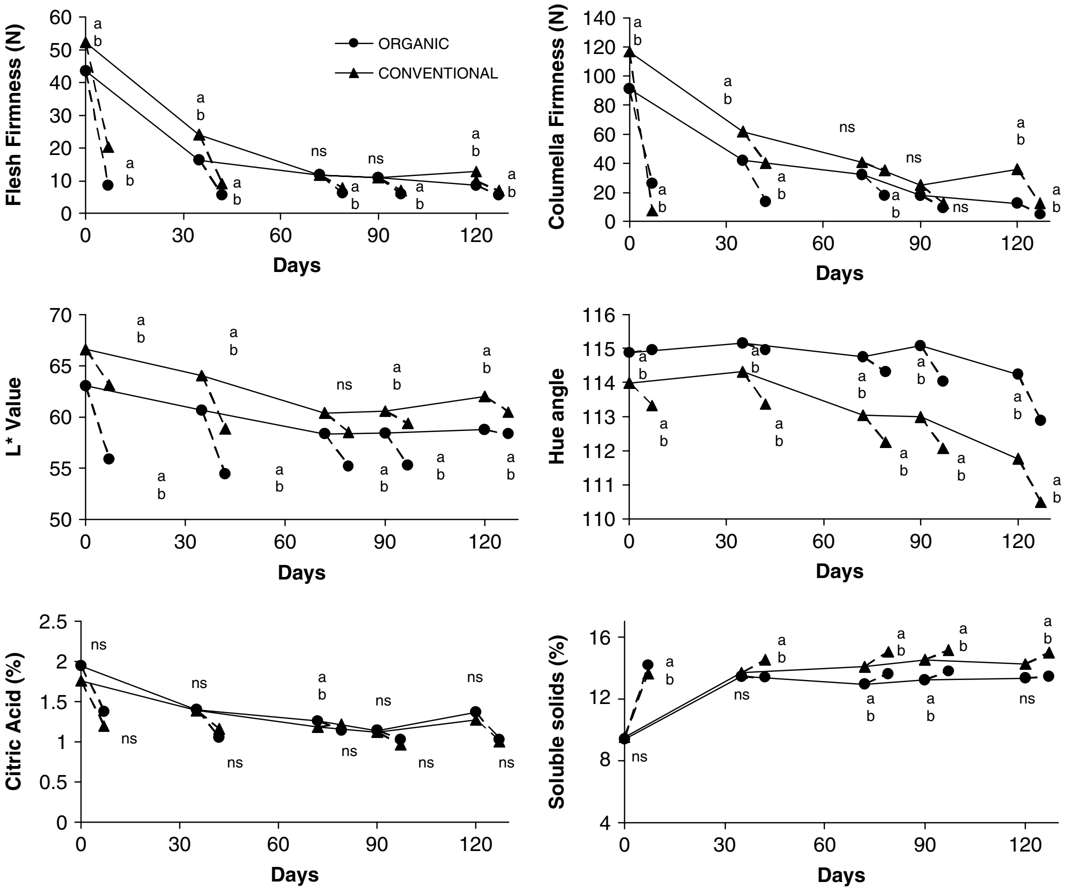

Figure 2. Flesh and columella firmness, flesh color (L^* and hue angle), soluble solids and titratable acidity of organic and conventional kiwifruits, after storage at 0 °C for 4 months (solid line) and shelf-life simulation (broken line) at 20 °C. Values for each storage time marked by different letters are significantly different, $P < 0.05$.

Table 3. Sugar and organic acid composition of organic and conventional kiwifruits, after storage at 0 °C for 4 months and after shelf-life simulation at 20 °C

	Storage at 0 °C		Storage at 0 °C + 7 d of shelf-life at 20 °C	
Sugars and organic acids	Organic	Conventional	Organic	Conventional
Sucrose (g kg^{-1})	8 ns	9 ns	8 ns	9 ns
Fructose (g kg^{-1})	25 ns	29 ns	32 ns	35 ns
Glucose (g kg^{-1})	24 ns	29 ns	31 ns	34 ns
Citric acid (g kg^{-1})	10 ns	10 ns	11 ns	10 ns
Malic acid (g kg^{-1})	2 ns	2 ns	2 ns	2 ns
Quinic acid (g kg^{-1})	6a	5b	7 ns	6 ns

Values for each parameter followed by a different letter within each row are significantly different, $P < 0.05$.

at 0 °C resulted in about 25 g kg^{-1} of fresh weight of fructose and 24 g kg^{-1} of glucose for organic kiwifruits, while both sugars were 29 g kg^{-1} in conventional kiwifruits. Sucrose concentrations were 8 and 9 g kg^{-1} for organic and conventional kiwifruits, respectively. Fructose and glucose increased after the shelf-life simulation to about 31 g kg^{-1} for organic fruits and to 35 g kg^{-1} for conventional fruits, but these values were not statistically different. Citric acid was about 10 g kg^{-1} and malic acid 2 g kg^{-1} for kiwifruits from both production systems, remaining almost stable after the shelf-life simulation. Quinic acid was significantly different between the two production systems: 6 g kg^{-1} for organic and 5 g kg^{-1} for conventional kiwifruits. After the shelf-life simulation, the same difference of about 1 g kg^{-1} was maintained, but without evidence of statistical difference.

Regarding the mineral composition, no traces of nitrate and ammonium were found in either sample, having a threshold of sensitivity of 10 ppm.

All the measured concentrations of minerals were higher in organically grown kiwifruits (Table 4), which also received a higher amount of fertilizers. Benge *et al.*[18] reported a higher calcium content for organic kiwifruits, but no information was given about the types and amounts of fertilizers applied in their investigation. The higher calcium content did not affect the softening behavior of the organic kiwifruits, which were softer than conventional, also because nitrogen and potassium are reported to have opposite actions on firmness, as discussed previously.

The higher nitrogen content did not affect ascorbic acid content, which is supposed to be lower in plants grown with high nitrogen because of the reduced carbohydrate production from which vitamin C is made.[5] These results confirmed the finding of

Whortington,[5] who after reviewing 41 comparative studies concluded that organic produces are richer in vitamin C.

The ascorbic acid and total phenolic contents were higher in the organic kiwifruits, which also presented a higher antioxidant activity (Table 5). These results agreed with the general finding that organic produce contains higher phenolic than conventionally grown produce, such as peaches and pears,[8] strawberry and marionberry,[9] wine grapes,[10] and plums.[11] For both production systems the ascorbic acid content was lower than expected, starting from about 0.45 g kg^{-1} of fresh weight and decreasing at the end of the storage to about 0.25 g kg^{-1}. The content at harvest was about the same as reported by Selman,[36] while several authors reported a higher ascorbic acid value for 'Hayward' kiwifruits.[37,38] The average value was 0.33 mg kg^{-1} for organic and 0.29 mg kg^{-1} for conventional kiwifruits. The difference became nonsignificant after storage at 20 °C.

The total phenolic content, expressed as grams of *p*-coumaric acid per kilogram of fresh weight, was 0.56 for organic and 0.48 for conventional fruits, averaged for all storage durations, increasing to respectively 0.61 and 0.51 after the shelf-life simulation (Table 5). It is possible that conventional growing practices utilize levels of pesticides that can result in a disruption of phenolic metabolites in the plant, that have a protective role in plant defense mechanisms.[6] It is reported that sublethal treatments of the herbicide glyphosate (which has been used on conventionally produced kiwifruits) altered phenol accumulation in young developing velvetleaf tissues, causing a decrease in hydroxybenzaldehyde and *p*-coumarate that was recovered after treatment, but its effects on fruits have been not investigated.[39]

Table 4. Mineral composition of organic and conventional kiwifruits, after storage at 0 °C for 4 months and after shelf-life simulation at 20 °C

	Storage at 0 °C		Storage at 0 °C + 7 d of shelf-life at 20 °C	
Mineral composition	Organic	Conventional	Organic	Conventional
Total N (% of DW)	1.09a	0.88b	1.16a	0.87b
Total P (% of DW)	0.27a	0.24b	0.30a	0.25b
K (% of DW)	2.14a	1.77b	2.25a	1.78b
Total S (ppm)	1242.33a	1021.67b	1310.33a	1051.33b
Total B (ppm)	14.47a	12.27b	14.87a	12.20b
Total Ca (% of DW)	0.21a	0.19b	0.22a	0.20b
Total Mg (% of DW)	0.14a	0.11b	0.15a	0.11b

Values for each parameter followed by a different letter within each row are significantly different, $P < 0.05$.

Table 5. Antioxidant activity and compounds of organic and conventional kiwifruits, after storage at 0 °C for 4 months and after shelf-life simulation at 20 °C

	Storage at 0 °C		Storage at 0 °C + 7 d of shelf-life at 20 °C	
Antioxidant-related compounds	Organic	Conventional	Organic	Conventional
Ascorbic acid (g kg^{-1})	0.33a	0.29b	0.28 ns	0.27 ns
Total phenolics (g kg^{-1})	0.56a	0.48b	0.61a	0.51b
DPPH (mol L^{-1} kg^{-1})	12.35a	9.69b	13.84a	10.09b

Values for each parameter followed by a different letter within each row are significantly different, $P < 0.05$.

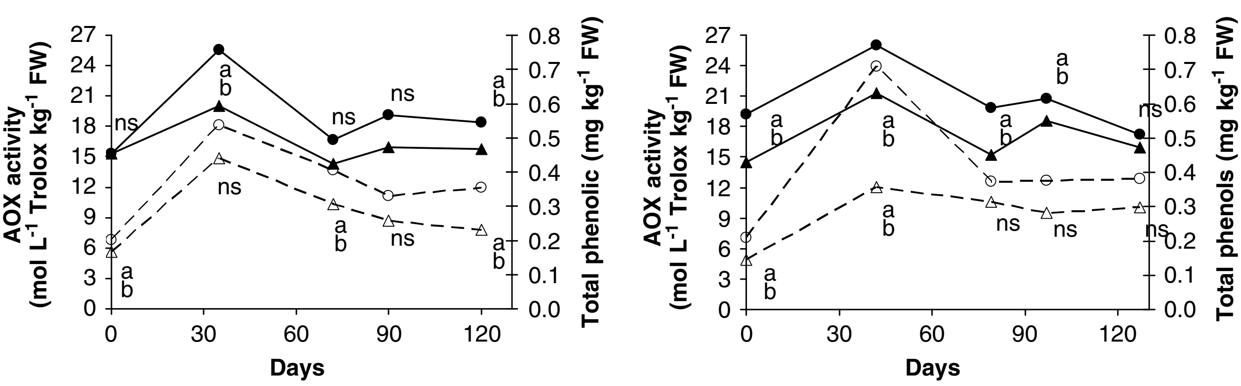

Figure 3. Antioxidant activity (AOX) as mol L^{-1} of Trolox kg^{-1} of fresh weight and total phenolic content as mg kg^{-1} of organic and conventional kiwifruits, after storage at 0 °C for 4 months (on the right) and shelf-life simulation at 20 °C (on the left). △: AOX Conventional; ○: AOX Organic; ●: Total phenols Conventional; ▲: Total phenols Organic. Values for each storage time marked by the different letters are significantly different, $P < 0.05$.

Antioxidant activity determined using the DPPH method and expressed as mol L^{-1} kg^{-1} of Trolox was around 12.0 for organic and 9.70 for conventional kiwifruits, increasing during the shelf-life to almost 14.0 and 10.0 mol L^{-1} kg^{-1}, respectively (Table 5).

The total phenolic content and antioxidant activity presented the same pattern as shown in Fig. 3, with higher values after the shelf life simulation than after storage at 0 °C; both increased up to 35 days of storage, and then decreased during the following months, with differences becoming less significant.

CONCLUSION

Organic and conventional kiwifruits from nearby vineyards on the same farm in Marysville, California, presented the same soluble solids content at harvest but different flesh firmness and color. Conventionally grown kiwifruits had a higher firmness and L^* value and a lower hue angle and chromaticity, resulting in a lighter green flesh color, when compared to the organic kiwifruits. These differences were maintained throughout all the storage durations, with the soluble solids content increasing more in the conventionally grown kiwifruits, but this result was not supported by a higher amount of sugars, and it could be related to other soluble solids (acids, soluble pectins, phenolic compounds). Organic kiwifruits had a larger total and columella area, smaller flesh area, more spherical shape, and thicker skin compared to conventional kiwifruits. All the main mineral constituents were more concentrated in the organic kiwifruits, which also had higher ascorbic acid and total phenolic contents, resulting in a higher antioxidant activity. Sugar and organic acid composition was not affected by the production system.

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