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Effect of the application timing of 1-MCP on postharvest traits and sensory quality of a yellow-fleshed kiwifruit

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ABSTRACT

Chile is the third largest exporter of kiwifruit in the world. Its varietal production has traditionally been focused on green-fleshed kiwifruit varieties, with 'Hayward' being the most exported variety. 'Soreli' is a new Italian kiwifruit variety, which is characterized by its early ripening, big size, sweet taste, as well as its yellow flesh. This gives 'Soreli' a good opportunity to promote the consumption of yellow-fleshed varieties, and a wider assortment of kiwifruit in the market. The aim of this work is to evaluate postharvest traits and consumer acceptance in kiwifruit var. 'Soreli', with a combination of storage temperatures of 0 °C and 20 °C and 1-methylcyclopropene (1-MCP) applications.

Cold storage and 1-MCP treatments caused a positive response in kiwifruit var. 'Soreli'. In the case of fruits stored at 20 °C, 1-MCP treatment extended the postharvest life of the fruits at least 3 weeks while the fruits stored in cold at 0 °C treated with 1-MCP reached 8 weeks. In general, the respiration rate was higher in the control treatments with respect to the 1-MCP treatments, as well as the ethylene emission occurred earlier in the control. In addition, the kiwifruit sensory quality attributes were adequate in all cases, reaching a medium or high acceptability in the evaluation panel.

1. Introduction

In the last years worldwide kiwifruit production has increased substantially, from 2.5 MT to 4.3 MT. Sixty percent of kiwifruit production is generated in Asia, with China being the world's largest producer (2.39 MT), followed by Italy (0.52 MT), New Zealand (0.43 MT), Iran (0.29 MT) and Chile (0.23 MT). However, the largest exporters in the world are Italy, New Zealand and Chile, with 0.34, 0.32 and 0.21 MT exported, respectively (FAOSTAT, data retrieved in 2018). The production of kiwifruit worldwide is based mainly on green-fleshed kiwi, especially var. 'Hayward' (Cruzat, 2014). It was not until the late 1990s that the first varieties of yellow-fleshed kiwi appeared, highlighted by 'Jintao', 'Enza Gold', and recently by 'Soreli'.

On these days, the fresh fruit market is in search of novelties for an empowered and much more demanding consumer, and the yellow-fleshed kiwifruit appear to be an interesting option due to their lower acidity and high fruit quality. New cultivars with yellow flesh have been developed in the last 20 years, some of them gaining a consistent place in the market. Currently, the demand for the presence of new varieties in the market is becoming more evident, which requires a better knowledge of fruit quality and postharvest behavior of yellow-fleshed kiwi varieties.

In the yellow-fleshed cultivars, more so than the green cultivars, there is the need to prolong the postharvest life span, because these cultivars naturally have less viability after harvest than 'Hayward' or other green fleshed varieties. 'Hayward' could be kept in cold storage for 140 days or even more (Park et al., 2015a), but a yellow-fleshed cultivar such as 'Sanuki Gold' rarely maintains edibility for more than 60 days in cold storage (Asiche et al., 2017).

The product 1-methylcyclopropene (1-MCP) is an inhibitor of ethylene action that delays the natural senescence of fleshy fruit and is applied commercially in some climateric fruit that have a final destination in distant markets and require prolonged postharvest. 1-MCP has been used commercially for more than 10 years in different fresh horticulture products, widening the window for fresh produce in cold storage. Thus, it is left to the companies that pick and package the fruit to control the flesh softening and ripening processes through the application of 1-MCP. The fruit is subsequently drawn from the cold chamber, at different times, to be displayed on store shelves. The beneficial effect of 1-MCP on decreasing the softening rate in green-

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fleshed kiwifruit is accomplished through the higher activities of phenylalanine ammonia-lyase, cinnamyl-alcohol dehydrogenase, peroxidase and higher lignification postharvest (Li et al., 2017). This effect has been profusely documented, particularly in cultivars 'Hayward' (Boquete et al., 2004; Koukounaras and Sfakiotakis, 2007; Park et al., 2015a; Vieira et al., 2012), 'Allison' (Sharma et al., 2012), 'Quinmei' (Deng et al., 2015), and in hardy kiwifruit too (A. arguta (Siebold and Zucc.) Planch. ex. Miq.) (Lim et al., 2016: Wang et al., 2015). However, it has been shown that its application in kiwifruit may reduce the sensorial quality of these products (Deng et al., 2015).

The increased excitement currently enjoyed by yellow-fleshed kiwifruit varieties is a fantastic opportunity to introduce them more broadly and consistently into the market. To do this, studies are required, not only of sensorial quality and consumer acceptance, but of their postharvest behavior as well. Therefore, the aim of this work is to determine the effect of the application timing of 1-MCP on the quality and postharvest behavior of the yellow-fleshed 'Soreli' kiwifruit.

2. Material and methods

2.1. Plant material

'Soreli' (*Actinidia chinensis*) is a kiwifruit variety which is characterized by its big size, yellow flesh, sweet taste, and early harvest date. This variety was grafted on 'Hayward' vines (*Actinidia deliciosa*) in 2012, in 1 ha of a commercial orchard located in Teno, region VII, Chile (longitude -71° 12' 48'' and latitude -34° 52' 58''). Rows were distributed 4 m apart, and vines were planted 2 m apart in the row. Each row was irrigated with drip irrigation under conventional management. In 2015, for assuring homogeneous fruit size, manual pollination was performed using pollen of the male cultivar 'Belén'. The storage and fruit quality evaluations were carried out in Fruit Breeding and Quality Laboratory of the University of Chile.

2.2. Experimental trial and fruit quality evaluation

A total of 500 'Soreli' kiwi fruit were harvested when the flesh turned to yellow color with a soluble solids concentration (SSC) of 9.15% and flesh firmness around 50 Newtons (N) (Table 1). Finally, 300 homogeneous fruit were selected to perform 1-MCP applications for storage at 20 °C (F1) and storage at 0 °C for 45 days and 20 °C after cold (F2).

Table 1
Summary of descriptive analysis of the evaluated traits in kiwi fruit 'Soreli' at harvest.

Trait	n	Mean	SE	Min	Max
Fruit weight (g)	12	105.98	2.61	92.72	123.01
Ecuatorial diameter 1 (mm)	12	52.03	0.62	47.87	56.08
Ecuatorial diameter 2 (mm)	12	49.37	0.40	46.77	52.60
Polar diameter (mm)	12	65.98	0.78	60.25	70.44
Skin I_{AD}	24	0.71	0.02	0.53	0.87
Skin color (L*)	24	52.10	0.65	45.69	57.74
Skin color (a*)	24	0.42	0.57	−3.79	6.81
Skin color (b*)	24	29.04	0.33	25.66	31.88
Skin color (C)	24	29.17	0.32	25.76	31.92
Skin color (H°)	24	89.07	1.15	75.96	97.27
Flesh I_{AD}	24	0.07	0.01	0.00	0.16
Flesh color (L*)	24	71.43	0.69	64.75	76.30
Flesh color (a*)	24	−7.22	0.13	−8.49	−5.62
Flesh color (b*)	24	37.74	0.59	29.60	41.66
Flesh color (C)	24	38.43	0.59	30.39	42.34
Flesh color (H°)	24	100.87	0.22	97.68	103.08
Flesh firmness (N)	24	52.08	1.99	31.99	63.84
Placenta firmness (N)	12	10.89	0.68	6.48	14.33
Dry matter (%)	12	17.03	0.34	14.91	18.75
Soluble solids (%)	12	9.15	0.40	7.10	11.00
pH	6	3.30	0.03	3.18	3.37
Acidity (g/l)	6	1.23	0.05	1.07	1.38

Thus, immediately after harvest, the F1 fruit set was divided in two subgroups, 0 ppb of 1-MCP as control (T0) and 625 ppb of 1-MCP (T1) which it was applied for 24 h, storing both at 20 °C.

Fruit quality evaluations started 24 h after harvest for both treatments. The F2 fruit set was divided into three subgroups; 0 ppb of 1-MCP as control (T0), 625 ppb of 1-MCP (T1, pre-cold storage) and 625 ppb of 1-MCP (T2, post-cold storage) storing all of them at 0 °C for 45 days before fruit quality evaluation. 1-MCP treatments were applied before cold storage (T1) and after 45 days of cold storage (T2) for 24 h and then all of them were storage at 20 °C. All evaluations were carried out until consumption maturity (6–8 N).

1-MCP treatments for F1 and F2 fruit set were carried out in watertight polypropylene chambers of 70 litres and 1-methyl cyclopropene (1-MCP) was gasified as a SmartFresh™ product 0.14% (625 ppb).

To characterize the quality and postharvest behavior of 'Soreli', weight loss, chlorophyll absorbance (I_{AD}), soluble solid content (SSC), dry matter, skin and flesh color, the flesh and placenta firmness, respiration rate (CO_2) and ethylene production were evaluated.

The chlorophyll absorbance at two wave-length (I_{AD}) as a maturity index was monitored by the kiwifruit specific DA-meter device (T.R. Turoni, Forlì, Italy; Gottardi et al., 2009), until consumption maturity.

The SSC was determined using a hand-held refractometer (ATAGO Co. LTD., Tokyo, Japan), calibrated as the percentage of sucrose at 20 °C, and dry matter was determined as a percentage of weight after 16 h in air dryer. SSC and dry matter were evaluated at 60, 20 and 8 N in both treatments (T0 and T1) in the F1 fruit set (storage at 20 °C), and at consumption maturity (6–8 N) for F2 fruit set (45 days after cold storage). The skin and flesh color (H°, L*, a*, b*) of the fruit were determined using a CR-400 colorimeter (Konica Minolta Inc., Marunouchi, Chiyoda, Tokyo) at consumption maturity in each treatment. Firmness was quantified in Newton (N) by a texture analyzer (TA.XT plus, Texture Technologies, Hamilton, MA, USA) using 7.9 mm and 2 mm diameter plungers by penetration of 8 mm, and a 20 mm cylinder by compression of 3 mm depth (non-destructive method). Firmness was measured in alternative days (at least 6 measurements) according to the fruit maturity.

Respiration rate (ml $CO_2\,kg^{-1}\,h^{-1}$) and ethylene production (µl $kg^{-1}\,h^{-1}$) were monitored until consumption maturity using PBI Dansensor check mate 3 (MOCON Inc., Minneapolis, MN, USA) and SHIMADZU GC 2014 gas chromatograph (Shimadzu Corp., Kyoto, Japan) equipped with FID detector and alumina column, respectively.

In addition, sensory quality parameters were evaluated by twelve trained evaluators on a continuous and unstructured scale of 15 cm using a visual phase for skin color (light-dark brown), flesh color (light-dark yellow), flesh brightness (opaque-gloss), and seed color (pale-dark); nasal phase including typical aroma (low-high), and aromatic intensity (low-high); gustatory phase as sweetness (low-intense), acidity (low-high), and strange taste (low-intense); texture phase including hardness (very soft-very hard), chewability (little-much), and juiciness (little-much) and finally general acceptability (dislike much-like very much) (Table S1).

2.3. Experimental design and fruit quality data analysis

In all cases, a completely randomized experimental design was followed. The experimental unit corresponded to ten fruit per treatment and evaluation for destructive methods (firmness by punction, dry matter, SSC and flesh color), and fifteen fruit for non-destructive methods (fruit weight, skin I_{AD} and firmness by compression and skin color), except for respiration rate and ethylene emission that used five fruit. The results were analyzed by analysis of variance (ANOVA) and Tukey multiple comparison test (p-value ≤ 0.05). In addition, a multivariate analysis of principal components was performed. All analyses were calculated and edited using INFOSTAT v16 software (Universidad Nacional de Córdoba, Argentina).