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Enhancement of postharvest sensory quality and antioxidant capacity of sweet pepper fruits by foliar applying calcium lactate and ascorbic acid

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ABSTRACT

In this experiment, the impact of foliar spraying of ascorbic acid (AsA; 100, 200, and 300 mg L^{-1}) and calcium lactate (CaL; 0.5, 1 and 1.5 g L^{-1}) on sensory quality and antioxidant capacity of sweet pepper fruits during storage at 7 °C for 30 days was investigated. Our results showed that sweet pepper fruits sprayed by AsA or CaL exhibited higher fruit firmness, chlorophyll, carotenoid, total soluble solids (TSS) and titratable acidity (TA) accompanied by lower weight loss. In addition to enhancing sensory quality, sweet pepper fruits sprayed by AsA or CaL exhibited higher DPPH scavenging capacity arising from higher phenols, flavonoids and ascorbic acid accumulation during storage at 7 °C for 30 days. According to our results, foliar AsA or CaL spraying may be promising strategies for enhancing sensory and nutritional quality of sweet pepper fruits during storage at 7 °C for 30 days.

1. Introduction

Nutritional and clinical studies have revealed that diets rich in fresh fruits and vegetables are associated with a reduced risk of diseases, including cancers and cardiovascular disease (Isabelle et al., 2010; Bunea et al., 2013). The health-promoting attributes of fruits and vegetables are derived from the phytochemicals with antioxidant activity, dietary fiber, vitamins and minerals (Tomas-Barberan and Espin, 2001). Sweet pepper (*Capsicum annuum* L.) is a worldwide used vegetable, which is an excellent source of ascorbic acid and has high antioxidant capacity against oxidative damage caused by reactive oxygen species (ROS; Loizzo et al., 2008,2013; Pugliese et al., 2013,2014a,b; Farhoudi et al., 2017). However, it is a very perishable with a short shelf life due to susceptibility to fungal diseases, wilting and chilling injury (Finger and Pereira, 2016; Lownds et al., 1994). Therefore, it is necessary to develop an effective and safe pre and postharvest treatment for maintaining the quality attributes of sweet pepper during cold storage.

Ascorbic acid (AsA) is a water-soluble vitamin that plays a key physiological role in scavenging reactive oxygen species (ROS) (Fang et al., 2017). In recent years, the application of exogenous AsA has received much attention for use as a biologically safe molecule for postharvest quality maintenance of horticulture crops. It has been reported that AsA treatment delayed the onset of browning of pear (Lin et al., 2007), pomegranate arils (Özdemir and Gökmen, 2017), apple slices (Prestamo and Arroyo, 1999), mung bean sprouts (Sikora and Swieca, 2018) either alone or in combination with chitosan. Sogvar et al. (2016) also suggested that AsA in combination with *Aloe vera* had benefit in delaying changes in the ripening and reducing microbial populations of strawberry fruit.

Calcium is an essential macronutrient that plays a vital role in maintaining cell wall stabilization and integrity and determining fruit quality (Manganaris et al., 2005). Preharvest calcium treatment has shown to be effective in retaining the quality (Wang and Long, 2015), enhancing antioxidant capacity (Koutinas et al., 2010; Naser et al., 2018), preventing softening (Wang and Long, 2015; Naser et al., 2018), alleviating chilling injury (Gerasopoulos and Drogoudi, 2005), controlling postharvest decay (Sugar and Basile, 2011), delaying the ripening process and extending storage life (Madani et al., 2014., Gerasopoulos and Drogoudi, 2005) of fruits and vegetables. Manganaris et al (2005) treated peaches with calcium chloride, calcium lactate and calcium propionate and reported that calcium lactate provided both better textural features and sensory attributes.

To our knowledge, however, little information is available regarding the effect of ascorbic acid and calcium lactate on pepper fruits. Thus, the aim of this study was to investigate the foliar application of ascorbic acid and calcium lactate on quality attributes and antioxidant capacity of sweet peppers under cold storage.

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Table 1
Soil physical and chemical properties on the site of experimental field.

pH	EC ($ds.m^{-1}$)	N (%)	Ca ($g.kg^{-1}$)	Na ($g.kg^{-1}$)	K ($g.kg^{-1}$)	OM (%)	Soil texture	Sand (%)	Silt (%)	Clay (%)
7.40	1.49	0.07	0.12	0.13	0.2	0.94	Silt loam	25	38	37

OM: Organic mater.

Table 2
Mean-long meteorological parameters of Zanjan Synoptic station during the growth seasons (2016) of sweet pepper.

Rainfall (mm)	Relative humidity (%)			Wind rate ($m.sec^{-1}$)	Air temperature (°C)		
	Minimum	Maximum	Mean		Minimum	Maximum	Mean
4.4	21	58	39.5	1.6	13.7	31.2	22.5

2. Materials and methods

2.1. Experimental site

To study the effect of foliar application of calcium lactae (CaL) and ascorbic acid (AsA) on fruit quality, antioxidant properties and shelf life of sweet pepper, the field experiment was carried out from June to September 2016 at Research Farm of Agriculture Faculty, at the University of Zanjan, Iran. The soil texture was sandy loam with 7.4 pH. Some soil characteristics were showed in Table 1. The Mean-long climate data during the growing seasons (2016) was shown in Table 2.

2.2. Plant materials and treatments

Pepper plants (cv. California Wonder) were cultivated by applying conventional farming practice for growing in open air conditions. Different concentrations of CaL (0, 0.5, 1 and 1.5 g L^{-1}) and AsA (100, 200 and 300 mg L^{-1}) (approximately 50 mL per plant) were sprayed in full bloom, 15 and 30 days after full bloom for 3 times onto the leaves and fruits until runoff using a mechanical mist sprayer, and Tween 20 (0.04% v/v) was used as a surfactant. Distilled water was used as a control. For each treatment, 30 plants were used. Each treatment was carried out with three replicates. Pepper fruit were harvested at commercial maturity stage, and transferred to the laboratory on the same day. Then, 24 fruits, homogeneous in color and size and freedom from physical damage and infections were selected from each replicate and randomly divided into 4 groups of 6 fruits. One group was analyzed 24 h after harvest and another groups stored at 7 ± 1 °C and 85% RH for 30 days. At 10-day intervals, one group was taken at random and transferred for 1 day at 20 °C (shelf-life), and subjected to physico-chemical analysis.

2.3. Measurements

2.3.1. Quality attributes

Fruit firmness was determined with an Effegi penetrometer (model -I-OSK- 10576), using an 8 mm penetrating tip. Results were expressed in kilogram per square centimeter (kg cm^{-2}). The pH values of solutions were monitored with a pH meter. TSS was measured in the extract obtained from three fruits of each replicate with a digital refractometer Atago PR-101 (Atago Co., Ltd., Tokyo, Japan) at 20 °C. The titrable acidity (TA) was determined by titration of 1 mL of diluted extract in 25 mL of distilled water to pH 8.2 using 0.1 N NaOH. The results were expressed as grams of citric acid equivalent per 100 g of fresh weight (Valero et al., 2011). Vitamin C (ascorbic acid) content was determined using the 2, 6- dichlorophenol-indophenol dye solution (AOAC, 1984). Total ascorbic acid content was expressed as mg per 100 g of juice.

2.3.2. Total chlorophyll and carotenoid contents

Chlorophyll and carotenoids contents in fruit tissue were determined according to the method of Arnon (1967). Chlorophyll and carotenoids was extracted from a sample of 1 g fresh fruit pericarp in acetone 80% (v/v). Absorption was measured at 663 and 645 nm for chlorophyll and 480 and 510 for carotenoids using a spectrophotometer. Concentration of total chlorophyll and carotenoids were expressed as mg/g fresh weight and determined using the formula:

Total chlorophyll (mg g^{-1} FW) = [20.2 (A_{645}) + 8.02 (A_{663})] × V/ W 1000

Carotenoids = [7.6(A_{480}) – 1.49(A_{510})] × V/W1000

Where: A_{645} = absorption value at 645 nm, A_{663} = absorption value at 663 nm, A_{470} = absorption value at 470 nm, V = total volume of filtrate, W = tissue weight.

2.3.3. Total phenols and flavonoids content

The fruit tissues (5.0 g) was washed with deionized water, and homogenized in 15 mL water/methanol (50:50, V/V). The homogenate was centrifuged at 10,000*g* for 10 min at 4 °C, and the supernatant was collected for the measurement of antioxidant capacity and total phenolic and flavonoid content. Total phenolics assay was carried out according to the procedure described in the literature (Singleton and Rossi, 1965). The results were expressed as milligrams of gallic acid equivalents (GAE) per 100 g of fresh weight on the basis of a standard curve using gallic acid as standard. Total flavonoids were determined by the colorimetric method (Kaijv et al., 2006). Quercetin was used as a reference standard, and the results were expressed as milligram quercetin equivalents per 100 g fresh weight of fruit.

2.3.4. Total antioxidant activity

The method of Wettasinghe and Shahidi (2000) as modified by Dehghan and Khoshkam. (2012) was used for measuring the DPPH radical scavenging ability of sweet peppers extracts. 50 µL of extracts were allowed to react with 1.95 mL of DPPH radical solution (0.1 mM in methanol) for 30 min. The decrease in absorbance from the resulting solution (AS) was monitored at 517 nm in a UV–vis spectrophotometer (Specorp 250 Jena-History). Absorbance of the blank solution of DPPH (2 ml) was used as an experimental control (AC). The radical scavenging activity (RSA%) of the pepper fruits extracts was calculated according to the following formula:

RSA% = 100 (Ac − As) / Ac

2.3.5. Weight loss

Fruits were weighed at day 0 and at the end of each storage interval. Weight loss was calculated as the percentage loss of weight with respect to the initial weight.