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Effects of postharvest methyl jasmonate treatment on main health-promoting components and volatile organic compounds in cherry tomato fruits

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ABSTRACT

Effects of postharvest methyl jasmonate (MeJA) treatment on the contents of ascorbic acid and carotenoids, as well as the compositions and contents of volatile organic compounds (VOCs) in cherry tomato fruits were investigated during 11 days of storage at room temperature (25 °C). The results showed that MeJA treatment significantly increased the contents of ascorbic acid and carotenoids, especially lycopene in postharvest cherry tomato fruits. Moreover, MeJA treatment improved the contents of carotenoids derived VOCs such as 6-methyl-5-hepten-2-one (MHO), while had no effect on firmness, sugars and titratable acidity. All above results suggested that the exogenous MeJA application is potential in enhancement of main health-promoting components and VOCs in postharvest cherry tomato fruits.

1. Introduction

Cherry tomatoes (*Solanum lycopersicum* L.) are popular tomato cultivars with consumers around the world. Their small size fruits have delicate and succulent taste, and are excellent for fresh eating, which are usually made into salad. Former studies have shown that cherry tomato has higher fruit quality (Figas et al., 2015; Kavitha, et al., 2014), which is beneficial in terms of marketing and consumer consumption. The quality of tomato fruit comprises sensory quality, nutritional quality and flavor quality (Klee & Giovannoni, 2011; Liu, Shao, Zhang, & Wang, 2015; Uluisik et al., 2016). Sensory quality includes color, appearance and firmness. It is well known that firmness is vital for transportation, shelf life and chewiness (Han et al., 2017; Yang et al., 2017). As main health-promoting components, ascorbic acid and carotenoids are usually considered to be major contributors to the nutritional quality of cherry tomato. Ascorbic acid, also named vitamin C, is an alternative edible source to help reduce oxidative stress (Bahorun, Luximon-Ramma, Crozier, & Aruoma, 2004). The main carotenoids benefiting for human health in tomato are lycopene, β-carotene and lutein, with lycopene being the most abundant in the range between 7.8 and 18.1 mg 100 g^{-1} fresh weight (FW) (Galpaz, Ronen, Khalfa, Zamir, & Hirschberg, 2006; Slimestad, Fossen, & Verheul, 2008). Dietary lycopene is reported to defend critical cellular biomolecules and confer protection against cardiovascular disease (Rissanen et al., 2001), and it has also been hypothesized to protect against prostate, breast, lung, colorectal, endometrial, oral and stomach cancers (Seren et al., 2008). As an important dietary provitamin A, β-carotene also functions as a strong antioxidant (Barba, Hurtado, Mata, Ruiz, & de Tejada, 2006). Lutein is believed to keep eyes safe from oxidative stress for human being (Granado, Olmedilla, & Blanco, 2003).

Sugars, acids, and volatiles are three major classes of chemicals responsible for flavor quality of tomato. The composition and contents of sugars are direct factors influencing sweetness of tomato. Increased sweetness was found to be the results of increased sucrose and glucose in tomato (Baxter et al., 2005). Although sugars and acids are absolutely essential for good taste, it is the volatiles that really determine the unique flavor of tomato. Volatile organic compounds (VOCs), also called aroma or volatiles, are central parts of tomato flavor and also benefit human for antimicrobial and anticarcinogenic activity (Goff & Klee, 2006). Volatiles that own positive impact on the flavor profile mostly derive from fatty acid, carotenoids and amino acid. For instance, β-ionone, a β-carotene-derived product, and geranylacetone, a volatile likely derived from a lycopene precursor, have strong effects on tomato flavor (Simkin, Schwartz, Auldridge, Taylor, & Klee, 2004). In addition,

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6-methyl-5-hepten-2-one (MHO), comes from lycopene directly and contributes greatly to the flavor of tomato (Goff & Klee, 2006; Tieman et al., 2017). However, some volatiles like guaiacol and methyl salicylate (MeSA) are defined as medicinal-like aroma, which is disliked by some consumers (Zanor et al., 2009; Zierler, Siegmund, & Pfannhauser, 2004)

Methyl jasmonate (MeJA), a natural volatile form of jasmonates, is proved to be involved in regulating tomato fruit nutritional quality, including the content of a series of secondary metabolites, such as lycopene and anthocyanin (Chen, Jones, & Howe, 2006; Seo et al., 2001; Uppalapati et al., 2005; Wasternack & Hause, 2013). It was reported that mature green tomato fruits had a lower lycopene concentration with 0.5% (w/w) MeJA in lanolin paste when compared with the control (Saniewski & Czapski, 1983). However, exogenous MeJA vapor treatment has better effects on fruit quality, and the content of lycopene was found to be elevated in tomato fruits at red ripe stage after MeJA exposure treatment (Tzortzakis & Economakis, 2007). Our former study has also shown that exogenous jasmonates could induce lycopene accumulation in fruits of Castlemart (Liu et al., 2012), and several surveys have suggested that carotenoids accumulation could be regulated by endogenous jasmonates. JA-deficient mutant *def1* and *spr2* showed significant lower level of lycopene in tomato fruits (Howe, Lightner, Browse, & Ryan, 1996; Li et al., 2003; Liu et al., 2012), while lycopene accumulation was significantly increased in JA overexpression *35S::prosys* fruits (Howe & Ryan, 1999; Liu et al., 2012).

Cherry tomatoes are usually harvested at mature green stage for long distance transportation at room temperature in China, where the cold-chain transportation is not common. So, it is meaningful to develop methods to maintain or improve the quality of cherry tomato fruit during postharvest storage at room temperature. In the present study, we investigated the effects of detailed MeJA application, including accurate vapor treatment duration and suitable concentration, on sensory quality, nutritional quality and flavor quality of cherry tomato during postharvest storage under room temperature.

2. Material and methods

2.1. Fruit material

Cherry tomatoes (*Solanum lycopersicum* L. cv. ZheYingFen No1) were grown in greenhouse from 20 to 28 °C temperature cycle (night to day air temperature) and 16 h photoperiod. Fruits were harvested at mature green stage. Flowers were tagged at anthesis with tiny label, which didn't influence fruits development. Mature green stage was defined as green fruits without any color change at 35 days after anthesis. Uniform size fruits without mechanical injury were picked up.

2.2. MeJA treatment

Mature green fruits of cherry tomato were treated with 0.01 μM MeJA and 0.05 μM MeJA (Aldrich, Japan) or without MeJA (control) for 24 h at 25 °C. A 10 L plastic foam container was used to place fruits along with five cotton balls wetted with different concentration of MeJA or without MeJA. For control and MeJA treatment, sealed containers with transparent cover were put in a growth chamber (Safe experimental instrument company, Ningbo, China) with 16 h photoperiod at 25 °C and 85% relative humidity for 24 h. After treatment, the fruits were moved to new containers to replace MeJA with fresh air. Samples were collected at 1d, 4d, 8d and 11d after treatment to correspond with mature green stage, breaker stage, pink stage and red ripe stage (Fig. 1A and B). Thirty-six fruits of control and treatment at each stage were selected and divided into four groups for the measurement of appearance and firmness, and all these fruits were maintained at 25 °C and 85% relative humidity during the test. After firmness determination, four biological replicates of three fruits each were frozen by liquid nitrogen at once, and then stored at -80 °C for chemical analysis.

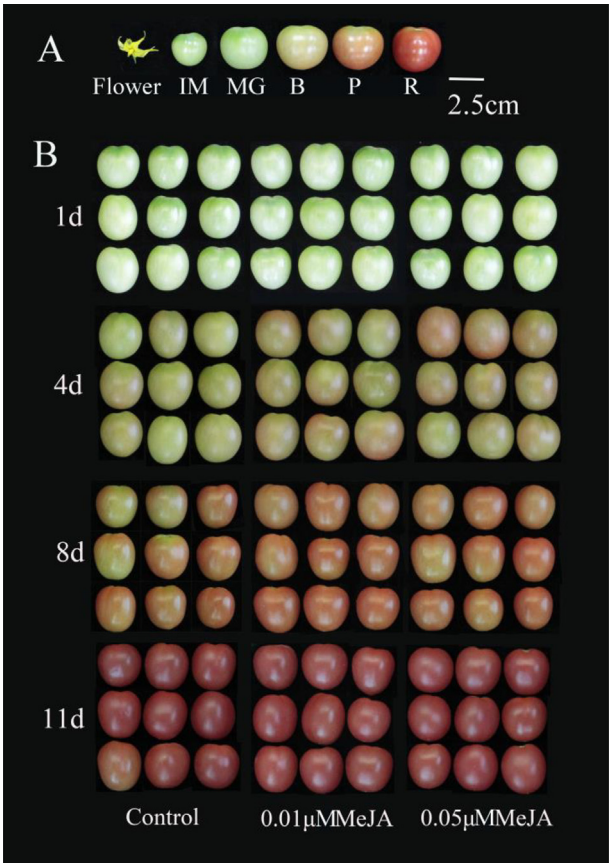

Fig. 1. The appearance of cherry tomato fruits during postharvest storage. (A) Typical developmental stages of cherry tomato fruits. (B) The appearance of cherry tomato fruits at different days after MeJA treatments.

2.3. Firmness determination

Fruit firmness was tested at four points of each fruit on the equatorial region with a TA-XT2i texture analyser (Stable Micro Systems Ltd., Godalming, UK) and a black plastic probe of 7.5 mm in diameter. The penetration depth was set at 10 mm and the penetration speed was set at 1 mm s^{-1}. The unit of force for firmness is Newton.

2.4. HPLC analysis of ascorbic acid

After frozen by liquid nitrogen, fruit fragments were ground into powder quickly with the mortar and pestle to avoid light and high temperature. 0.5 g powder of fruit was weighed accurately in 5 ml centrifuge tubes, then added with 2.5 ml 1% oxalic acid solution and centrifuged at 7000 rpm for 10 min under 4 °C, then the supernatant was collected and filtered for HPLC analysis. The whole process was done quickly in darkness.

HPLC analysis of ascorbic acid was measured using a Shimadzu HPLC system (Shimadzu, Kyoto, Japan) and a SPD-M20A diode array detector. C18 column (5 μm particle size, 4.6 mm × 250 mm, Elite analytical instruments Co., Ltd., Dalian, China) was used with 0.1% oxalic acid solution as the mobile phase while the flow rate was set at 1 ml min^{-1} under 30 °C. And 20 μl samples were injected onto the column by autosampler while absorbance was detected at 243 nm. Authentic ascorbic acid was chosen as a standard for the calculation of the amount of vitamin C. Result was presented as μg g^{-1} fresh weight (FW).