Journal of Integrative Agriculture 2017, 16(9): 2093–2100

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RESEARCH ARTICLE

Effect of post-harvest UV-C irradiation and calcium chloride on enzymatic activity and decay of tomato (*Lycopersicon esculentum* L.) fruit during storage

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Abstract

Tomato is one of the extensively consumed vegetable crops worldwide. The regular consumption of tomato decreases the incidence of chronic degenerative diseases such as certain types of cancer and cardiovascular diseases. The objective of this study was to find an appropriate method that not only reduces tomatoes decay, but also maintains its post-harvest quality. A factorial experiment based on randomized complete block design with three replications was conducted to evaluate effects of ultraviolet (UV)-C and $CaCl_2$ applications on tomato during storage. The traits studied included ethylene, polygalacturonase (PG) activity, pectin methyl esterase (PME) activity, firmness, total phenol content, and fungal-induced decay were measured weekly during 35 days of storage. Both UV-C and $CaCl_2$ treatments had positive effects on tomato quality as compared to control treatment. The 3 and 4.5 kJ m^{-2} levels of UV-C and 2% $CaCl_2$ had positive effects on quality characteristics, respectivly. Fruits treated by UV-C and $CaCl_2$ had higher phenol and firmness, and less PME activity, PG activity, ethylene production, and decay than the control fruits. In conclusion, increasing in storage duration significantly affected the fruits quality by increasing in ethylene, PME activity, PG activity, decay and decreasing the phenol content and firmness. But UV-C and $CaCl_2$ led to significant decrease in this adverse impact relative to control treatment.

Keywords: $CaCl_2$, ethylene production, firmness, PG, PME, phenol

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the major vegetable components of the human diet worldwide. The fleshy fruits, however, are susceptible to decay and loss of quality once they have been harvested, due to ethylene production and activities of cell wall-degrading enzymes (Zhu *et al*. 2016). A number of post-harvest treatments have been evaluated for their ability to prevent post-harvest

Received 13 August, 2016 Accepted 3 November, 2016
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doi: 10.1016/S2095-3119(16)61569-1

decay and extending the shelf-life of tomato fruits, including the high-pressure and thermal treatments (Krebbers *et al*. 2003), 1-methylcyclopropene (1-MCP) (Guillén *et al*. 2007) and sodium selenite (Zhu *et al*. 2016).

Among the mineral nutrients, calcium plays an important role in plant cell functions which has a key role in cross linking of cell wall polymers and, hence, cell wall strength, and is determinant in fruit quality and shelf life (Shiri *et al*. 2014). It is reported that calcium makes fruit more acceptable by reducing color change rate, maintaining membrane permeability and slow ripening processes (Shiri *et al*. 2014). The calcium bonds as pectate in the middle blades are also necessary to strengthen the cell walls and plant tissues. Polygalacturonase (PG) enzyme degrades pectate and changes insoluble pectic materials to soluble pectin which results in softening fruit tissue (Barka *et al*. 2000). The calcium also inhibits pectin methyl esterase (PME) which catalyzes the de-esterification of pectin into pectate and methanol, and decomposes the pectic compounds and leads to formation of two-phases of fruit juice (Hajiloo *et al*. 2012).

Calcium reduces respiration and ethylene production (Shiri *et al*. 2016). Ethylene is a natural plant hormone produced by many fruits and vegetables that enhances the rate of respiration and accelerates the senescence process. High concentration of ethylene in the storage air causes ripening, fruit softening and enhancing the storage diseases. It is reported that foliar application of calcium chloride reduces fungal growth on strawberries, because calcium ions make cross-linking among the pectin polysaccharides in the cell wall and septum, which strengthens the cells and their connection and increases tissue resistance to fungal enzymes activity (Cheour *et al*. 1991).

Ultraviolet (UV)-C irradiation is a technique that increases resistance to the decay and shelf life of fruits and vegetables (Stevens *et al*. 2005). However, the effectiveness of UV treatment in controlling decay and accumulating phytoalexins depends on cultivar type, UV irradiation intensity and expose duration (D'hallewin *et al*. 2000). It has been reported that mangoes treated with 2.46–4.93 kJ m^{-2} UV led to reduction of decay and increase of shelf life which may be because of positive effect of UV in increasing total phenol and flavonoids (Gonzalez-Aguilar *et al*. 2007). Furthermore, Stevens *et al*. (1998) observed that peaches irradiated by UV had less ethylene and decay as compared to control fruits. Similarly, Stevens *et al*. (2004) showed that tomatoes irradiated by UV-C had significantly more firmness and less PG activity than the control fruits. Also, Barka *et al*. (2000) reported a low cell wall degrading enzymes activity such as PG and PME in tomatoes treated by UV.

On the basis of the above findings, it is crucial to analyze the effects of $CaCl_2$ and UV-C irradiation on ethylene production and cell wall-degrading enzymes in fruits. Tomato fruit characteristically follows a pattern controlled by ethylene. To our knowledge, little information are available about the comparative effects of post-harvest $CaCl_2$ treatment and UV-C irradiation on physiological responses of tomato during storage. Therefore, the aim of this study was to find an appropriate method to reduce post-harvest losses in tomatoes and maintain fruits quality by post-harvest $CaCl_2$ treatment and UV-C irradiation.

2. Materials and methods

2.1. Plant materials and experiment condition

The tomato fruits (cultivar Valouro), which were harvested at the light-red ripening stage (pinkish-red or red color shows on over 60% but red color covers not more than 90% of the tomato surface), with uniform color, sizes, round shape and without bruises or signs of infection, were obtained from a commercial greenhouse Alborz Province, center of Iran. The tomatoes were randomly divided into groups of five fruits and used in factorial experiments based on completely randomized design with three replications in each experiment. In experiment I, treatment factors were $CaCl_2$ in four levels of 0 (control), 1, 1.5, and 2%, and sampling time at the 0, 7, 14, 21 and 35th day. To apply $CaCl_2$ treatment, fruits were fully immersed in the $CaCl_2$ solution for 10 min then dried and packed in hermetically sealed containers.

In experiment II, tomato fruits were arranged in a single layer and were subjected to 0 (control), 1.5, 3, and 4.5 kJ m^{-2} UV-C radiation for 5, 10 and 15 min, respectively. The tomatoes were placed 25 cm far from the UV light source with 30 W output power and 254 nm wavelength (30 W/G30T8 with spectral peak at 254 nm, Philips, Holland). The UV-C treated tomatoes were packed in hermetically sealed containers. As well as experiment I, sampling times were the 0, 7, 14, 21 and 35th day of storage. Storage conditions of the both experiments were 7°C temperature and 90% relative humidity. To isolate each treatment condition and prevent gas exchange from the containers in both experiments, treatments were performed in 1 L capacity hermetically sealed containers, as previously reported by Guillén *et al*. (2007).

2.2. Ethylene determination

Ethylene production was estimated according to Bu *et al*. (2013) with some modifications. Fruits were sealed in a 1.0-L jar and were kept at 18°C for 1 h. Then, headspace gas was sampled with a 1-mL syringe and injected to a gas chromatograph. The column oven temperature was held