Iron, Iodine and Selenium Effects on Quality, Shelf Life and Microbial Activity of Cherry Tomatoes

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Abstract
Tomatoes have high nutritional and economical value and its deterioration start after harvest. They need proper treatments to increase and maintain quality as well as shelf life. The objective of this study was to determine the effect of iron, iodine and selenium on quality, shelf life and microbial activity of cherry tomatoes. Iron (1 mg/L), iodine (1 mg/L) and selenium (1 mg/L) were supplied with nutrient solution for five weeks prior to harvest. Then, cherry tomatoes were stored at 5 °C to assess quality, shelf life and microbial activity. The highest Ca content (p < 0.05) revealed in selenium-treated cherry tomatoes. Lower respiration and ethylene production were showed in selenium-treated cherry tomatoes both harvest time and after storage compared with iron and iodine treatments. At harvest time and after storage, the respiration were 1.29 (p < 0.05) and 0.62 mL/kg/hr (p < 0.01), respectively in selenium-treated cherry tomatoes. Moreover at harvest time and after storage in selenium-treated cherry tomatoes, the ethylene production was 2.11 and 0.87 μL/kg/hr (p < 0.01), respectively. The lowest fresh weight loss, the longest shelf life (p < 0.01), the least fungal incidence rate and microbial activities were found in selenium-treated cherry tomatoes. The longest shelf life of selenium-treated cherry tomatoes was 22 days. Selenium-treated cherry tomatoes’ firmness increased (16.82N) at harvest time (p < 0.05) and it was significantly retained (12.70N) after storage (p < 0.01). Color development and lycopene content were more suppressed by selenium treatment after storage than iron and iodine treatments. Titratable acidity, vitamin C and soluble solids increased in selenium-treated cherry tomatoes after storage. Based on results, selenium-treated cherry tomatoes have significant potential to increase and maintain quality and shelf life.

Keywords: bacteria; firmness; fungi; respiration rate; Solanum lycopersicum

Introduction
Tomato (Solanum lycopersicum) is widely cultivated fruits and according to FAO (FAOSTAT, 2014), tomatoes harvested area was 7070 hectares, the production was 499960 tonnes, and yield was 707157 hectogram/hectare (calculated data) in Korea. Tomato has economical and nutritional values, and its pulp and seed obtain oil (Giuffrè and Capocasale, 2015; Giuffrè and Capocasale, 2016).

Iron, iodine and selenium are trace elements and plants need low concentrations (Broadley et al., 2012) that may have beneficial effects on quality, shelf life and microbial decontamination of cherry tomatoes. These elements are needed for plants as well as animals and humans. As plant can uptake these elements, so human can get from edible parts of plants. Close to 80% iron is localized in the chloroplast of growing leaves, stored in the stomata of plastids, and a deficient plant revealed a lower photosynthesis (Broadley et al., 2012).

Iodine can have a positive effect on the physiological, biochemical and molecular nature of plants (Kabata-Pendias, 2011) but plants’ reaction to physiological and biochemical from iodine is unclear (Smolen et al., 2014). The basic role of iodine in the biosynthesis of thyroid hormones - thyroxin and triiodothyronine is monitoring plants’ physiological and biochemical processes (Smolen et al., 2015). Globally, two-third of the population suffers from diseases because of insufficient iodine and selenium intake (Kabata-Pendias, 2011). Iodine and selenium may be easily transported through plants xylem (White and
Selenium is associated with the oxygen-sulfur-tellurium group and plants usually enable transfer from soil to the food chain although it has not been validated as an essential plant nutrient (Edelstein et al., 2016). It regulates antioxidants and reactive oxygen species (ROS), inhibits uptake of heavy metal, rebuilds cell membrane and chloroplast structures, maintains the photosynthetic system, regulates minerals uptake and distributes in the antioxidative systems, makes ion balance, and increases cell integrity (Feng et al., 2013). Selenium treatment increases selenium content in peaches, pears and cherry tomatoes (Pezzarossa et al., 2012; Pezzarossa et al., 2014).

There is insufficient research on iron, iodine and selenium in the hydroponic system of nutrient film technique (NFT) relative to use in large-scale production of cherry tomatoes. This study was conducted to determine the effect of iron, iodine and selenium on quality, shelf life and microbial activity of cherry tomatoes in the hydroponic system of NFT.

Materials and Methods

**Fruit material and treatments**

Cherry tomatoes (Solanum lycopersicum cv. ‘Unicorn’) were grown hydroponically at summer in 2016 with EC 2.3 dS m⁻¹ and pH 5.8–6.2 supplied nutrient solution based on the Japanese horticultural experiment station in the Republic of Korea. The plastic house was equipped with electrical fan to maintain maximum 32 °C temperature. The following treatments were used: (1) control (non-treatment); (2) 1 mg L⁻¹ iron (Fe) from Fe-EDTA (C₆H₈FeN₄O₈) (Smolen et al., 2014); (3) 1 mg L⁻¹ iodine (I) from potassium iodide (KI) (Li et al., 2017); and (4) 1 mg L⁻¹ selenium (Se) from sodium selenate (Na₂SeO₃) (Pezzarossa et al., 2014). They were applied for five weeks prior to harvest in nutrient solution of 10 plants in each treatment. The 31.17 mm sizes cherry tomatoes harvest time quality was measured at room temperature (20 °C). Harvested rest of tomatoes were kept at 5 °C with 85% relative humidity (Islam et al., 2013) to measure fruit quality, shelf life and microbial activity.

**Mineral contents**

Minerals were measured according to Simsek and Aykut (2007) and Islam et al. (2016). Inductively coupled plasmaatomic emission spectroscopy (Integra XL Dual, GBC, and Melbourne, Victoria) were used to measure minerals content.

**Fruit physiology parameters**

A PBI Dansensor (CheckMate 9900, Denmark) was used to measure carbon dioxide and oxygen. Ethylene was measured with a GC-2010 Shimadzu chromatograph (Shimadzu Corporation, Japan) (Mele et al., 2017).

**Fruits quality parameters**

Fresh weight loss of cherry tomatoes was measured on the basis of Mele et al. (2017) by subtracting present to previous weight loss and converting to percentage. Visual quality was observed on the scale of 1 to 5 (1 = very bad, 2 = bad, 3 = good, marketable, 4 = very good, and 5 = excellent) during 5 °C storage for 25 days and five panel members were designated to assess visual quality and fungus of the cherry tomatoes (Islam et al., 2016). Shelf life was measured according to visual quality (≥3; good, marketable) and determinants such as mold growth, decay, shriveling, smoothness, shininess, and homogeneity. Number of fungus-contaminated cherry tomatoes was counted and they were converted to fungal incidence percentage.

A fruit hardness tester (Lutron FR 5105, Taiwan) was used to measure firmness. Skin color values of the cherry tomatoes were measured using a chroma meter model CR-400 (Konica Minolta Sensing, Inc., Japan). Lycopene content was measured according to Islam et al. (2002).

A refractometer (Atago U.S.A, Inc., U.S.A.) was used to measure soluble solid. Titratable acidity was measured by a fruit acid meter (G-Won Hi-tech, Korea). Vitamin C was analyzed according to Islam et al. (2016) with Waters HPLC (Waters Associates, Milford, MA, USA) and the column was C₁₈ (250 mm × 46 mm, 5 μm, Agilent, USA) at 265 nm.

**Statistical analysis**

Significant differences of mean values were determined using Duncan’s multiple range test (DMRT) of the one-way ANOVA by SPSS V. 16 (SPSS Inc., Chicago, USA).

Results and Discussion

**Mineral contents**

Higher CaO, K₂O, MgO, and P₂O₅ content was found in selenium-treated cherry tomatoes compared with other treatments (Table 1). Selenium increased cytosolic Ca in hypocotyl (Colak et al., 2012) and after storage (Fig. 1). Selenium maintained cherry tomatoes, followed by iodine, iron and control tomatoes at harvest time and after storage (Fig. 1). Selenium maintained cherry tomatoes, lettuce and chicory quality by suppressing respiration rate and ethylene production at harvest time and during storage (Malenko et al., 2009; Pezzarossa et al., 2014; Zhu et al., 2017). The lowest respiration rate and ethylene production are desirable to maintain quality and increase shelf life of cherry tomatoes.
Fruits quality parameters

Selenium-treated cherry tomatoes revealed the lowest fresh weight loss compared with control and it is related to Zhu et al. (2017). Fresh weight loss may be influenced by respiration, transpiration, and moisture loss of cherry tomatoes (Islam et al., 2016). The highest visual quality and longest shelf life were attributed to selenium-treated cherry tomatoes in maintaining marketable visual quality (≥ 3). Lettuce and chicory of selenium treatment improved shelf life by decreasing ethylene production (Malorgio et al., 2009). Fungal incidence of selenium-treated cherry tomatoes was the lowest (Table 2) that can extend shelf life by maintaining quality. Selenium decreased fungal incidence in harvested cherry tomatoes by affecting intracellular ROS and plasma membrane of pathogens (Wu et al., 2016).

Highest firmness was revealed in selenium-treated cherry tomatoes at harvest time and after storage (Table 3). Firmness was higher in selenium-treated peaches, pears and cherry tomatoes compared with control at harvest time and after storage (Pezzarossa et al., 2012; Zhu et al., 2016) and occurred because of less ethylene production (Malorgio et al., 2009) that prevented softening of cherry tomatoes.

Color, lycopene, titratable acidity, vitamin C and soluble solids did not reveal significant differences at harvest with treatments, as selected cherry tomatoes were similar maturity-stage fruits (light red). Parameters revealed significant differences after storage in red maturity-stage cherry tomatoes. Color development and lycopene content of selenium-treated cherry tomatoes were lowest after storage (Table 3). Selenium effectively delays ripening because of less ethylene biosynthesis, controlling ROS level and oxidative damage (Pezzarossa et al., 2012; Zhu et al., 2017).

Highest titratable acidity and vitamin C content were observed in selenium-treated cherry tomatoes after storage (Table 4), and this result is related with Zhu et al. (2016). Soluble solids content was higher in selenium-treated cherry tomatoes compared with control after storage and may occur because of the breakdown of disaccharide (sucrose) into monosaccharide (fructose and glucose). Soluble solids content was highest in selenium-treated peaches, pears and cherry tomatoes after storage (Pezzarossa et al., 2012; Zhu et al., 2016).

Table 1. Mineral content of cherry tomato fruits which treated by iron, iodine and selenium

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CaO</th>
<th>K2O</th>
<th>MgO</th>
<th>NaO</th>
<th>P2O5</th>
<th>Fe</th>
<th>Mn</th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.107b</td>
<td>2.103b</td>
<td>0.130b</td>
<td>0.133b</td>
<td>0.447b</td>
<td>0.127b</td>
<td>0.040a</td>
<td>0.037a</td>
<td>0.097a</td>
</tr>
<tr>
<td>Iron</td>
<td>0.123ab</td>
<td>2.367ab</td>
<td>0.140ab</td>
<td>0.150ab</td>
<td>0.513ab</td>
<td>0.163a</td>
<td>0.043a</td>
<td>0.067a</td>
<td>0.093a</td>
</tr>
<tr>
<td>Iodine</td>
<td>0.113ab</td>
<td>2.503ab</td>
<td>0.150ab</td>
<td>0.137b</td>
<td>0.540ab</td>
<td>0.150ab</td>
<td>0.047a</td>
<td>0.030a</td>
<td>0.100a</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.130a</td>
<td>2.540a</td>
<td>0.153a</td>
<td>0.163a</td>
<td>0.653a</td>
<td>0.157ab</td>
<td>0.050a</td>
<td>0.033a</td>
<td>0.103a</td>
</tr>
</tbody>
</table>

Table 2. Fruit fresh weight loss, visual quality, shelf life and fungal incidence of cherry tomato after storage (25th day at 5 °C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fresh weight loss (%)</th>
<th>Visual quality</th>
<th>Shelf life (days)</th>
<th>Fungal incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.90b</td>
<td>2.20b</td>
<td>17b</td>
<td>26.50a</td>
</tr>
<tr>
<td>Iron</td>
<td>3.55ab</td>
<td>2.50ab</td>
<td>20ab</td>
<td>24.00ab</td>
</tr>
<tr>
<td>Iodine</td>
<td>3.20ab</td>
<td>2.35ab</td>
<td>18ab</td>
<td>21.50ab</td>
</tr>
<tr>
<td>Selenium</td>
<td>2.81b</td>
<td>2.70a</td>
<td>22a</td>
<td>18.00b</td>
</tr>
</tbody>
</table>

Note: Mean separation of columns by Duncan’s multiple range tests (DMRT) (n=10). *, **; not significant, or significant at p < 0.05, and 0.01, respectively.
Count of bacteria and fungi

All treatments revealed distinctive effectiveness in diminishing bacteria and fungi occurrence either at harvest time or after storage compared with control. Lowest bacterial and fungal count was revealed in selenium-treated cherry tomatoes at harvest time and after storage. Bacteria at harvest time or after storage were higher than fungal densities (Table 5). Selenium effectively reduced gray mold of cherry tomatoes caused by Botrytis cinerea and control from severe damage to the conidia plasma membrane and loss of cytoplasmic materials from the hyphae (Wu et al., 2016).

Conclusions

Effects of iron, iodine and selenium on quality, shelf life and microbial activity of cherry tomatoes were examined in this study. Selenium-treated cherry tomatoes revealed the lowest respiration rate and ethylene production that slowed the ripening process. The least fresh weight loss and the longest shelf life was revealed in selenium-treated cherry tomatoes among treatments. Tomatoes firmness was increased at harvest time and it retained after storage with selenium treatment. Fungal incidence and microbial activities were also lower in selenium-treated cherry tomatoes compared with iron and iodine treatments. Therefore, selenium treatment may be a useful tool to maintain quality and shelf life for cherry tomatoes by reducing microbial activities.

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References


