Estimation of Tomato Fruit Lycopene Content after Storage at Different Storage Temperatures and Durations

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(Received April 27, 2018; Accepted August 12, 2018)

Lycopene content in tomato fruit after storage was estimated using the multiple regression analysis at different storage temperatures and durations in this study. Tomatoes were grown hydroponically in greenhouse. Tomato fruit samples after harvesting were stored at 10, 15, 20, 25, and 30°C in cool incubator for 7 d. The tomato fruit color on the surface and lycopene content of the whole tomato fruit were measured for each temperature before storage (0 d) and after storage (2, 4, and 7 d). Tomato fruit color was measured with chroma meter and \( a^*/b^* \) was calculated. Lycopene content after storage was estimated using the multiple regression analysis with the variables of the tomato fruit color before storage, storage temperatures and durations. Our results showed that the color of tomato fruits stored above 10°C was increased after storage. With storage condition above 20°C, lycopene content of tomato fruit was increased after storage. Tomato fruit color change after storage was estimated with variables of tomato fruit color before storage, storage temperatures and durations by multiple regression (\( R^2 = 0.76 \)). Our results suggested that estimation model for lycopene content using the multiple regression analysis might be contributed for providing valuable tomato fruits included the high lycopene to customers.

Keywords : lycopene, multiple regression analysis, post-harvest, storage, tomato

INTRODUCTION

Lycopene is a red color pigment in tomato fruits and it is very popular for human health (Preedy and Watson, 2008). For example, the antioxidant capacity of lycopene is the highest among all dietary carotenoids (Rao and Agarwal, 1999; Ilahy et al., 2011). Therefore, tomato fruits production to maximize lycopene content is desirable for human health. Since lycopene in tomato fruits during ripening is increased under optimum environment (Takahashi and Nakayama, 1962; Maezawa et al., 1993; Motonaga et al., 1997), it is essential to control the storage environment for providing the valuable tomato fruits included the high lycopene content to customers.

To control the storage environment after harvesting the tomato fruits, it is necessary to know the effect of environmental factors on lycopene content of tomato fruits after storage. Tomato fruits color changes were known to depend on the maturity stage at harvesting and temperature during storage (Tjiskens and Evelo, 1994; Lana et al., 2006). Furthermore, it is found that lycopene content of tomato fruit after storage was also differed with the tomato color at harvesting (Maezawa et al., 1993; Suzuki et al., 2013). Lopez et al. (2004) reported that color changes during tomato fruit ripening were the result of changes in the values of \( a^* \) and \( b^* \), although the more important ones were along the \( a^* \) axis, related to chlorophyll degradation and lycopene synthesis. Arias et al. (2000) reported that tomato fruit color information for \( a^* /b^* \) measured with chroma meter can be used for predicting the lycopene content of tomato fruits. Our previous study found that tomato fruit color after storage was estimated with variables of tomato fruit color before storage, storage temperatures and durations by multiple regression analysis (Takahashi et al., 2014). The objective of this study was to estimate the lycopene content of tomato fruits after storage at different storage temperatures and durations with multiple regression analysis.

MATERIALS AND METHODS

Plant materials and storage conditions

Tomato plants (Lycopersicon esculentum Mill., cv. ‘Momotaro’) were grown hydroponically with high-wire system in high technology greenhouse (1.3 ha) in Ehime University, Matsuyama, Ehime, Japan (33°50’N, 132°47’E). Tomato seedlings were transplanted to the rockwool slabs (Grootop expert, Grodan, Roermond, Netherlands) on June 20 in 2013. The irrigation was performed with a nutrient solution containing the following fertilizer: KNO3, Ca(NO3)2, MgSO4·7H2O, KH2PO4, H3PO4, KH2PO4, KCl, MnSO4·H2O, Fe·EDTA, H3BO3, MnSO4·H2O, CuSO4·5H2O, NaNO3·2H2O, giving an electrical conductivity of 2.0 ds m−1 and a pH of 5.5–6.5. Tomato fruits with pink color were harvested from October 15 to
December 2 in 2013. The harvested tomatoes were stored for six different temperatures, 5, 10, 15, 20, 25, and 30°C in cool incubator (A1201-2V, Ikuta Sangyo Co., Ltd., Ueda, Japan) under continuous dark condition. Relative humidity was 90±15%. Four tomato fruit samples were used for the color and lycopene content measurement for each temperature before storage (0 d; tomato fruits were stored immediately after harvesting) and after storage (2, 4, and 7 d).

**Tomato fruit color measurement**

Tomato fruit color was measured for six different temperatures, 5, 10, 15, 20, 25, and 30°C before storage (0 d) and after storage (2, 4, and 7 d), non-destructively. Color information of tomato fruits for $a^*$ and $b^*$ were measured for three points, a fruit apex and two sides with chroma meter (CR-200, Konica Minolta Optics, Inc., Tokyo, Japan) and the mean of $a^*/b^*$ was calculated.

**Lycopene content determination and estimation**

Lycopene content in tomato fruit was determined with conventional method based on the method of Ito and Horie (2009). Lycopene content was extracted two times with acetone for 35 mL and 15 mL. Tomato fruits were homogenized using a blender and about 1.5 g of the puree was put in 35 mL brown tubes. Lycopene extraction solution (35 mL) consisting of acetone was added to the tubes and shaken for 10 min with 1,000 rpm using a shaker (M300, As One Co., Osaka, Japan) under room temperature (about 20°C). After standing, the supernatant solution was moved to a brown measuring flask (50 mL) and residual samples in the tubes were shaken with 15 mL of acetone for 5 min with 1,500 rpm. After shaking, supernatant solution was moved to a brown measuring flask and adjusted to 50 mL filling up with acetone. The supernatant solution was filtered using a 0.45 µm disposable filter (ADVANTEC, Tokyo Roshi Kaisha, Ltd., Tokyo, Japan). The absorbance of the supernatant was measured at 505 nm using a spectrophotometer (U-1900, Hitachi High-Technologies Co., Tokyo, Japan). The lycopene content was calculated using an absorption coefficient of 3,150% cm$^{-1}$ (Nagata and Yamashita, 1992; Nagata et al., 2007).

Lycopene content of tomato fruit after storage was estimated with multiple regression analysis using a statistical software (JMP 9.0.2, SAS Institute Inc., Cary, USA). Lycopene content ($y$) is estimated with equation as follow:

$$y = b_0 + b_1C + b_2T + b_3t$$

where $C$ is the tomato fruit color for $a^*/b^*$ before storage, $T$ is storage temperature (°C), $t$ is storage duration (h). To evaluate the regression model, the obtained data was divided into two sets for calibration and validation. The calibration data set was included both of the maximum and minimum value of lycopene content.

**Statistical analysis**

The mean values of lycopene content in tomato fruits were calculated for each treatment. The means between treatments were compared using Tukey-Kramer test with 5% as the level of significance by a statistical analysis software.

**RESULTS AND DISCUSSION**

**Effects of storage temperatures and durations on color and lycopene content of the tomato fruits**

Effects of storage temperatures (5, 10, 15, 20, 25, and 30°C) and durations on tomato fruit color for $a^*/b^*$ were shown in Fig. 1. The value of color index of tomato fruits stored above 10°C was increased after storage.

Table 1 shows the effects of storage temperatures and durations on lycopene content of the tomato fruits. Lycopene content of tomato fruit before storage was 18.3±1.75 mg/100 g FW ($n=4$). With storage condition above 20°C, lycopene content of tomato fruit was increased after storage (Table 1). Maezawa et al. (1993) also recommended that tomato fruits with pink color might be stored with 20°C for lycopene content production.

Relationship between lycopene content and $a^*/b^*$ of the tomato fruits was examined (Fig. 2). In this study, the exponential rise of lycopene and $a^*/b^*$ was observed, and the following equation show the lycopene content ($y$) as a logarithmic function:

$$y = 0.28 \ln \left( a^*/b^* \right) + 1.22$$

(R$=0.51, P<0.01$)

Arias et al. (2000) reported that the better fit was observed between $a^*/b^*$ and lycopene content of tomato fruits with exponential regression compared to the linear regression. According to their results, little color ($a^*/b^*$) change was observed from 10 to 16 mg/100 g FW of lycopene content. Since relation between $a^*/b^*$ and lycopene content of tomato fruit was saturated with mature, it seems to be difficult to estimate the lycopene content using the color information of tomato fruit after storage.

**Estimation of lycopene content after storage with multiple regression analysis**

The model for estimation of lycopene content in tomato fruit after storage was developed with calibration data obtained in this study. The multiple regression analysis was used for lycopene content estimation. In this study, the equation for multiple regression with tomato fruit color
LYCOPENE CONTENT ESTIMATION

Table 1 Effects of storage temperatures and durations on lycopene content of the tomato fruits.

<table>
<thead>
<tr>
<th>Storage temperature (°C)</th>
<th>Lycopene content (mg/100 g FW) after storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 d</td>
</tr>
<tr>
<td>5</td>
<td>18.4 ± 1.2 a</td>
</tr>
<tr>
<td>10</td>
<td>17.5 ± 1.5 a</td>
</tr>
<tr>
<td>15</td>
<td>16.4 ± 1.7 a</td>
</tr>
<tr>
<td>20</td>
<td>22.9 ± 2.4 a</td>
</tr>
<tr>
<td>25</td>
<td>23.6 ± 0.8 a</td>
</tr>
<tr>
<td>30</td>
<td>23.3 ± 3.7 a</td>
</tr>
</tbody>
</table>

* Values are means±standard error (n=4). Different letters indicate a significantly difference (P<0.05) according to one-way ANOVA followed by Tukey-Kramer test in within columns.

![Graph](image1.png)

Fig. 2 Relationship between lycopene content and color (a*/b*) of the tomato fruits. Tomato color information of a* and b* were measured for three points at top and two sides of the tomato fruits (n=66). **Significant at P<0.01.

![Graph](image2.png)

Fig. 3 Predicted and observed lycopene content of tomato fruits using the multiple linear analysis with variables for a*/b* values of the tomato fruits before storage, storage temperatures and durations with validation data set (n=33). **Significant at P<0.01.

![Graph](image3.png)

Fig. 4 Predicted and observed lycopene content of tomato fruits using the multiple linear analysis with variables for a*/b* values of the tomato fruits before storage, storage temperatures and durations with validation data set (n=33). **Significant at P<0.01.

before storage, storage temperatures and durations was obtained as follow:

\[ y = -11.76 + 11.73 (a*/b*) + 0.467 + 0.02r \]

(R = 0.81, P<0.01) (Fig. 3).

With validation data, lycopene content of tomato fruit after storage was estimated. The coefficient of correlation between estimated and observed lycopene content of tomato fruit after storage was 0.76 (Fig. 4). Tomato fruits color changes were known to depend on the maturity stage at harvesting and temperature during storage (Tijskens and Evelo, 1994; Lana et al., 2006), and lycopene content estimation using the tomato color information were reported (Arias et al., 2000), however, little is known the lycopene content estimation after the storage with different temperatures. Our results suggested that multiple regression equation obtained with tomato fruit color before storage, storage temperatures and durations could be used for the estimation of lycopene content after storage and this technique might be contributed for providing valuable tomato fruits included the high lycopene to customers.

REFERENCES


Ito, H., Horie, H. 2009. Proper solvent selection for lycopene extraction in tomatoes and application to a rapid determination.