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# Effect of Storage Temperatures on Color of Tomato Fruit (*Solanum lycopersicum* Mill.) Cultivated under Moderate Water Stress Treatment

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**Abstract**

Moderate water stress tomato cultivated hydroponically in the greenhouse contains high lycopene and very sensitive to storage temperatures. This study aimed to observe the effect of storage temperatures on the lycopene content and color quality parameters of tomato (both moderate water stress and no water stress tomato). The lycopene content of water stress tomato increased with the temperatures higher than 10 °C while no water stress tomato relatively stable or increased slightly. The lightness (L*) value of water stress and no water stress tomato decreased during storage in 10, 15, 25 and 30 °C temperatures. The redness (a*), yellowness (b*), a*/b*, hue (h), and chroma (C*) remained stable after 4 days storage in those temperatures. Storage with temperatures above 15 °C increased the color parameters value of both water stress and no water stress tomato. Moderate water stress treatment increased the redness color and harvesting tomato in ripening stage will only shows lightness (L*) major change during storage.


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*Keywords:* color; postharvest quality; storage temperature; tomato; water stress

## 1. Introduction

Color is one of the most important quality parameter of tomato fruit that affects customer purchase decision. The main color quality of tomato is redness and it is affected by lycopene content. Popular tomato fruit with high selling

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price (reached ¥10.000/kg in 2007) was obtained from abiotic stress treatment and called “high lycopene tomato” (Takayama and Nishina, 2007). Greenhouse of Ehime University Japan had developed controlled water irrigation in moderate level (called *moderate water stress* treatment) for tomato cultivation. This treatment reduced tomato yields but improved the fruit quality as well (Patanè and Cosentino, 2010).

Khairi and Takahashi (2013) have reported that some physical and chemical parameters of water stress tomato showed different changes compared to no water stress treatment after storage, especially on lycopene content. In this study some parameters that were related to the color quality of tomato fruit (*Solanum lycopersicum* Mill. cv *taiankitijitsu*) stored with various temperatures had been observed. Lycopene content of tomato was also being observed as lycopene plays great role in redness of tomato fruit.

## 2. Materials and methods

### *2.1. Research Objects and Storage Condition*

Tomato plants (*Solanum lycopersicum* Mill. *cv Taiankitijitsu*) were grown hydroponically in the greenhouse of Faculty of Agriculture, Ehime University, Ehime, Japan according to the methodology of Takayama and Nishina (2007). The early tomato plants were sown on June, 2013 and transplanted on August, 2013 with rock wool slabs. The air temperature and relative humidity were approximately 22 °C and 70% during the days and 13 °C and 83% at nights. Water stress tomato irrigated with moderate water stress treatment and no water stress tomato with normal irrigation. Moderate water stress treatment started on week 14 after sowing with 83% of normal water irrigation reduction and after week 15 with 63% of normal irrigation. Tomato harvested on week 21 at ripening stage (light red color). The size and color homogenized in the same level based on visual subjective appearance. After being harvested, tomato stored in chambers with 10 $^{o}$C, 15 $^{o}$C , 25 $^{o}$C, and 30 $^{o}$C temperatures during 16 days.

### *2.2. Lycopene Content*

The lycopene content was measured using Ito et al. (2009) method. This method contains of two main steps, extraction of juiced tomato to get lycopene extract and standard, then measured the absorbance value of the solution (purity check) at 505 nm (U-1900 spectrophotometer, Hitachi, Japan) using a solvent blank, acetone, and absorbance value used to get the lycopene content of the samples and calculated lycopene content using equation (1):

$$Lycopene\ content = \frac{(10 \times absorbance\ value)}{(0.315 \times sample\ volume\ (g)} \quad (1)$$

### *2.3. Color Quality Values*

Color measurements were performed on the surface of tomato three point in the bottom and equatorial region. The measurements were made every 4 days with a portable colorimeter (CR-400, Konica Minolta, Tokyo, Japan) during storage. Before the color measurement, the colorimeter was calibrated with a standard white ceramic plate ($L$*=96; $a$*=0.14*; $b$*=1.63). $L$* describes lightness ($L$*=0 for black, $L$*=100 for white), $a$* describes intensity in red-green ($a$*>0 for red, $a$*<0 for green), $b$* describes intensity in blue-yellow ($b$*>0 for yellow, $b$*<0 for blue). Equations for further analysis to describe color qualities were shown in Table 1.

Table 1. Color quality parameter equations

| Color Quality Parameters | Equation | |
|---|---|---|
| Redness compared to yellowness (a*/b*) | a*/b* | (2) |
| Chroma (C*) | $C^{*} = \sqrt{(a^2 + b)^2}$ | (3) |
| Hue (h) | Hue = [tan-1(b*/a*)] | (4) |

The *a*/b** value was calculated to measure the stage of red color, hue (h) to express tomato color changes (Shewfelt *et al*., 1987; Choi *et al*., 1995) and Chroma (C*) to analyze the color value of tomato.

### *2.4. 3D Surface Analysis and Statistical Analysis*

The 3D surface analysis was performed with Matlab software pack analysis to analyze the changes values distribution thus easy to assume the highest and the lowest value. Experiments were executed in four replicates. An analysis of variance (one-way ANOVA) was performed to assess the storage time and temperature conditions significant effect ($p<0.05$) on quality parameters using SPSS 16 software pack.

## **3. Results and Discussions**

### *3.1. Lycopene Content and Redness of Tomato*

Lycopene content of water stress tomato continue to increase with the temperatures higher than 10 °C and slightly increased in 10 °C storage temperature. However, lycopene content of no water stress tomato slightly decreased with 10 °C during 4 days storage and stable up to day 16 and slightly increased with the temperature higher than 10 °C. Initial lycopene content (day 0) of water stress tomato was 6.042 mg/100g and 6.459 mg/100g for no water stress tomato. This value continued to increase for water stress tomato up to day 16 with all temperatures. In the end of the storage, the value reached 8.152 mg/100g, 11.636 mg/100g, 11.782 mg/100g, and 11.947 mg/100g for 10 °C, 15 °C, 25 °C, and 30 °C. The highest value occurred at day 12 of 25 °C storage temperature. For no water stress tomato stored with 25 °C and 30 °C temperatures showed insignificant increased trends and the highest value reached after day 8 of 30 °C storage temperature at 11.5 mg/100g but decreased at the end of storage.

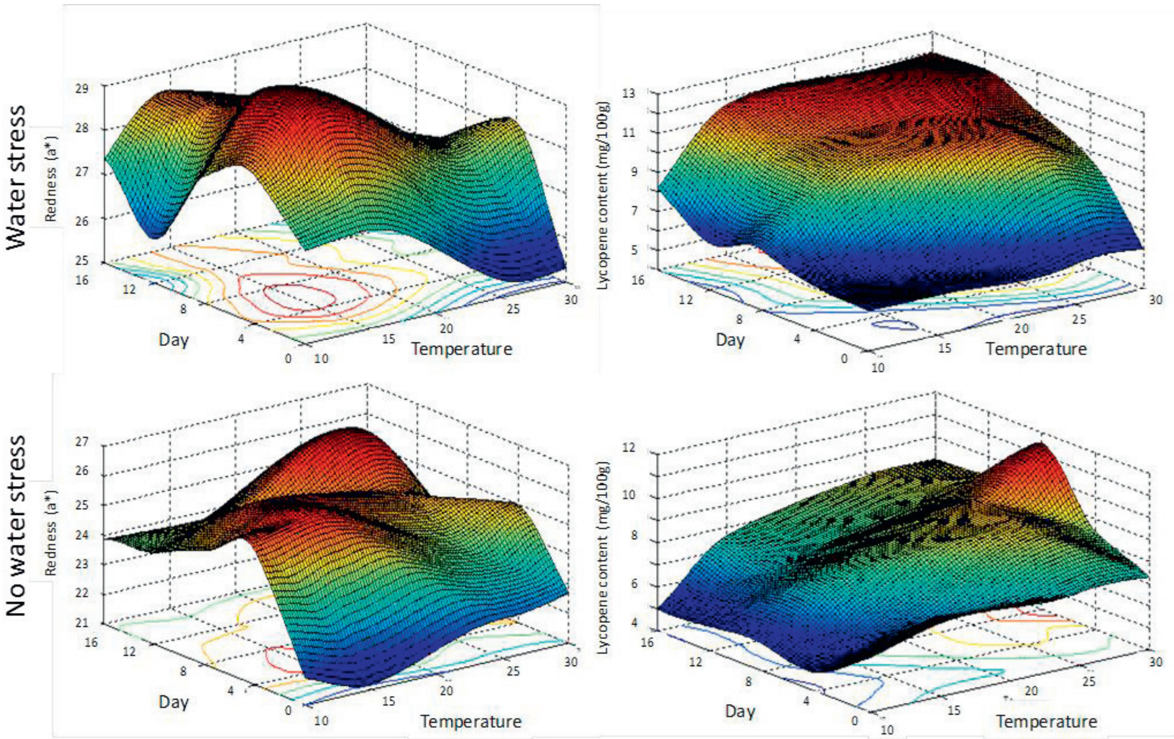


Fig. 1. 3D surface graph of redness and lycopene content of water stress and no water stress tomato during storage in various temperatures

The results in this study were in agreement of Javanmardi and Kubota (2006) that stated storage with low temperature will cause lower lycopene content during storage. The rate of ripening processes which associate with increasing of lycopene content in low temperature stored were slowed compare to room temperature stored tomatoes. It has been also reported that the formation of lycopene depends on the temperature range between 12 °C and 32 °C (Leoni, 1992). Further result reported by Turk et al (1994) that temperature to optimized lycopene content of tomato was between 16–18 °C and 26 °C.

The visual appearance of water stress tomato showed darker red than no water stress tomato. Color parameter that indicates this quality is redness (a*). According to Camelo and Gomez (2004), redness (a*) value will increase sharply between stage 2 and 5 (breaker to light red) from negative (green color) to positive (red color) values and will experiencing greatest change during storage. However, because the harvesting time of tomato used in this research was at ripening stage (thin red stage), the redness changes values of water stress and no water stress tomatoes were small. Redness value of no water stress tomato were lower compared to water stress tomato. The redness (a*) changes during storage were different with the changes shown in lycopene content. These results indicated that lycopene played major role in redness of tomato before ripening stage. After the storage, redness value stopped to change while lycopene content continued to increase/decrease. Figure 1 showed the surface different of lycopene content and redness value of ripe tomato during storage with various temperatures. Redness value of no water stress tomato mostly decreased in all temperatures after day 4 of the storage, except for storage with 25 °C. Water stress tomato showed stable trend of redness value after slight increased during 4 days storage.

### 3.2. Color Qualities

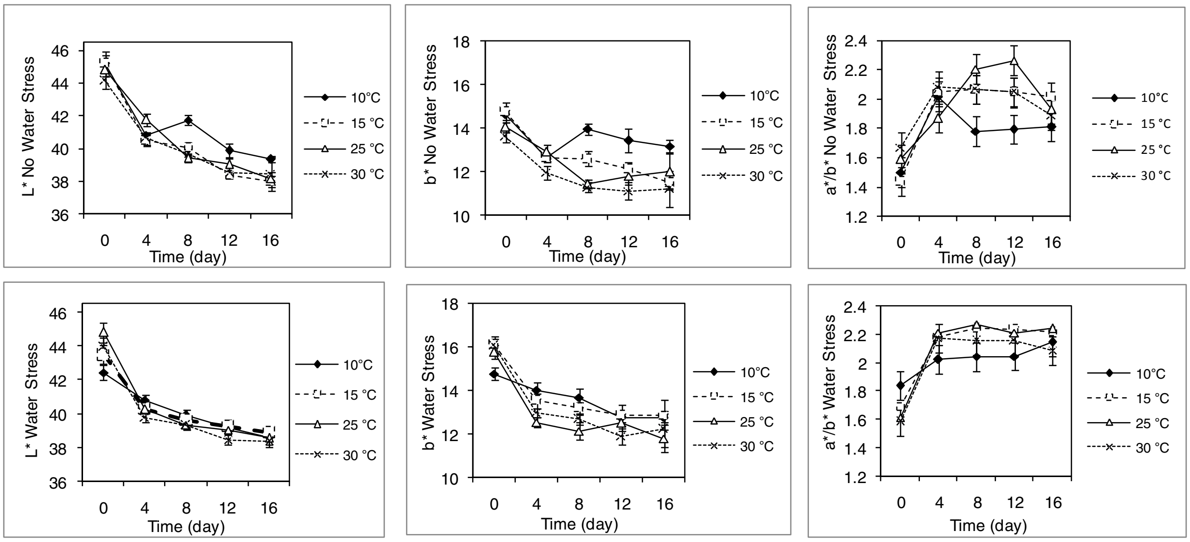


Fig. 2. Lightness (L*), yellowness (b*) and a*/b* index of tomato during storage

Lightness value of water stress and no water stress tomato as shown in Fig. 2 decreased during 16 days storage. The value were slightly different for no water stress and water stress tomato in all temperatures and storage time. Lightness value of water stress tomato were higher than no water stress tomato except in 10 °C storage. Yellowness (b*) value of no water stress and water stress tomato were not significantly different in all temperatures and storage time. During 16 days of storage, yellowness value of both water stress and no water stress tomato decreased continuously until the end of storage. Another studies such as Camelo and Gomez (2004) and Arias *et al.*, (2000) stated that b* values changed insignificantly during ripening and the value were higher at the pink-light red stage. This may be related to the fact that ς-carotenes (pale-yellow color) reach their highest concentration before full ripening, when lycopene (red color) and β-carotene (orange color) achieve their peaks (Fraser *et al.*, (1994); Choi *et* *al*., (1995) in Camelo and Gomez (2004)). The result of this study was in agreement of the studies above because tomatoes observed in ripening stage. The a*/b* parameter of no water stress and water stress tomato showed almost similar value and increased trend during storage with all temperatures (Fig. 2).

Chroma (C*) value of water stress tomato was higher than no water stress tomato. For no water stress tomato, slight increase of C* occurred during first 4 days of storage and after that decreased until the end of storage. For water stress tomato stored with 30 °C increased the C* during first 4 days and decreased until the end of storage. Hue (h) values of water stress and no water stress tomato were mostly similar and the trend were not different for all temperature and storage time. Significant decreased occurred during first 4 days and then showed stable or slightly changes. Although the trends were similar, the 3D surface of both chroma (C*) and hue (h) were different (see Fig. 3). An analysis of variance (one-way ANOVA) showed insignificant different of color quality both water stress and no water stress tomato with temperatures as independent variable of this study.

## 4. Conclusion

Storage with temperatures above 10 °C increased the lycopene and color value of both water stress and no water stress tomato. Moderate water stress treatment increased the redness of tomato compared to no water stress treatment. The lightness (L*) value of water stress and no water stress tomato decreased during storage in 10, 15, 25 and 30 °C temperatures. The redness (a*), yellowness (b*), a*/b*, hue (h), and chroma (C*) slightly changed or remained stable after 4 days storage in those temperatures. Harvesting tomato in light red stage (ripening stage) will only shows lightness (L*) major change during storage.

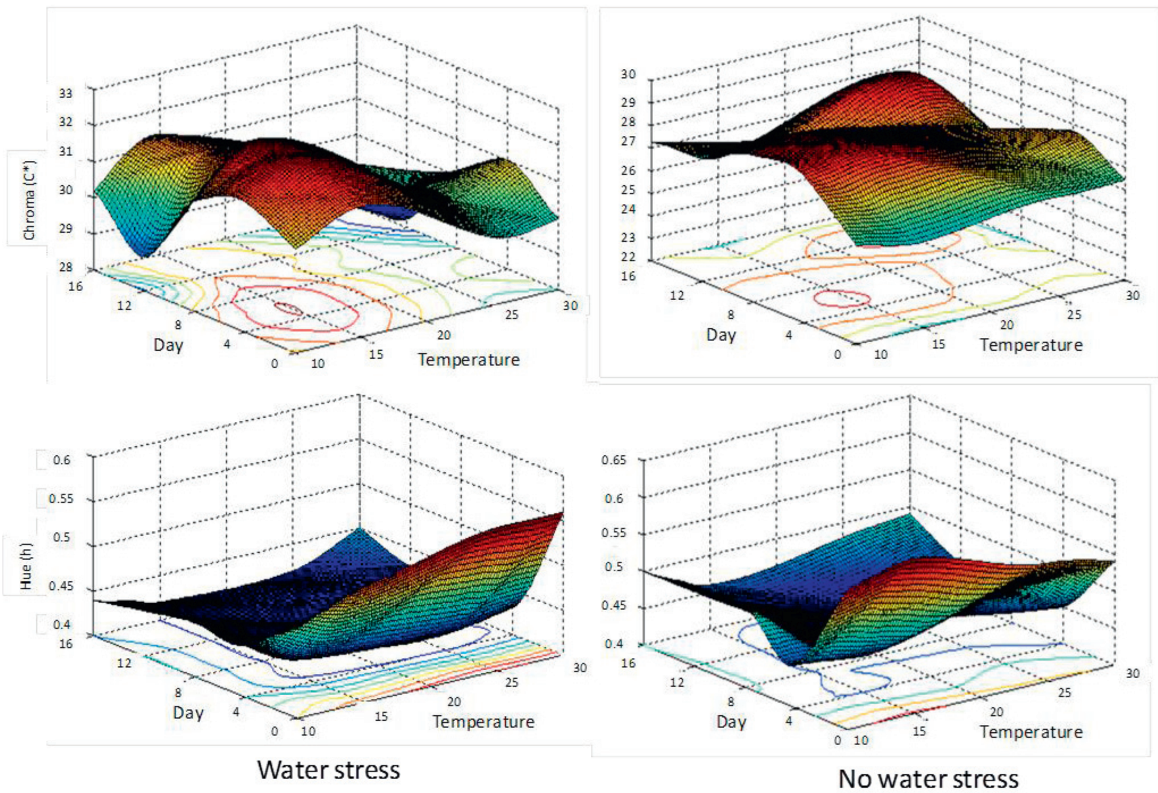


Fig. 3. Chroma (C*) and hue (h) of tomato during storage

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