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Optimization of storage temperatures to maintain Lycopene content of tomato from moderate water stress irrigated greenhouse

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Abstract. This research objective is to analyze the storage temperatures that optimize lycopene of tomato (*Lycopersicon esculentum*, cv. Taiankitijitsu) from moderate water stress irrigation and to compare it with normal irrigated tomato in hydroponic greenhouse system. Harvested tomatoes were stored in various temperatures (10, 15, 25 and 30 °C) until mature stage and lycopene content was observed with destructive method using spectrophotometer. Optimum temperature was analyzed by Minitab 15 Statistical Software using *surface response methodology*. After 16 days of storage, lycopene of water stress tomato attained 8,152 mg/100 g (10 °C), 11,636 mg/100 g (15 °C), 11,747 mg/100 g (25 °C), and 11,947 mg/100 g (30 °C) respectively. Storing tomato at 10 °C remained the lycopene of water stress tomato in stable trend. Temperatures above 15°C increased lycopene of both water stress and normal irrigated tomato. Lycopene of normal irrigated tomato increased only for first 8 days with temperature 15 °C (slightly increase), 25 °C, and 30 °C (highest lycopene value). After 8 days of storage, the trends tend to drop. Analysis of multivariate multiple regressions showed low R² value of lycopene during storage. Optimization using Minitab 15 Statistical Software showed temperature of 24.52°C with 11 days storage and might reached 10.71 mg/100g.

1. Introduction

Plants suffer from water shortages when supplies to the roots are limited or when the transpiration process is excessive. Water stress is largely occurred due to water shortages from drought or salinity of soil is high. In the case of high soil salinity or other conditions such as flooding or low temperatures of soil, soil water is available however plants cannot absorb it, or often called 'physiological drought'. Water stress is caused by the retain of water affects physical changes on the environment and physiological crop [1].

One of the most popular tomato was a sweet tasting tomato called "tomato fruit" or "high brix tomato", "high sugar content tomato", and "high lycopene tomato". High lycopene tomato was developed to answer the needs on functional quality of fresh product with a high market demand. However, the selling price was very high; reached ¥10.000/kg [2]. This tomato was produced by imposing abiotic stress. Ehime University Greenhouses evolved a mid-level controlled irrigation

called moderate water stress treatment for tomato implantation [3]. The lycopene content of tomato is well known for its impact on inhibiting cancer cell developments. Therefore, the method to preserve its quality is necessary to develop.

Tomato is climacteric and easily rotten fruit that requires technology to retard the decay process, preserve qualities, and prolong postharvest shelf life [4]. The methods to restrain the decay of tomatoes were widely developed. However, the study of effectiveness of those methods to preserve quality especially water stress tomato was very limit. The context of this study is to find the simply best method to store and preserve the lycopene content of tomato from water stress irrigation. The lycopene content of water stress tomato and no stress tomato after storage will be compared after adjusting some storing methods.

Generally, fresh products require low temperature and high relative humidity to reduce physiological and biochemical decay, also microbiological activity that are major causes of spoiling process occurred [5]. As temperatures play significant role in preserving the postharvest qualities of normal irrigated tomato, the objectives of this study was to find the effects of temperatures to lycopene content of water stress irrigated tomato. Optimization of storage temperatures will be conducted to obtain the best storage condition for water stress tomato.

2. Material and method

Tomato (*Lycopersicon esculentum*, cv.Taiankitijitsu) was sowed hydroponically with rockwool slabs in greenhouse of Ehime University, Japan. Average daily air temperature during the day was 22 °C and relative humidity was 70%, while at night was 13 °C and 83%. Tomatoes were irrigated with moderate water stress and normal irrigation. moderate water stress irrigation began at week 14 after sowing with 83% of nutrient water subtracted from normal irrigation which is 100%. After the 15th week reduced again 63% of normal irrigation be diminished. Tomatoes were harvested at the 21st week at ripening levels (bright reddish color). After harvesting, tomatoes were put at 10 °C, 15 °C, 25 °C, and 30 °C chambers for 16 days storage [3].

2.1. Lycopene content analysis

The content of lycopene was observed with absorbance value determined from spectrophotometer. First step was extracting juice tomato to obtain the standard of lycopene solution. The determination of solution absorbance value was done with spectrophotometer (U-1900 Hitachi spectrophotometer, Japan) clarity check at 505 nm wavelength. The measurement of absorbance value used blank solvent, acetone, and used equation (1) to obtain the value of lycopene content.

$$\text{Lycopene content} = (10 \times \text{absorbance value}) / (0.315 \times \text{sample volume (gr)}) \quad (1)$$

2.2. 3-D plot, multiple regression, and optimum storage condition

The (x,y,z) plot was done by Matlab Simulink computational software and multiple regression by Ms. Excel to make estimation of each quality change caused by temperature and time. Temperature as x axis, storage time as y axis, and quality parameters as z axis.

- Test of linearity and curve estimation was done by SPSS 16 that analyzed the value of R^2 of the model. The highest value of R^2 have been considered as the best model of quality parameters changes during storage.
- Goodness of fit was done by test of significance of SPSS 16.
- Optimization of Storage Temperature was done by Minitab 15 Statistical Software using *surface response methodology* to select the best temperature to store the tomato.

3. Results and discussion

3.1. Lycopene content

Changes in lycopene content during storage could be seen in figure 1. The initial conditions of lycopene of both water stress and normal irrigated tomato were relatively similar. Initial lycopene content of water stress tomato was 7.024 mg/100g and 6.459 mg/100g of normal irrigated tomato.

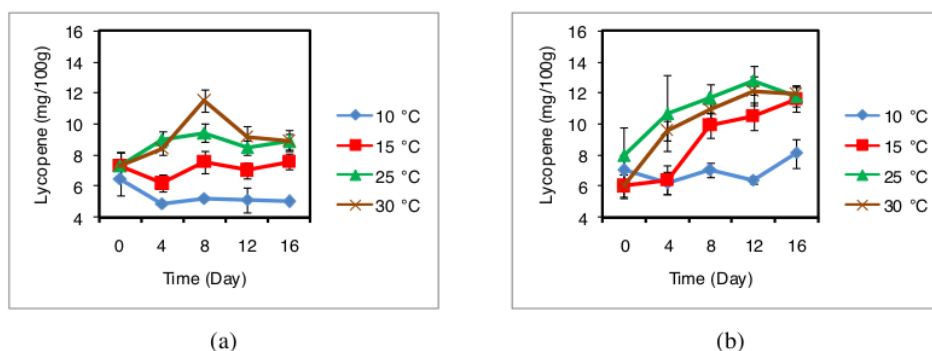


Figure 1. Lycopene value during storage (a) normal irrigated tomato (b) water stress tomato.

Lycopene of water stress tomatoes showed increase trend at more than 10 °C storage temperature, while at 10 °C increased slightly. At day 16, the lycopene of water stress tomato reached 8.152 mg/100 g, 11.636 mg/100 g, 11.782 mg/100 g, and 11.947 mg/100 g for 10 °C, 15 °C, 25 °C, and 30 °C. The highest value obtained at day 12 of 25 °C storage temperature for water stress tomato. Normal irrigated tomato with 10 °C storing slightly increasing of lycopene content occurred in first 4 days and stable at day 4 until day 16. Storing at 10 °C and 15 °C did not significantly affect lycopene of the normal irrigated tomato. Normal irrigated tomato increased the lycopene content only for 8 days storage with temperature 15 °C, 25 °C, and 30 °C. More than 8 days storage showed the value of lycopene tended to decrease. Meanwhile in water stress tomato only on 10 °C storage temperature the lycopene content value was stable, relatively. Higher temperatures (25-30°C) increase the lycopene content of water stress and normal irrigated tomato. In this study, temperatures of 15 °C, 25 °C and 30 °C induce an increase trend in lycopene of water stress tomato during storage.

Storage temperature is significantly affect the lycopene of tomato harvested at mature and light red level. Low temperature induces low lycopene content of tomato during storage. An increased of lycopene content occurs as a correspond of tomato ripening process [6]. The development of lycopene structure will be optimized at temperatures of 12 °C and 32 °C [7]. Some research results also suggest that the optimal temperature for increasing tomato lycopene content is 16-18 °C and 26 °C [8]. Temperatures above 25 °C will increase respiration rate, red color pigment formation, and develop more ethylene than fruit in chilled storage [9]. Treatment with hot water (60 °C for 3 minutes) before storage prolong the shelf life of tomatoes up to 29 days [10]. In fresh cut tomatoes, storage with temperatures above 8 °C might increase lycopene content [11].

3.2. Multiple Regression and 3-D Plot of Lycopene Content

Lycopene parameter during storage of water stress tomatoes were higher than no water stress tomatoes in all temperatures respectively. Significant increase occurred on 30 °C storing temperature for water stress tomato.

In this study, temperature and storage time become two independent variables that caused the changes of lycopene content of no water stress and water stress tomato. Multiple regression model of quality parameters calculated to estimate the changed of each parameter caused by storage temperature and time. The mathematical models then were tested with R^2 value to confirm the applicability of the models. The result of this analysis shown in figure 2 that explain the 3D-plot graphics using Matlab made to see the surface of quality changing during storage.

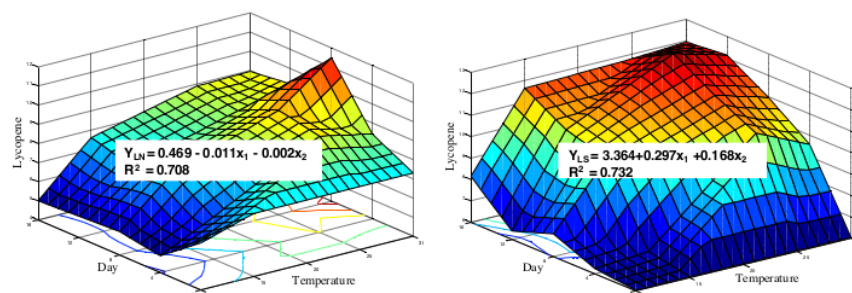


Figure 2. 3-D plot of lycopene content of tomato.

3.3. Optimization of storage condition of water stress tomato

Temperatures that good for water stress tomato were different according to the quality parameter that want to be preserved. Physical qualities (firmness and weight) preservation better to be stored with low temperature (10°C) and chemical qualities parameters (lycopene content) was better to be stored with room temperature. For next analysis, optimum storage condition to store water stress tomato will be analyzed further. The step for optimization were:

3.3.1. Goodness of fit to be optimize. This step completed with test of linearity, significant test, and curve estimation using SPSS. Curve that has high coefficient correlation (R^2) and significant to error degree α , will be considered as the curve that fit the reality. The result of this analysis shown in table 1. The table below showed that the lycopene fit to be optimized (linear, quadratic, and cubic curve).

Table 1. Test of significancy ($\alpha=0.05$).

Quality Parameters	Regression Function	Significancy	Fittess To Be Optimized
Lycopene	Linear	0.001	√
	Quadratic	0.004	√
	Cubic	0.015	√

• √ = fit to be optimized

Lycopene content increased 100.91% compared with initial value in storing at 30 °C. Using this result, lycopene content of water stress tomato will be optimized to get the optimum storage condition. This result also supported many previous study that water stress tomato is 'high lycopene content' tomato thus lycopene was the most important quality parameter inside the tomato.

3.3.2. Test of surface response methodology. This analysis was done by the test of steepest ascent method and supported by Minitab 15 statistic software and was finalized with surface and contour analysis. This test started with optimizing model analysis to get fitted model. The x_1 was temperature, x_2 was time, and x_3 was lycopene factor estimated by Minitab. With degree of significancy, $\alpha=0.05$, the result of this test shown in Fig 4. below. The optimization model of lycopene content of water stress tomato was shown in equation (2).

$$Y=10.53+0.21x_1+0.82x_2+0.4951x_3-0.51x_1^2-1.46x_2^2-0.096x_3^2+0.595x_1x_2+0.24x_1x_3+0.13x_2x_3 \quad (2)$$

a) Model goodness of fit test

Significancy or model fit will be obtained if the P_{value} and *lack of fit* value was higher than degree of significancy. From figure 2, we can see that the P_{value} of all regression coefficients and *lack of fit* value were higher than 0.05. This result can be considered that the model fit the optimization model of lycopene content of water stress tomato.

b) Optimization test

Test of optimum storage condition was done by surface and contour plot analysis. Lack of fit value from the analysis was 0.27. The result that was done by Minitab 15 shown in table 2 and figure 3.

Table 2. Regression analysis test for optimizing model.

	Constant	Temperatures	Times	Lycopene	Temperatures vs temperatures	Times vs times	Lycopene vs Lycopene	Temperature vs times	Temperatures vs lycopene	Times vs lycopene
F	0.00	0.785	0.298	0.522	0.496	0.071	0.898	0.555	0.813	0.899

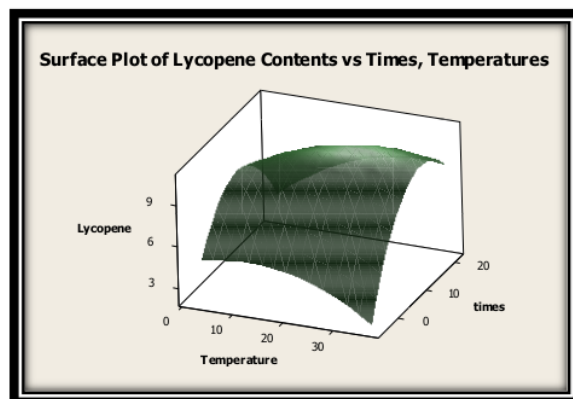


Figure 3. Surface plot of lycopene vs times and temperatures.

From figure 3, optimum value of lycopene was in range of 20-30 (temperatures axis) and range of 10-20 (times axis). To know the exact value of optimum storage condition, contour plot was conducted, shown in figure 4.

Optimum value of lycopene content was reached at:
 Temperature: 24.52°C.
 Time: 11 days.
 Lycopene: 10.71 mg/100g.

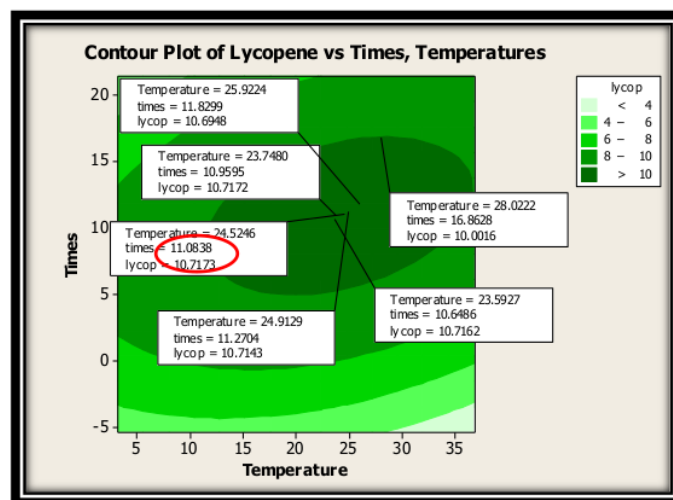


Figure 4. Contour plot of lycopene vs temperatures and times (*lycop= lycopene content).

From figure 5, the darker the green color, the higher the value of lycopene. To get the optimum value, plant flag analysis was conducted with randomly shot on the darkest green area. From the value in the boxes of the figure, highest value of lycopene was considered as optimum storage condition.

4. Conclusion

Temperature above 10 °C increase lycopene of water stress irrigated tomato. On 12nd day of storing in 25 °C, lycopene reached the highest value. After 16 days of storage with temperatures of 10 °C, 15 °C, 25 °C, and 30 °C, lycopene of water stress tomato attained 8,152 mg/100 g, 11,636 mg/100 g, 11,747 mg/100 g, and 11,947 mg/100 g respectively. The optimal storage temperature of water stress tomato was 24.52 °C during 11 days storage with lycopene content potentially reach 10.71 mg/100g, analyzed by Minitab 15 software for optimization. Tomatoes with normal irrigation showed nearly stable trends of lycopene content on 10 °C and 15 °C storage temperatures. Lycopene of normal irrigated tomato increased only for first 8 days with temperature 15 °C (slightly increase), 25 °C, and 30 °C (highest lycopene value of normal irrigated tomato). After 8 days of storage, lycopene contents showed the trends that tend to drop.

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