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Fruit Qualities of De-astringent Persimmon 'Fuyu' Affected by Various Light Sources under Low and High Temperatures before Storage of Harvested Fruit

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Abstract

Harvested de-astringent persimmon 'Fuyu' were treated with various lighting sources under low (3 ℃) and high (22 ℃) temperatures. The weight loss rate of fruits was lower in those with Red LED than Fluorescence and Blue LED under both temperature conditions. Hardness and soluble solid content of fruits were higher in those with 3 ℃ / Blue LED or mixed LED (Blue+Red LEDs). Beta-carotene and lycopene content of fruit peel were higher in those with 3 ℃ than 22 ℃ and with Red LED or light sources with mixed red wavelength under both temperatures. When the fruits treated with light and temperature were stored for 4 days under 3 ℃ / dark condition, the hardness of the fruits did not significant difference among the treatments. Taken together all the results, it would be best to treat it light sources mixed red wavelength under 3 ℃.

Keywords: *carotenoid, de-astringent persimmon, lighting sources, storage*

1. INTRODUCTION

1.1 Theoretical background

It is known that not only fruit growth, but also pigment changes in fruits such as chlorophyll, anthocyanin, carotenoid, etc. are affected by temperature [1], and light quality [2, 3, 4]. Coloring is accompanied during the maturation process, and the degree of coloring is influenced by the difference in chlorophyll break down and pigments biosynthesis. In particular, the degree of coloration is determined by the carotenoid pigment at the final stage of maturation, and is influenced by the initial yellow pigment, the cryptoxanthin, and the later period by the red pigment, the lycopene [5, 6]. Then, genes involved in the expression of each pigment have been studied, and the correlation between the degree of gene expression and the content of substances has been studied [7]. Fruit softening is facilitated by ethylene in a persimmon that is a client-metric fruit [8, 9].

1.2 Study background and purpose

Various indicators are used for the merchantability of fruits, but the weight and color of fruits are used as important indicators. Persimmons are consumed raw, but consumers have less purchasing power than other major fruits such as an apple, a pear and a tangerine. One of the reasons is that the soluble solid content and

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coloring are not enough due to early harvesting before physiological maturation in consideration of the shipping date (national holiday 'Chuseok'). Efforts are being made to promote coloration while preventing the softening, as a factor that directly stimulates the consumer's desire to purchase it focusing on the export persimmon. Research on the use of light emitting diodes (LEDs) for the cultivation of crops and the improvement of functional ingredients is very active. However, it was limited to most indoor plants and vegetables, and in fruit trees were concentrated on reflective films and summer pruning during the cultivation process. In particular, research on the use of light to promote coloration of fruits after harvesting in fruit trees was conducted only on a small part of UV [2, 3], LED [4], etc., and the responsiveness was revealed. Currently, because the most consumed date, the 'Chuseok', has become faster and harvests immature persimmons, the certainty is that it is less competitive than apples and pears that of quality. In order to improve this, it is priority to improve the coloring of the de-astringent persimmon which is being sold at the market. Therefore, here we tried to develop a light and temperature treatment method that improve the coloring of immature de-astringent persimmon immediately after harvesting, targeting the 'Fuyu' cultivar.

2. MATERIALS AND METHODS

2.1 Temperature and lighting source and its treatment

The de-astringent persimmon '*Diospyros kaki* Thunb. cv. Fuyu' was examined for color change by exposing the type of light source before storage after harvest. Fruits of the same weight were selected after harvesting the de-astringent persimmon 'Fuyu' cultivated in Chungnam in early Nov. 2016 and measuring the weight. Light treatment is performed for four types of fluorescent light (32W) with three colors, Red LED (650nm), Blue LED (450nm), and the Red LED + the Blue LED (1: 1). LED for experiment application is a bar shape and is manufactured by placing 72 in number 0.3W chips in 2 rows on a 60cm x 6cm bar. The manufactured LED bar was installed so that it could be replaced within the growth chamber (LFC-1154, Daihan labtech Co. Ltd., Korea). Temperature of the growth chamber was set at 3℃ and 22℃. 3℃ was set assuming the temperature inside the cold storage, and 22 ° C was set based on temperature conditions of the field before storage at the low temperature. In the light and temperature treatment, 20 fruits were placed in single layer in the growth chamber where temperature can be set, and light from a height of 30 cm from the tray was treated for 24 hours (Fig. 1). After treatment, it was stored for 4 days at 3℃ / dark condition.

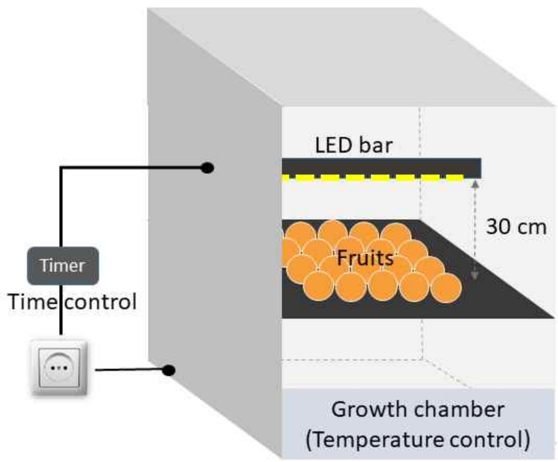

Figure 1. Growth Chamber manufactured for treating light and temperature

2.2 Analysis of basic quality characteristics of fruit

Fruit weight, soluble solid content, pulp, peel hardness, and a and b values of peel were measured after treatment with light source and temperature for 24 hours. In addition, the fruits treated for 24 hours were stored at 3℃ in dark condition for 4 days. Fruit weight was measured with an electronic scale, and the color of peel was measured with a color difference meter (CR-200, Minolta Co., Ltd., Japan). The soluble solid content was measured with a digital refractometer (PR-100, Atago Co., Ltd., Japan), and the hardness was measured with a physical property measuring instrument (Compact-100II, Sun Scientific co., Ltd., Japan). Loss of fruit weight was displayed as a percentage by multiplying by 100 after subtracting the value immediately before treatment from the value after each processing.

2.3 Analysis of fruit pigments

The content of lycopene and β-carotene of fruits with the light and temperature were extracted at the top of fruit peeled thinly 0.5 g to 1 mm, then adding 25 mL of acetone: ethanol: hexane (250: 250: 500, v / v / v) and grinding with homogenizer, the supernatant obtained by centrifuging at 2,000 rpm for 10 minutes at 4℃ was measured at 448 nm and 472 nm with UV / Visible Spectrophotometer (V-560, JASCO Co., Japan), respectively [10], and lycopene (Sigma, L 9879) and β-carotene (Sigma, C 4582) were used as control. The content of chlorophyll a and b were measured at 0.1g of peeled at the top of fruit to 1mm, followed by adding 7 mL of dimethyl sulfoxide (DMSO), then bathed for 30 minutes at 65℃ in hot water for 10 minutes. Measurement was performed by UV / Visible Spectrophotometer (V-560, JASCO Co., Japan). Chlorophyll content ($mg \cdot cm^{-2}$) was determined by the following method [11].

$$\text{Chlorophyll a} = 0.0127 \cdot A_{663} - 0.00269 \cdot A_{645}$$

$$\text{Chlorophyll b} = 0.0229 \cdot A_{645} - 0.00468 \cdot A_{663}$$

$$\text{Total chlorophyll} = 0.0202 \cdot A_{645} + 0.000802 \cdot A_{663}$$

3. RESULTS AND DISCUSSION

3.1 Difference in external qualities of fruit

The characteristics of the fruits were investigated after treatment for 24 hours for each light source at low temperature (3℃) and room temperature (22℃) (Table 1). The rate of loss of fruit weight tended to be higher in the 22℃ treatment than in the 3℃ treatment. Although the 3℃ treatment did not show a difference by all light condition, the 22℃ treatment was significantly higher in the Fluorescence and Blue LED treatment.

The peel and pulp hardness after treatment was high at 3℃/ Blue LED and Blue + Red LED, and the degree of softening after treatment was low. In particular, the reduction rate of hardness and de-astringent persimmon weight (moisture) was low in all Red LED treatment under two temperature conditions, but it was necessary to check whether the hardness result of this study came from the difference of moisture in fruit itself. The post-treatment soluble solid content was significantly higher in the treatment where the hardness was kept high, and was not consistent with the relationship between the decrease in hardness accompanied by maturation and the increase in soluble solid content. Given the soluble solid content (Brix), which indicates the availability of solids content, considerable research into what certain wavelengths would destroy solids of fruit is required. The softening of the de-astringent persimmon pulp is an aspect of quality change after harvest [2], markedly by the ripening and the ethylene generated during stress [12].

After processing for 24 hours for each light source at low temperature (3℃) and room temperature (22℃), color of peel was investigated (Table 2). The Hunter a value, which indicates the red scale, was significantly higher in the Blue LED and Blue + Red treatments compared to the other treatments in both temperature conditions.

Table 1. Fruit characteristics of de-astringent persimmon 'Fuyu' treated with light sources (Fluorescence, LED) and temperatures (3℃ and 22℃) for 24 hours at post-harvest

Temperature	Lighting sources	Decrement of fruit weight (%)	Hardness of fruit peel (g/Ø1mm)		Soluble solid content (Brix)
			Peel	Flesh	
3℃	Fluorescence	0.62 c[z]	316.2 b	188.0 b	13.9 ab
	Red LED	0.32 c	313.0 b	161.6 c	13.6 b
	Blue LED	0.42 c	359.0 a	211.6 a	14.1 a
	Blue + Red LED	0.33 c	373.8 a	220.0 a	14.5 a
	Mean ± SD	*0.42 ± 0.14*	*340.5 ± 30.5*	*195.3 ± 26.2*	*14.0 ± 0.38*
22℃	Fluorescence	2.34 a	366.0 a	190.8 b	13.6 b
	Red LED	1.90 b	309.0 b	134.6 d	13.9 ab
	Blue LED	2.03 a	316.0 b	157.2 c	14.3 a
	Blue + Red LED	1.98 a	375.0 a	194.2 b	13.3 b
	Mean ± SD	*2.06 ± 0.19*	*341.5 ± 33.8*	*169.2 ± 28.5*	*13.8 ± 0.43*

[z]Mean separation within columns by Duncan's multiple range test at 5% levels.

Table 2. Color in fruit peel of de-astringent persimmon 'Fuyu' treated with light sources (Fluorescence, LED) and temperatures (3℃ and 22℃) for 24 hours at post-harvest

Temperature	Lighting sources	Color of fruit peel	
		Hunter a*	Hunter b*
3℃	Fluorescence	16.7 bc[z]	57.1 b
	Red LED	19.5 a	55.3 b
	Blue LED	14.4 c	52.4 c
	Blue + Red LED	17.4 a	59.5 a
	Mean ± SD	*17.0 ± 2.1*	*56.1 ± 3.0*
22℃	Fluorescence	16.8 b	57.0 b
	Red LED	19.1 a	52.9 c
	Blue LED	15.6 bc	57.9 b
	Blue + Red LED	18.5 a	56.5 b
	Mean ± SD	*17.5 ± 1.6*	*56.1 ±2.2*

[z]Mean separation within columns by Duncan's multiple range test at 5% levels.

3.2 Difference in pigment content of fruit

The content of the de-astringent persimmon pigment treated as above was investigated (Table 3). The contents of β-carotene and lycopene were significantly higher in the 22℃-treated group than in 3℃, but were especially highest in the Red LED and Blue + Red LED-treated groups. It was higher in Red LED and Fluorescence treatment than other treatment at 3℃. Both temperatures showed a high tendency in the treatment where both Red wavelengths were high. And in the treatment where the content of the two coloring was high, the content of chlorophyll a and b was low, but it tended to be lower than 22℃ under the low temperature condition of 3℃. And there was a tendency to show a negative relationship between the content of β-carotene and lycopene and the content of chlorophyll (a + b). Chlorophyll content is used as an indicator of other color or degree of coloration and decreases in maturation stage, while other pigments tend to increase [13].

Previous studies with persimmon and mandarin have reported that the use of short wavelengths, such as blue LED and UV, increased the coloration of the peel and the content of anthocyanins and carotenoid pigments [2, 3, 4]. In addition, it has been reported that it is effective to increase the amount of light by using a reflective film in order to increase the color and soluble solid content of the fruit [14]. However, in this study, the effect was demonstrated with a red LED with a longer wavelength. Research is required on whether these differences come from differences in fruit cultivar.

Taken together the results of this study and existing studies, post-harvest pre-harvest light irradiation can increase functional substances in the fruits and increase very strong radical scavenging ability substances such as lycopene [15]. Recently, it is considered to contribute to the production of fruits that conform to consumer needs.

There was a high relationship between β-carotene and lycopene content. However, although there is no correlation between the lycopene content and the peeler Hunter a value, it is judged to be due to the difference in the principle of the peel colorimeter that measures the surface of the peel and the actual distribution of lycopene in the peel.

Table 3. Pigments concentration in fruits peel of de-astringent persimmon 'Fuyu' treated with light sources (Fluorescence, LED) and temperatures (3℃ and 22℃) for 24 hours at post-harvest

Temperature	Lighting sources	β-Carotene ($mg \cdot L^{-1}$)	Lycopene ($mg \cdot L^{-1}$)	Chlorophyll a ($mg \cdot cm^{-2}$)	Chlorophyll b ($mg \cdot cm^{-2}$)
3℃	Fluorescence	288.2 b[z]	65.8 bc	0.028 c	0.010 c
	Red LED	229.3 c	62.0 bc	0.027 c	0.015 c
	Blue LED	200.6 c	57.5 c	0.022 c	0.021 bc
	Blue + Red LED	189.3 c	55.4 c	0.046 b	0.033 b
	Mean ± SD	*226.9 ± 44.2*	*60.2 ± 4.7*	*0.031 ±0.010*	*0.020 ± 0.010*
22℃	Fluorescence	290.0 b	83.3 b	0.048 b	0.041 a
	Red LED	463.8 a	139.0 a	0.047 b	0.021 bc
	Blue LED	288.8 b	80.5 b	0.062 a	0.042 a
	Blue + Red LED	368.6 a	103.8 a	0.031 bc	0.022 bc

Mean ± SD	*352.8 ± 82.9*	*101.7 ± 27.0*	*0.047 ± 0.013*	*0.032 ±0.012*

zMean separation within columns by Duncan's multiple range test at 5% levels.

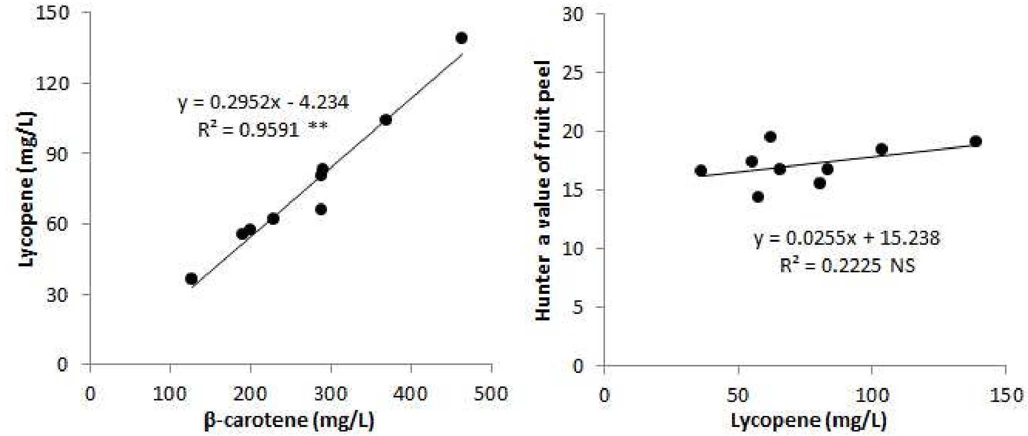

Figure 2. Relationship between carotenoid pigments, peel color (Hunter a value) of de-astringent persimmon 'Fuyu' treated with light sources (Fluorescence, LED) and temperatures (3℃ and 22℃) for 24 hours at post-harvest (NS and ** in figure: non-significant and significant difference at P≦1%)

3.3 Difference in hardness of fruit stored for 24 hours after treatment of light and temperature

We investigated the rate of decrease in fruit hardness stored for 4 days from the storage at 3℃ / dark condition and temperature treatment (Fig. 3). Overall, the decrease in pulp hardness was more significant than the peel hardness. However, although there was a tendency for the decrease rate to be low in the fluorescence treatment, no significant tendency was observed due to the treatment temperature and the light source. In this study, we did not investigate the amount of ethylene generation that promotes the softening of the persimmon, but considering the results in Table 2 and Table 3 based on the results in Figure 3, there is no relationship between the amount of ethylene generation and pigment expression. Carotenoid pigment and skin color during storage after UV treatment of de-astringent persimmon were reported to be unaffected by ethylene [2].

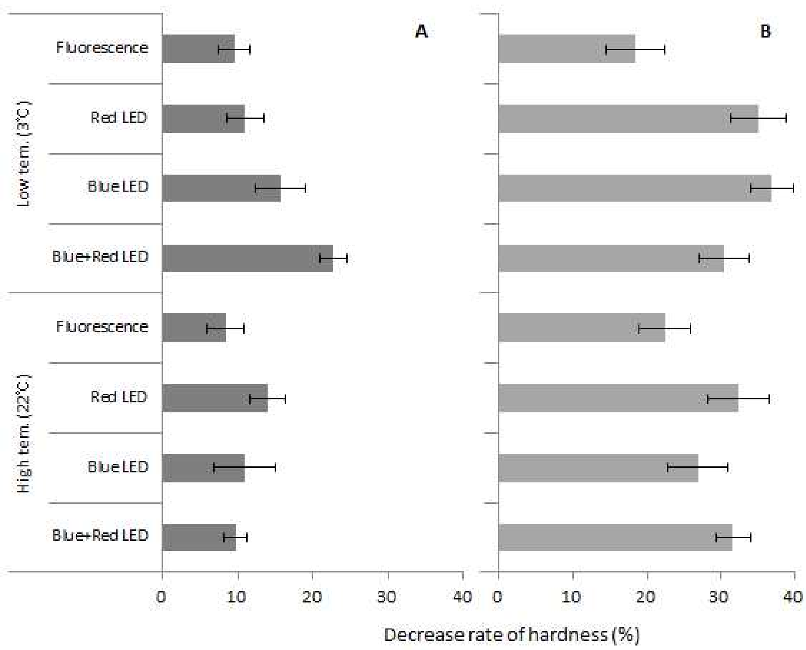

Figure 3. Decrease rate in fruits peel (A) and flesh (B) hardness of de-astringent persimmon 'Fuyu' stored for 4 days at 3℃ / dark condition after light sources (Fluorescence, LED) and temperatures (3℃ and 22℃) treatments (Vertical bars: standard error)

Considering the results of this study comprehensively, light irradiation on the harvested fruit has a definite effect to increase the color or pigment content. In particular, it is referred that the Red wavelength is relevant in order to increase the synthesis of carotenoid dyes rather than the destruction of chlorophyll. At low temperatures, the red wavelength suppressed the hard drop somewhat and increased the party content. It was considered that it is better to use a light source at the center of the red wavelength at 3℃ when looking at rate of a low fruit weight reduction, high pulp hardness, high soluble solid content, high carotenoid content, etc. which were excellent fruit quality conditions. In this study, since the amount of ethylene generation was not investigated, it was necessary to study the relationship between the wavelength of light, the amount of ethylene generation, and the hardness.

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