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Fruit Characteristics and Mineral Nutrient Concentrations Depending on Different Sizes of "Fuyu" Persimmon Fruits

Seong-Tae Choi*, Gwang-Hwan Ahn, Eun-Gyeong Kim, Ji-Young Son, Yeo-Ok Park, Wan-Kyu Joung

Sweet Persimmon Research Institute, Gyeongsangnam-do Agricultural Research and Extension Services, Gimhae, Republic of Korea
Email: *stchoi1234@korea.kr

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Abstract

This study investigated the relationships between fruit size and other fruit quality components in "Fuyu" persimmon. The flower buds were thinned to leave one or two buds per bearing shoot in mid-May. All fruits were harvested on November 12 and they were divided into six size classes by fresh weight. The length/diameter (L/D) ratio and flesh firmness significantly decreased as fruit size increased. Large fruits had a redder skin color with more seeds than small ones. There was a strong negative relationship between fruit size and the L/D ratio ($R^2 = 0.741$, $p \le 0.01$) and firmness ($R^2 = 0.604$, $p \le 0.01$). Skin color and number of seeds per fruit were positively related to fruit size, especially skin color where the relationship was highly positive ($R^2 = 0.771$, $p \le 0.01$). There was a weak, but non-significant positive relation between fruit size and soluble solids. P, K, and Ca concentrations significantly decreased with increasing fruit size. Highly negative relationships were found between fruit size and fruit P ($R^2 = 0.393$, $p \le 0.01$), K ($R^2 = 0.446$, $p \le 0.01$), and Ca ($R^2 = 0.417$, $p \le 0.01$) concentrations. Fruit N and Mg concentrations were not affected by fruit size. It was concluded that fruit size is related to shape, coloration, flesh firmness, and number of seeds per fruit, affecting concentrations of some mineral nutrients in fruits.

Keywords

Fruit Quality, Fruit Weight, Maturity, Seed, Inorganic Element

1. Introduction

Fresh fruit from the late maturing persimmon cultivar "Fuyu" accounts for the largest portion of the total persimmon production in Korea. In general, the size of the fresh fruits determines the grade of the fruit, which is the most important factor affecting the price. The production of large fruits is strongly correlated with farmer profits. Therefore, most "Fuyu" growers hand-thin flower buds before flowering and some of the fruitlets after June-drop to reduce crop load so that the remaining fruits become larger at harvest. However, the production of medium-sized fruits, produced by maintaining high fruit loads, has gradually increased because producing large-sized fruits requires substantial labor inputs and medium size becomes more attractive to some consumers. In export markets, such as Southeast Asia, small- or medium-sized fruits have become better acceptable to consumers due to their long self-life with low price. "Fuyu" growers harvest the fruits over a short period of time just before heavy frosts occur in early to mid-November, and they grade the fruit mainly by their size. These fruits are then shipped to diverse markets or they are stored at low temperature. Therefore, other quality factors, such as skin color, firmness, and soluble solids, are mostly overlooked compared to fruit size.

Changes in fruit quality due to fruit size have been mainly investigated by comparing fruit-load treatments in many other studies. Large fruits from low fruit-load trees tend to have higher soluble solid concentration and coloration, but lower flesh firmness [1] [2] [3]. These characteristics are probably due to greater carbohydrate availability [4] [5]. Previous studies have shown that large apple fruits tend to mature faster than small ones with higher coloration and soluble solid concentration [3] [4]. However, the relationships between persimmon fruit size and other fruit quality components are not clear for fruits harvested at the same time, regardless of fruit load. Even on the same tree, fruit weight could be affected by several factors, including the light environment [6], different fruit loads [7], and number of seeds per fruit [8]. Under different fruit loads, fruit concentrations of mineral nutrients could vary depending on the fruit size [3] [9] [10] [11], which may also affect other fruit characteristics and storability [12].

Therefore, knowing how fruit sizes are related to other quality components is critically important to post-harvest management based on fruit size, but the mutual relationships have not been specifically elucidated for persimmon. The aim of this study was to investigate changes in fruit characteristics and their mineral nutrients when different sized fruits were harvested at the same time in mid-November.

2. Materials and Methods

2.1. Plant Material

Sixteen-year-old "Fuyu" trees (*Diospyros kaki*), grafted on *D. kaki* seedlings, were used in this experiment. The trees were spaced 6 × 5 m apart and grown on flat land (35˚28'29" N, 128˚71'78" W) with sandy loam soils at Gimhae, South Korea. Annual rainfall of the area ranges 1200 to 1500 mm and annual mean temperature 12.3˚C to 14˚C. Conventional fertilization and irrigation recommended by RDA (2013) [13] were applied to the trees. For this experiment, Three similar sized trees were selected and their flower buds were thinned in mid-May to leave one bud in a below 20-cm long shoot and two buds in an over 20-cm long shoot. Unmarketable fruits were removed from early July to harvest after physiological fruit drop had finished. Since physiological fruit drop differed depending on the position of the fruit in the tree canopy, the leaf-to-fruit ratio per 1-year-old branch varied from 10 to 20.

2.2. Sampling and Measurement

All fruits were harvested on November 12 and were divided into six size classes. These were 161 - 180 g, 181 - 210 g, 211 - 230 g, 231 - 250 g, 251 - 280 g, and 281 - 320 g. Ten fruits per size class were randomly sampled from each tree, and all 180 fruits from the three trees were used to measure individual fruit characteristics. The weights, lengths and diameters of the fruits were recorded first, and then skin color was measured as Hunter a value using a colorimeter (CM-2500d, Konica Minolta Sensing Inc., Japan). A fruit firmness tester (53,205, Turoni srl., Forlì, Italy) equipped with a 5-mm plunger was used to measure flesh firmness. Fruit juice was collected from sliced mesocarps using a hand presser, and the soluble solids were determined by a digital refractometer with an accuracy of ± 0.2% (PAL-1, Atago Co., Tokyo, Japan). Seeds were numbered from the cross section of the fruits. The dry matter ratios of the fruits were calculated from fresh weight of some flesh slices and dry weight of the slices dried at 80˚C for 48 h.

2.3. Nutrient Analysis

The dried samples used to measure the dry matter ratio were ground to pass through a 20-mesh. To determine total N, 0.2-g sub-samples were analyzed by a Kjeldahl instrument (Kjeltec 2300, Foss Tecator AB, Höganäs, Sweden) using the micro-Kjeldahl method [14]. P, K, Ca, and Mg were analyzed using an inductively coupled plasma emission spectrometer (ICPS-7510, Shimadzu Co., Tokyo, Japan) after digesting 0.5 g of the samples with $HClO_4$ and H_2SO_4 in a heating block.

2.4. Statistical Analysis

Three single-tree replicates for each size class were arranged in a completely randomized design. Differences among the data were detected by Duncan's multiple-range test using the SAS System for Windows V8 (SAS Institute, Inc., Cary, NC, USA). Regression analysis was also performed in order to determine the relationships between fruit size and other fruit characteristics and mineral nutrient concentrations.

3. Results and Discussion

3.1. Fruit Characteristic

Table 1 shows the characteristic of the fruits from the different size classes after

Table 1. Fruit characteristics as affected by different sizes of "Fuyu" persimmon fruits harvested on November 12.

Fruit size (g)	Avg. fresh wt (g)	Length/ diameter	Skin color (Hunter a)	Flesh firmness (N)	Soluble solids (˚Brix)	Seeds (No./fruit)	Dry matter (%)
161 - 180	171f[z]	0.71a	32.9cd	30.0a	14.7a	1.5b	16.7a
181 - 210	197e	0.70ab	32.3d	27.9ab	14.9a	2.9ab	16.9a
211 - 230	220d	0.68bc	33.5cd	27.5ab	14.8a	2.7ab	16.7a
231 - 250	239c	0.68c	34.5bc	26.7bc	15.0a	2.7ab	17.1a
251 - 280	259b	0.67c	35.9ab	26.2bc	15.0a	3.1a	17.0a
281 - 320	292a	0.66c	37.1a	24.2c	15.1a	3.0a	17.0a

[z]Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.

they had been harvested on November 12. The L/D ratio and flesh firmness significantly decreased as fruit size increased. The L/D ratio gradually changed from 0.71 for 161 - 180 g size class to 0.66 for 281 - 320 g size and flesh firmness fell from 30 to 24.2 N, respectively. Large fruits had a redder skin color with more seeds than small ones. As fruit size increased from 161 - 180 g to 281 - 320 g, Hunter a value of the fruit skin increased from 32.9 to 37.1 and the number of seeds increased 2-fold more. Although soluble solids were higher in larger sized fruit, this difference was not statistically significant. Fruit size did not affect the dry matter ratio. Table 2 shows that there was a strong negative relationship between fruit size and the L/D ratio ($R^2 = 0.741$) and firmness ($R^2 = 0.604$). Skin color and the number of seeds were positively related to fruit size, especially skin color ($R^2 = 0.771$). Although not significant, there was a weak positive relationship between fruit size and soluble solids.

Previous studies suggested that increasing fruit size by reducing the fruit load could advance fruit coloration and maturity [1] since carbohydrate availability increased [4] [5]. However, the fruit characteristics in this study might be affected by other factors as well as fruit load. Different light interceptions within a tree canopy could change physiological fruit drop, which would alter fruit load on the branches [15] [16]. The different light environments might also affect growth, coloration, and soluble sugar concentration in fruits [15] [17] [18]. It has previously been shown that the number of seeds per fruit could change fruit growth and coloration, since fruit seeds enhance sink activity for photosynthates [8] [16] [19].

Regardless of the various factors, large fruits in this study might mature faster than small ones, when their higher skin color and lower flesh firmness are considered. The lower L/D ratios of large fruits indicated that the active growth of diameter occurs with increasing fruit weight. Higher skin color in large fruit indicated that the large fruits were produced from branches with better light interception or with low fruit load. Lower firmness in large fruits could be directly related to earlier maturation at harvest [3] [10] and higher cell volumes [20], compared with the small fruits. In addition, Johnson (1992) [2] observed that the increased proportion of intercellular spaces in large fruits was negatively related to flesh firmness. Insignificant change in soluble solids, despite a clear difference between fruit size and skin color, reflected that the soluble solids were more affected by other factors. The positive relationship between fruit size and the number of seeds (**Table 2**) confirmed that the number of seeds is positively correlated with fruit growth as previously reported [16].

3.2. Mineral Nutrient

Concentrations of P, K, and Ca significantly decreased as fruit size increased (**Table 3**). The concentrations did not apparently change when fruit size class increased from 161 - 180 to 211 - 230 g. However, when fruit size increased from 211 - 230 g to 281 - 320 g, P decreased from 0.093 to 0.078%, K from 0.99 to 0.94%, and Ca from 0.092 to 0.82%. Therefore, there were highly negative relationships in the linear regression model between fruit size and fruit P (R^2 = 0.393**), K (R^2 = 0.446**), and Ca (R^2 = 0.417**) concentrations (**Table 4**). On the other hand, increasing fruit size did not affect concentrations of N and Mg in the fruit (**Table 3**) and there is no significant relationship between fruit size and concentrations of N and Mg.

In persimmon, contents of mineral nutrientsper fruit increase with fruit growth until harvest, but their concentrations gradually decrease as the fruit approaches the maturing stage because they are diluted by rapid fruit swelling [21] [22]. In contrast, there was an increase in N and P concentrations as apple fruit size increased [9] [23]. Wünsche and Ferguson (2005) [3] suggested that low concentrations of some mineral nutrients in large fruits under low fruit load are related to the increase in dry matter due to high fruit carbohydrate levels. In particular, rapidly growing fruits contain lower Ca concentration since the Ca accumulation cannot keep up with fruit expansion, whereas it is more likely to be accumulated in slowly growing fruits [3] [23]. Fallahi *et al.* (1984) [9] also reported that the flesh Ca concentrations decreased in large apple fruits produced

Table 2. Regression equations and coefficients of determination (R^2) between size (X) and other characteristic factors (Y) in fruits harvested on November 12 (n = 18).

Fruit characteristic	Regression equation	R^2
Length/diameter (%)	Y = −0.044X + 78.6	0.741**
Skin color (Hunter a)	Y = 0.041X + 25.1	0.771**
Firmness (N)	Y = −0.043X + 36.9	0.604**
Soluble solids (°Brix)	Y = 0.003X + 14.2	0.184^{NS}
Seeds (No./fruit)	Y = 0.010X + 0.3	0.260*
Dry matter (%)	Y = 3E−05X + 0.2	0.145^{NS}

^{NS}, *, ** Non-significant or significant at $P \le 0.05$ and $P \le 0.01$, respectively.

Table 3. Concentration of mineral nutrients in the fruit as affected by different sizes of "Fuyu" persimmon fruits harvested on November 12.

Fruit size (g)	Mineral nutrients (% DW)				
	N	P	K	Ca	Mg
161 - 180	0.36a[z]	0.092a	1.03a	0.091ab	0.045a
181 - 210	0.38a	0.095a	1.00ab	0.093a	0.043a
211 - 230	0.39a	0.093a	0.99ab	0.092a	0.044a
231 - 250	0.40a	0.083ab	0.95ab	0.088ab	0.044a
251 - 280	0.36a	0.087ab	0.95ab	0.085ab	0.043a
281 - 320	0.37a	0.078b	0.94b	0.082b	0.043a

[z]Mean values in each column with the same letter are not significantly different by Duncan's multiple range test at $P \leq 0.05$.

Table 4. Regression equations and coefficients of determination (R^2) between size (X) and mineral nutrient concentrations (Y) in fruits harvested on November 12 (n = 18).

Mineral nutrients (% DW)	Regression equation	R^2
Nitrogen	Y = 2E−07X + 0.374	$R^2 = 9E{-}08^{NS}$
Phosphorous	Y = −0.0001X + 0.117	$R^2 = 0.393^{**}$
Potassium	Y = −0.0008X + 1.158	$R^2 = 0.446^{**}$
Calcium	Y = −9E−05X + 0.109	$R^2 = 0.417^{**}$
Magnesium	Y = −8E−06X + 0.046	$R^2 = 0.022^{NS}$

^{NS}, ** Non-significant or significant at $P \leq 0.01$, respectively.

from low fruit load trees. Low Ca concentration in large fruits could reduce fruit storability [10]. Therefore, low flesh firmness in the large fruits (**Table 1**) could be related to their low Ca concentration. Non-significant changes in N and Mg concentrations of fruit (**Table 3**) indicated that the larger the fruits, the more they absorbed N and Mg, compared to the other nutrients. However, some previous reports have indicated that fruit N and Mg concentrations were not affected by fruit size [11] [23].

4. Conclusion

Taken together, the consumer market for small "Fuyu" fruits could be limited due to their lower coloration and higher firmness when the fruits are difficult to mature sufficiently under the risk of early frost damage as in the major persimmon growing areas of Korea. However, higher firmness of the small could improve long-term storage, which is important for the export market. Large fruits are more suitable for short-term consumption because they have better skin coloration with soft flesh, but careful attention should be paid to prevent large fruits from rapidly softening during the postharvest period. The result from this study also indicated that flesh firmness of fruit could be partially related to changes in the concentrations of some mineral nutrients in the fruit, especially Ca.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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