

Effect of Delayed Harvesting of Sweet Persimmon ‘Yangfeng’ Mature Fruit on Its Mineral and Other Nutritional Components and Quality

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Abstract By measuring the mineral, vitamin, total sugar, protein, hardness, color and other components of the mature fruit of sweet persimmon ‘Yangfeng’ during the normal harvesting period and delayed period, the results showed that the total sugar content of mature fruit during the delayed period increased by more than 56% and the protein content increased by more than 44.8% compared to the fruit during normal period, with an average increase of over 25% in calcium, potassium, and magnesium content. In addition, the main color of the fruit changed from light yellow to light yellow with dark yellow on the top, and its frequency increased by 300% compared to the fruits during normal period.

Key words Sweet persimmon ‘Yangfeng’, Delayed harvesting fruits, Quality, Measurement and analysis

0 Introduction

In recent years, the sweet persimmon variety ‘Yangfeng’ has been highly favored by fruit farmers due to its excellent quality, strong stress resistance, easy cultivation, high yield, and good benefits. At the same time, it is also popular among white-collar women and the elderly and young people due to its late ripening, bright red color, crispy and sweet taste, and rich nutritional content^[1-3]. Therefore, the production and sales of its high-quality commodity fruit are thriving, with a supply shortage and high economic benefits. At present, a sweet persimmon base with ‘Yangfeng’ as the main variety has been formed in Meixian County and Fufeng County of Baoji City, covering nearly 2 000 ha, with an annual total output of about 20 million kg. Two product brands, ‘Meifeng’ and ‘Yangjiling’, have been registered, and sales have reached 120 million yuan^[4-6]. But during the harvesting process of sweet persimmon ‘Yangfeng’, it is found that the harvested fruits in the later stage (from mid to late October or even mid to early November) not only have high sweetness and bright red color, but also are easily sold out at high prices, resulting in abundant economic income. Given the aforementioned favorable factors, will the delayed harvesting of fruits affect their nutritional composition and quality? To this end, sampling surveys and nutrient composition measurements were conducted on the mature fruits of sweet persimmon ‘Yangfeng’ 2022, including the early stage (*i. e.* mid October during normal harvesting) and the late stage (*i. e.* early November during delayed harvesting). The results were summarized as follows.

1 Overview of the survey site

The survey was conducted in Yangjiling Village, Famen Town, Fufeng County, Baoji City, at the Sweet Persimmon Demonstration Zone built by Baoji Qiaoshan Agricultural Development Professional Cooperative. The park is located in the central and western part of Qinchuan, Guanzhong, Shaanxi Province. It belongs to the warm temperate continental monsoon semi humid climate zone, with four distinct seasons, abundant sunshine, and sufficient heat. The average annual precipitation is in the range of 660–1 000 mm, especially in the summer when the water and heat are synchronized. The number of days with a ≥ 10 °C effective accumulated temperature of 4 000–4 600 °C is 280 d. In addition, the deep soil layer, especially from July to September when the water and heat are synchronized, is very conducive to the growth and development of persimmon trees.

The park was established in 2010, and a total area was approximately 33.33 ha, with multiple block shaped square fields (3.33–6.67 ha). There is flat land and orderly production roads within the park. The average altitude is around 600 m, with a height difference of less than 2 m. The loess parent material is deep and thick, and the soil fertility is moderate. The artificial well pumping irrigation facilities are complete. The main variety planted is ‘Yangfeng’, with a cultivation density of 2.5 m × 3.5 m, 76 plants/667 m². The fruiting age is 5–6 years, and the average unit yield is 1 750–2 000 kg/667 m². The average annual unit output value is 8 000–10 000 yuan/667 m².

2 Survey design and sampling processing

2.1 Sampling design method In order to understand the impact of changes in the nutritional content of sweet persimmon ‘Yangfeng’ fruits during the normal ripening period (mid October) and its delayed period (mid November) on the quality of commercial fruits, and to achieve better production value and provide theoretical basis for scientific harvesting, a square plot of

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about 4 ha in the central area of the park was set up to select 3 groups of sample plants, with 6 plants in each group, for a total of 18 plants, according to the following standards: individual plant height range of $2.5 \text{ m} \leq h \leq 3.0 \text{ m}$, average crown width of $1.5 \text{ m} \leq f \leq 2.5 \text{ m}$; average diameter of $10.0 \text{ cm} \leq d \leq 12.0 \text{ cm}$, number of fruits per plant of $100 \leq m \leq 120$, healthy growth, no pest or disease hazards, non edge, and distance between individual plants no less than 20 m. Moreover, they were marked with red paint on obvious parts of the trunk as b1...6, b2...6, b3...6). On the afternoon of October 15 and November 15, 2022 (non rainy days), fruit samples were collected according to the fruit collection standard of single plant sample group ($85.0 \text{ cm} \leq$ average fruit diameter $\leq 100.0 \text{ cm}$, no deformities, no pest or disease hazards, golden or light red color). 6 standard fruit samples were collected in sequence from the east, south, west, north, and top directions of each sample plant, with 1 sample from the east, 1 sample from the south, 1 sample from the west, 1 sample from the

north, 1 sample from the east side of the top, and 1 sample from the west side of the top. 36 standard samples were collected in each group, and a total of 108 standard samples were collected in 3 groups. A total of 216 standard samples were collected from 2 batches.

2.2 Quality testing and processing

2.2.1 Quality determination and statistical analysis of standard single fruit.

According to the pre- and post sampling batches, each group of samples should be numbered one by one, and then the mass (unit: g) should be recorded using an electronic balance (model FA1104). According to the principle of significance test for mean difference in mathematical statistics (large sample), the $|U|$ value was calculated using the formula $U = (x_1 - x_2) / \sigma_{x_1 - x_2}$, and then was compared with (taking 95% of reliability) $U_\alpha = 1.96$. Based on the comparison results, whether the difference in sample quality collected between the normal and delayed periods was significant was determined (Table 1).

Table 1 Determination results for protein and total sugar

Component	Unit	Normal period (60 fruits) on October 16, 2022				Delayed period (112 fruits) on November 2, 2022				Delayed period increased compared to normal period	
										Proportion//%	Numerical value
Total sugar	%	8.54				13.33				56.1	4.79
Protein	g/100 g	0.58				0.84				44.8	0.26
Hardness	N/cm ²	103.80				94.60				-8.8	-9.20
Fruit color	Grade	I	II	III	IV	I	II	III	IV		
	Frequency//%	18	59	17	6	0	16	68	16		

NOTE Classification standards for color palettes: I – light green and light yellow; II – light yellow; III – light yellow with dark yellow on the top; IV – deep yellow with light red on the top.

2.2.2 Determination and comparison of fruit color.

According to the sampling design concept of delayed and normal periods, the standard samples collected in the early and late stages of the standard site were compared with the four grading standards of the color chart one by one in batches and by sample group category. The results were analyzed based on the frequency (unit: %) of each color level and difference performance of its frequency between the previous and subsequent batches (Table 1).

2.2.3 Determination of hardness, minerals, vitamins and other items.

After completing the various tests in Section 3.2, all samples were packaged and labeled by group. They were sent to the Food Testing Center of Northwest A&F University in two batches for determining hardness, sugar, minerals and vitamin content. Vitamins A, D and E were determined by the first method of GB 5009.82-2016; vitamin C was determined by the first method of GB 5009.86-2016; the hardness was determined using the method of GB/T 10651-2008 (appendix C).

2.2.4 Determination of protein and sugar content.

Protein was determined by the method of GB 5009.5-2025; total sugar content was determined using the method of NY/T 2742-2015.

2.2.5 Determination of metal element content.

The magnesium content was determined by adopting the method of GB 5009.268-2025; the calcium content was determined by adopting the method of GB 5009.92-2016; the potassium content was determined by adopting the method of GB 5009.91-2017; the contents of heavy

metals copper and lead were determined by adopting the prescribed methods of GB 5009.13-2017 and GB 5009.12-2023.

3 Results and analysis

3.1 Measurement results of protein, hardness, and total sugar

3.1.1 Total sugar determination.

The delayed harvesting period was postponed by 15 d, resulting in a significant increase in the total sugar content of the fruit and a noticeable sweetness and palatability. According to the measurement results in Table 1, the total sugar content (13.33%) of the ripe fruit samples of sweet persimmon ‘Yangfeng’ harvested on November 2, 2022, was 56.1% higher than that of the fruit samples harvested during the normal period (8.54%).

3.1.2

According to Table 1, the hardness of the fruit samples harvested during the delayed period was 94.6 N/cm^2 , decreased slightly by 8.8% when compared to that during the normal period (103.8 N/cm^2). At the same time, the protein content was 0.84 g/100 g , with an increase of 44.8% when compared to that during the normal period (0.58 g/100 g). This result fully demonstrated that delayed harvesting improves the nutritional quality of the fruit. Especially in terms of taste, the sweetness of the fruit increases significantly compared to the normal period, and its taste quickly changes from hard and crispy to soft and smooth, and from light sweet to sweet and crispy. And it is particularly popular

among the elderly and young groups. From the perspective of market consumption, this characteristic perfectly fits the consumption preferences of the elderly, weak, and young, and relatively expands the consumer group and consumption volume. The increase in sales prices of fruit during the delayed period is also an inevitable result.

3.2 Comparison of fruit color According to Table 1, compared to the normal period, the fruits during the delayed period no longer had a light green yellow. Among them, the frequency of fruits in light yellow with dark yellow on the top (referred to as the main color) was the highest at 68%, which was 300% higher than that in the normal period. Next are light yellow and dark yellow with light red on the top, both with a frequency of 16%, which was 72.9% lower than the frequency of light yellow in normal period (59%), with an increase of 166.7% compared to the fruit during the normal period in dark yellow with light red on the top (6%). The above results fully demonstrated that the color of delayed fruits is generally dominated by light yellow and dark yellow with light red on the top, which is brighter and more attractive than that during the normal period. It is particularly in line with the traditional Chinese custom of liking red for auspicious celebrations, and has become another highlight for expanding consumption.

3.3 Determination results and analysis of vitamins A, D, C, E According to the measurement results, vitamins A and D were not detected in the fruit samples of delayed harvest, only vitamins C and E were detected. The results indicated that the mature sweet persimmon ‘Yangfeng’ fruit had a low content of vitamins A and D, while the content of vitamin C was the highest, regardless of the harvest period. The content of vitamin C was 44.4 and 42.5 mg/100 g during the delayed and normal periods, and it steadily increased by 4.47% with the harvest period prolonged. However, the content of vitamin E in the delayed and normal phases only accounted for 1.2% and 1.0% of the content of vitamin C, respectively, and its content decreased by 29.1% with the harvest period prolonged. Therefore, the results showed that in the mature fruit of sweet persimmon ‘Yangfeng’, the content of vitamin C was the highest and relatively stable, with little change in the delayed harvesting. However, the content of vitamin E was relatively low compared to vitamin C, accounting for only about 1% of the vitamin C content. With the delay of the harvest period of mature fruit (15 d in this paper), its content decreased significantly, and its stability was poor.

3.4 Determination results of minerals (calcium, magnesium, potassium) and heavy metals copper and lead The potassium content was the highest, nearly 14 and 1.5 times of calci-

um and magnesium contents. According to the measurement results, potassium had the highest content in the fruit samples harvested during the delayed and normal periods, reaching 1 940.0 and 1 550.0 mg/kg. The calcium content was second, with 137.0 and 108.0 mg/kg. The magnesium content was the lowest, at 95.4 and 66.3 mg/kg. It fully demonstrated that the potassium content in fruits during the delayed period was the highest compared to the normal period, and the increase was significant.

The contents of potassium, calcium, and magnesium in the fruit samples during the delayed period were more than 25% higher than that in the normal period. Among them, the highest ratio of magnesium content to the normal period was 43.9%, followed by calcium and potassium, with ratios of 26.9% and 25.2%. The above results fully demonstrated that it is beneficial for the rapid increase of minerals potassium, calcium, and magnesium contents in the fruit by delaying the fruit harvesting period.

During both the normal and delayed periods, heavy metals lead and copper were not detected. According to the measurement results, no copper and lead content was detected in the fruit samples during both normal and delayed periods.

4.5 Measurement results of fruit mass There was a significant difference in the average mass of individual fruits between the delayed and normal periods. According to the measurement results, it was assumed that the two-stage samplings during the normal and delayed periods were both spatially and temporally independent populations, and there was no significant difference in the mass of the fruits. Then, based on the number of independent samples collected in the previous and subsequent periods and the average mass of the samples, the standard deviations for the normal and delayed periods were determined to be 16.49 and 25.06. According to the formula $U = (x_1 - x_2) / \sigma_{x_1 - x_2}$, $U = 3.1388$ was calculated. Taking $U_\alpha = 1.96$ with a reliability of 95% for comparison, $|U| = 3.1388 > U_\alpha (1.96)$. Therefore, the hypothesis was overturned, it fully demonstrated that there was a significant difference in the average mass of individual fruits between the delayed and normal periods (Table 2).

The average mass of a single fruit decreased by 12.8 g during the delay period compared to the normal period, with a decrease ratio of 4.71%. It illustrated that the average mass of a single fruit during the delayed period decreased by 4.71 g than that during the normal period. If estimated based on the average fruiting number per standard plant of 100, the actual yield per plant in that year decreased by 471 g \leq 500 g, it meant the yield per plant decreased by nearly 1.73 average fruit masses (Table 2).

Table 2 Determination results of fruit mass during the delayed and normal periods

Harvest period	Number of samples	Average mass of sampled single fruit//g	Standard deviation//g	Comparison results (taking $U_\alpha = 1.96$ with a reliability of 95%)
Normal period on October 16, 2022	$N_1 = 112$	$X_1 = 271.9$	$S_1 = 16.49$	Calculation formula: $U = (x_1 - x_2) / \sigma_{x_1 - x_2}$, $U = 3.1388$
Delayed period on November 2, 2022	$N_2 = 60$	$X_2 = 259.1$	$S_2 = 25.06$	
Average mass difference and percentage of single fruit between normal and delayed periods	12.8 g, decreased by 4.71%			

4 Conclusions

If the ripe fruit of sweet persimmon ‘Yangfeng’ is delayed for 15–20 d until early November, its total sugar content will significantly increase, and the frequency of main chromaticity will increase by 300%. The color will change from light yellow red to golden yellow, appearing more auspicious, bright and tempting, and the taste will become pleasant and sweet.

The fruits of delayed harvest have higher contents of calcium, magnesium, potassium, as well as vitamin C and protein, and they are all higher than the fruits during the normal harvest period. The nutritional quality of the fruits is significantly improved, which is more beneficial for human consumption and health care.

Production enterprises with the necessary conditions can appropriately delay the fruit harvesting period to around early November, which can achieve higher economic benefits while harvesting high-quality fruits^[7–9].

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