Effect of Bagging on Fruit Quality of Three Pummelo (Citrus grandis Osbeck) Cultivars

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Abstract. In this study, the effect of bagging on fruit quality of three pummelo (Citrus grandis Osbeck) cultivars was evaluated in order to provide basis for high-quality and high-efficient cultivation of pummelo cultivars. Seven bagging times was set at 35, 50, 65, 80, 95, 110, and 125 days after flowering (DAF). Different bagging treatments all effectively improved the external fruit quality, such as beautiful peel color and smooth oil vacuole. The weight per fruit, longitudinal and transverse diameter revealed decrease trends along with the delay of bagging times. In addition, bagging treatments somewhat decreased the content of internal quality, including total soluble solid, vitamin C and sugar, being significantly lower than that in control check. Taking the external and internal fruit quality into consideration, we determined the appropriate bagging times for three cultivars. The best bagging time was at 35, 80, and 65 days after flowering for 'Sanhongmiyou', 'Hongroumiyou' and 'Huangjinmiyou', respectively. It will provide effective basis for bagging treatments in the pummelo producing area.

1. Introduction
Pummelo, Citrus grandis (L.) osbeck, belongs to genus Citrus L., family Rutaceae [1]. China is one of major centers of origination and genetic diversity, possessing abundant pummelo germplasms. The cultivation history of pummelo can date back to 3000 years ago [2], including three major cultivation areas, Southeast coastal, South China and Southwest China [3]. Until now, more than 200 pummelo varieties have been selected and cultivated in China [4]. 'Hongroumiyou' [5], 'Sanhongmiyou' [6], and 'Huangjinmiyou' [7] are mutated from 'Guanximiyou', which have been widely cultivated in Fujian and Sichuan Provinces.

Bagging could effectively improve the external fruit quality [8], reduce risk of pest and disease damage [9, 10], as well as expand the storage life of fruits [11]. It is important for the improvement of fruit quality to bagging in the right time. Previous studies suggested that bag cover should be carried out after the second physiological fruit drop [7, 12]. During the past decades, we observed that the second physiological fruit drop happened at about 35 days after flowering of the three pummelo cultivars in Sichuan Province.
In this study, we compared the fruit quality by setting different bagging times to determine the appropriate bagging time for better improving the fruit quality, which provided basis for high-quality and high-efficient cultivation of pummelo cultivars.

2. Materials and methods

2.1. Plant materials
We selected three pummelo cultivars, *C. grandis* cv. 'Sanhongmiyou', 'Hongroumiyou', and 'Huangjinmiyou' rootstocked by wild *C. grandis*, as the materials in this study. The experiments were carried out using fruit bags (Guonong GN-32) in the orchard in Pujiang County, Chengdu, Sichuan Province, from May to September 2016. We set seven bagging times at 35 (5 June 2016), 50 (20 June), 65 (5 July), 80 (20 July), 95 (5 August), 110 (20 August), and 125 (5 September) days after flowering (DAF). Ten fruits from four orientations of the trees were bagged for each treatment with three repeats per treatment.

2.2. Fruit quality detection
The external fruit quality contained peel color, flesh and spongy layer color, and oil vacuole, which were detected by visual observation. Vernier caliper was used to detect the thickness of spongy layer, longitudinal and transverse diameter, fruit and flesh weight. According to these data, fruit shape index and edible rate were calculated.

The content of total soluble solid (TSS) was detected by the hand-held refractometer. 2,6-dichloroindophenol titration method was used to detect the content of Vitamin C [13]. Total sugar and acid was measured by using anthrone colorimetric [14] and acid-base neutralization method [14], respectively. The sugar contents were calculated according to Xiong et al. [15]: Reducing sugar = D/V1 × 1000, Invert sugar = D/V2 × 1000, Sucrose = (invert sugar − reducing sugar) × 0.95, Total sugar = reducing sugar + sucrose, where D, V1, and V2 represent the glucose content corresponding to 10 mL of Fehling reagent, titration volume of reducing sugar solution and invert sugar solution, respectively.

2.3. Data analysis
Significant differences between the means of the treatments were determined with 95% confidence (p < 0.05) limit by Duncan multiple range test using SPSS18.0 (IBM, USA). Data are shown as the means of three replicates.

3. Results

3.1. External fruit quality
As we can see from the Table 1, bagging treatments improved pericarp coloring of pummelo cultivars, revealing light yellow or yellow in 'Sanhongmiyou' and 'Hongroumiyou', and light yellow or olivine in 'Huangjinmiyou'. The fruit fleshes appeared red or light orange in this study. There were smaller vertical and transverse diameter, fruit weight in 'Sanhongmiyou' and 'Huangjinmiyou' for bagging treatments than that in control check, while these parameters revealed different trend in 'Hongroumiyou'. Significant differences were observed among different bagging treatments. Taking 'Sanhongmiyou' as example, the biggest and smallest fruit were obtained by bagging at 125 and 35 days after flowering, with the weight per fruit of 1.64 kilograms in 'Sanhongmiyou'. Edible rate had an increase trend along with the delay of bagging times. There were no significant differences among other parameters such as flesh color and segments.
As shown in Table 1, bagging treatments decreased the content of internal fruit quality. The content of total soluble solid (TSS) revealed an increase change along with the delay of bagging times, which were all lower than that in control check in 'Sanhongmiyou'. While in 'Hongroumiyou' and 'Huangjinmiyou', the highest TSS content occurred at 125 days after flowering, with the value of 10.90% and 11.17%, respectively. They were no significant differences with that in control. Compared with TSS, bagging treatments increased the accumulation of total acid content. In addition, bagging treatments decreased the content of vitamin C and sugar, being significantly lower than that in control check.

Table 1. Effect of bagging on external fruit quality of three pummelo cultivars

| Cultivar            | Bagging time (DAF) | Peel color | Flesh color | Spongy layer Color | Thickness /cm | longitudinal diameter /cm | Transverse diameter /cm | Fruit shape index | Weight per fruit /kg | Flesh weight /kg | Edible rate /% | Oil vacuole | Segments |
|---------------------|-------------------|------------|-------------|--------------------|---------------|----------------------------|-----------------------|-------------------|---------------------|----------------|--------------|-------------|----------|
| 'Sanhongmiyou'      | 35                | Lavender blush | Light yellow with lustre | 1.01ab | 14.18h | 13.81h | 1.03a | 1.47h | 0.98b | 66.87h | Fine grained, dense & smooth | 14 |
|                     | 50                | Light yellow with lustre | 1.03a | 15.43g | 15.75g | 0.98b | 1.49g | 1.02g | 68.80g | Fine grained, dense & smooth | 15 |
|                     | 65                | Light yellow with lustre | 0.97e | 17.32f | 17.51f | 0.99b | 1.52f | 1.10f | 72.46f | Fine grained, dense & smooth | 14 |
|                     | 80                | Yellow with lustre | 1.00bc | 17.83e | 17.92e | 0.99b | 1.55e | 1.13c | 72.72e | Fine grained, dense & smooth | 13 |
|                     | 95                | Yellow with lustre | Red Pink | 0.99cd | 18.06fd | 18.34b | 0.98b | 1.57d | 1.15d | 73.05d | Fine grained, dense & slightly convex | 14 |
|                     | 110               | Yellow with lustre | 1.01ab | 18.21c | 18.01d | 0.97b | 1.60c | 1.17c | 73.45c | Grained, loose & slightly convex | 16 |
|                     | 125               | Yellow with lustre | 0.98de | 18.28b | 18.59a | 0.98b | 1.64b | 1.22b | 74.73b | Rough, loose & slightly convex | 15 |
|                     | CK                | Oliveine without lustre | 0.98de | 18.67a | 18.32c | 1.02a | 1.71a | 1.29a | 75.89a | Rough, loose & convex | 15 |
| 'Hongroumiyou'      | 50                | Light yellow with lustre | 1.57d | 16.30e | 16.58d | 0.98c | 1.47f | 1.13f | 76.76a | Fine grained, dense & smooth | 15 |
|                     | 65                | Light yellow with lustre | 1.52e | 17.70c | 17.23c | 1.03b | 1.83a | 1.38a | 75.19d | Fine grained, dense & smooth | 14 |
|                     | 80                | Yellow with lustre | 1.73h | 17.70c | 17.23c | 1.03b | 1.73b | 1.30b | 75.25c | Fine grained, dense & slightly convex | 16 |
|                     | 95                | Yellow with lustre | Red — | 1.73h | 17.80b | 17.33b | 1.03b | 1.69c | 1.27c | 75.18d | Grained, loose & slightly convex | 14 |
|                     | 110               | Yellow with lustre | 1.50e | 17.97a | 17.37a | 1.03b | 1.64d | 1.23d | 75.11e | Rough, loose & slightly convex | 14 |
|                     | 125               | Yellow with lustre | 1.83a | 17.27d | 15.90e | 1.09a | 1.57e | 1.18e | 75.50b | Rough, loose & slightly convex | 15 |
|                     | CK                | Oliveine without lustre | 1.60c | 16.07f | 15.53f | 1.03b | 1.33g | 0.99g | 74.84f | Rough, loose & convex | 15 |
| 'Huangjinmiyou'     | 50                | Light yellow with lustre | 1.52b | 16.36c | 16.17c | 0.99a | 1.38e | 0.99d | 0.69ab | Fine grained, dense & smooth | 15 |
|                     | 65                | Light yellow | 1.70a | 16.21c | 16.41c | 1.01a | 1.40d | 0.94d | 0.71a | Fine grained, dense & smooth | 16 |
|                     | 80                | Oliveine | 1.66a | 17.92ab | 17.43b | 0.97a | 1.81c | 1.41c | 0.75a | Fine grained, dense & smooth | 17 |
|                     | 95                | Oliveine | Light orange — | 1.65a | 17.42b | 17.42b | 1.00a | 1.94b | 1.47c | 0.76a | Fine grained, dense & slightly convex | 17 |
|                     | 110               | Oliveine | 1.53b | 17.82ab | 17.79ab | 0.99a | 1.99b | 1.55b | 0.76a | Grained, loose & slightly convex | 18 |
|                     | 125               | Oliveine | 1.55b | 17.68ab | 17.86ab | 1.01a | 2.03a | 1.58b | 0.78a | Rough, loose & slightly convex | 18 |
|                     | CK                | Oliveine | 1.61a | 18.27a | 18.21a | 0.99a | 2.15a | 1.65a | 0.79a | Rough, loose & convex | 17 |

Note: The different normal letters indicate significant difference at 0.05 level. The same as below.

3.2. Internal fruit quality

As shown in Table 2, bagging treatments decreased the content of internal fruit quality. The content of total soluble solid (TSS) revealed an increase change along with the delay of bagging times, which were all lower than that in control check in 'Sanhongmiyou'. While in 'Hongroumiyou' and 'Huangjinmiyou', the highest TSS content occurred at 125 days after flowering, with the value of 10.90% and 11.17%, respectively. They were no significant differences with that in control. Compared with TSS, bagging treatments increased the accumulation of total acid content. In addition, bagging treatments decreased the content of vitamin C and sugar, being significantly lower than that in control check.

Table 2. Effect of bagging on internal fruit quality of three pummelo cultivars

| Cultivar            | Bagging time (DAF) | Total soluble solid%/ | Total acid/g•100mL⁻¹ | TSS-acid ratio | Vitamin C/mg•100mL⁻¹ | Reducing sugar/g•100mL⁻¹ | Sucrose/g•100mL⁻¹ | Total sugar/g•100mL⁻¹ |
|---------------------|-------------------|----------------------|----------------------|----------------|---------------------|-------------------------|------------------|---------------------|
| 'Sanhongmiyou'      | 35                | 10.47f               | 0.97a                | 10.79h         | 39.68g              | 3.51f                   | 5.61bc           | 9.12f               |
|                     | 50                | 10.50ef              | 0.93ab               | 11.29g         | 39.91f              | 3.58g                   | 5.55d            | 9.13g               |
|                     | 65                | 10.60e               | 0.90bc               | 11.78          | 40.16e              | 3.65f                   | 5.72b            | 9.37f               |
|                     | 80                | 10.87d               | 0.86cd               | 12.64e         | 40.16e              | 3.72e                   | 5.74b            | 9.47e               |
|                     | 95                | 11.13c               | 0.82de               | 13.57d         | 40.22d              | 3.87d                   | 5.75b            | 9.63d               |

Note: The different normal letters indicate significant difference at 0.05 level. The same as below.
4. Discussion

Fruit bagging is one of the key factors in producing green fruits. This study indicated that bagging treatments effectively improved the external fruit quality of three pummelo cultivars, such as well-coloured peel, exquisite and smooth oil vacuole. The bagging fruits are in the moderate microenvironment, which makes the waxy cuticle distribute uniformly, and epidermal cells arrange closely [16]. In addition, bagging treatments make epidermis cells secrete wax, reduce lignin synthesis, few and small lenticels. These factors make the bagging fruit have smooth and light peel. The longitudinal, transverse diameter and weight per fruit have increase trends along with the delay of bagging times, all lower than that in the control check. This might be caused by the microenvironment with higher temperature and less photosynthetic products due to light deficiency, which make fruits grow slowly in the short time. Bagging fruits started to recover growth at 20 to 30 days after bagging treatments because they adapted to the new environment of bags [17]. This is consistent with previous reports about the navel orange, pear, and apple [18-20]. The remaining parameters, the thickness of spongy layer, segments, fruit shape index and edible rate are not closely related to the bagging treatments.

Previous studies suggested that the content of total soluble solid, sugar and vitamin C have decrease trends in bagging fruits [21-23]. Similar results were observed among three pummelo cultivars. The content of TSS, Vc, and sugar in no bagging fruits were all higher than that in bagging fruits. It is not helpful to accumulate the photosynthetic products and carbohydrates because bagging treatments reduce the light intensity in the bags. In addition, bagging treatments promote the accumulation of total acid. Thus, to some extent, bagging changed the taste of pummelo cultivars for eating quality. Taking the external and internal fruit quality into consideration, we considered that the best bagging time was at 35, 80, and 65 days after flowering for ‘Sanhongmiyou’, ‘Hongroumiyou’ and ‘Huangjinmiyou’. This study will provide effective basis for bagging treatments in the pummelo producing area.

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|                | 110  | 11.20c | 0.80e | 14.00c | 40.40b | 3.92c | 5.81a | 9.73c |
|----------------|------|--------|-------|--------|--------|-------|-------|-------|
| 125            |      | 11.47b | 0.77ef | 14.90b | 40.34c | 4.04b | 5.76b | 9.80b |
| CK             |      | 11.63a | 0.74f | 15.72a | 40.46a | 4.17a | 5.73b | 9.90a |
| 'Hongroumiyou' | 50   | 9.50d  | 1.04a | 9.13g  | 35.68g | 4.04b | 5.76b | 9.80b |
|                | 65   | 10.10e | 0.99b | 10.20f | 36.23f | 4.04b | 5.76b | 9.80b |
|                | 80   | 10.40bc| 0.97bc| 10.72c | 36.96e | 4.04b | 5.76b | 9.80b |
|                | 95   | 10.70ab| 0.94c | 11.34d | 37.54f | 4.04b | 5.76b | 9.80b |
| 'Huangjinmiyou' | 110  | 10.82a | 0.89d | 12.16e | 38.01c | 4.04b | 5.76b | 9.80b |
|                | 125  | 10.90a | 0.85e | 12.82b | 39.56b | 4.04b | 5.76b | 9.80b |
| CK             |      | 11.00a | 0.81f | 13.58a | 40.01a | 4.04b | 5.76b | 9.80b |

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Fruit bagging is one of the key factors in producing green fruits. This study indicated that bagging treatments effectively improved the external fruit quality of three pummelo cultivars, such as well-coloured peel, exquisite and smooth oil vacuole. The bagging fruits are in the moderate microenvironment, which makes the waxy cuticle distribute uniformly, and epidermal cells arrange closely [16]. In addition, bagging treatments make epidermis cells secrete wax, reduce lignin synthesis, few and small lenticels. These factors make the bagging fruit have smooth and light peel. The longitudinal, transverse diameter and weight per fruit have increase trends along with the delay of bagging times, all lower than that in the control check. This might be caused by the microenvironment with higher temperature and less photosynthetic products due to light deficiency, which make fruits grow slowly in the short time. Bagging fruits started to recover growth at 20 to 30 days after bagging treatments because they adapted to the new environment of bags [17]. This is consistent with previous reports about the navel orange, pear, and apple [18-20]. The remaining parameters, the thickness of spongy layer, segments, fruit shape index and edible rate are not closely related to the bagging treatments.

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