Effect of Bagging on 'Shiranuhi' Mandarin Fruit Quality during Growth and Storage

Doo-Gyung Moon, Sang-Woog Ko, Sung-Gap Han, Chun-Hwan Kim, Chang-Kyu Lim, Jae-Ho Joa

Abstract— **Soluble solids content and acidity are major determinants of fruit taste in citrus. It has been observed that fruit from top-grafted trees retain higher acidity than on-root stock in 'Shiranuhi' mandarin [(*C. unshiu* x *C. sinensis)* x *C. reticulata*]. In order to identify cultural practices that affect acidity in 'Shiranuhi' mandarin, we tested the effect of cover (fruit bagging) on fruit quality(size; soluble solids; acidity) from 50 days after anthesis, to 90 days postharvest in 7-8 year-old 'Shiranuhi' mandarin trees secondary grafted onto satsuma mandarin scaffolds on trifoliate orange rootstocks. Transverse diameter and longitudinal length were smallest in fruit covered with the black printed paper. No differences were observed between treatments in soluble solids content, but acidity in fruit juice was higher in non-bagged controls from 95 days after anthesis to 90 days postharvest. Citric and malic acid content was highest in the control at 125 days after anthesis. Mean temperature was 0.3-0.7℃ higher than ambient in fruit bags during fruit maturation. These results suggest higher temperature during growth and ripening may be responsible for lowered acidity in bagged 'Shiranuhi' mandarin fruit.**

Index Terms— **Acidity, Fruit bagging, Fruit size, Temperature**

I. INTRODUCTION

Sales of 'Shiranuhi' mandarin are increasing annually in Korea owing to the high quality of domestically grown fruit. 'Shiranuhi' mandarin is generally known to have higher soluble solids content (SSC), acidity, and fruit weight when compared with other mandarins. For this reason,growers have top-grafted 'Shiranuhi' mandarin onto satsuma mandarin trees and are shipping fruit 3-4 years after grafting.

However, the acidity in fruit from top-grafted trees has been found to be higher than in fruit from planted stock on 'Shiranuhi' mandarin trees [1]. Among approaches to addressing this problem, work is underway to evaluate the effect that trifoliate orange (*Poncirus trifoliata*) has on tree growth and fruit acidity when used as rootstock for 'Shiranui' mandarin.

However, cultural practices like fruit thinning [2-4], regulation of soil moisture [5], and other factors including the position of fruit within the canopy and harvesting pattern [4] have been found to influence fruit SSC and acidity in citrus. Also, fruit bagging during growth and maturation has been found to affect sugar and organic acid content in peach and pear fruits [6-8].

In addition to the observation that fruit from top-grafted stock retained more acidity than planted stock on 'Shiranuhi' mandarin trees [1], it has been reported that acidity in fruit from planted stock on 'Shiranui' mandarin was higher in the upper parts of the canopy [4], and that Shiranuhi' mandarin retains more acid and accumulates less sugar when exposed to moisture stress [5]. These observations point to the potential of targeted cultural practices as a means for manipulating fruit acidity in 'Shiranui' mandarin including in top-grafted stock.

This study investigated the effect of fruit bagging on fruit size, SSC, and acidity in fruit from top-grafted 'Shiranuhi' mandarin trees. We report the effect of bagging on fruit size and acidity during growth, maturation and storage.

II. MATERIAL AND METHODS

2.1. Plant Materials and Experimental Design

'Shiranuhi' mandarin [(*C. unshiu* x *C. sinensis*) x *C. reticulata*] secondary grafted onto 7-8-year-old satsuma mandarin trees on trifoliate orange rootstocks were obtained from a commercial orchard in Jeju (Korea). The trees were transferred into a non-heated plastic house and used for the study. The bagging treatments consisted of gray paper or black printed bags (Figure 1-A). The paper bags, supplied by Namhae Fruit Paper Bag Product Co., Ltd. (Namhae, Korea), were constructed with twin layers: a yellow inner layer, and a gray (gray paper bag) or black printed (black printed bag) outer layer and coated with wax.

Doo-Gyung Moon, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2564

Sang-Woog Ko, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-63-238-6740.

Sung-Gap Han, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-730-4172

Chun-Hwan Kim, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2540

Chang-Kyu Lim, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2550

Jae-Ho Joa, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2581

Figure 1: Graphic representation of bagging treatments (A) and fruit storage conditions post-harvest (B) in 'Shiranuhi' [(*C. unshiu x C. sinensis*) x *C. reticulata*] mandarin trees top-grafted onto satsuma mandarin and grown in a non-heated greenhouse.

A total of 300 fruit per treatment (10 fruit per tree for 10 trees replicated three times) were bagged after fruit thinning in early June. Care was taken to ensure that selected fruit in bagged and non-bagged (control) treatments were similar in terms of size and canopy position. Ten fruits per treatment were sampled monthly starting from 50 days after anthesis (DAA) to 90 days after storage (DAS) and used to characterize growth and quality. Fruit storage (Figure 1-B) occurred after harvesting (230 DAA) and was conducted for 90 days. Temperature in fruit bags was measured using a HOBO (HOBO U23 Pro v2, Onset Computer Corp., USA) from 50 DAA (1 July) to 90 DAS (15 May).

2.2. Fruit Growth Characteristics and Fruit Quality Analysis

Fruit diameter and length were measured during growth and maturation (65 DAA to 185 DAA) using a pair of digital calipers (Matsui, Japan).

Juice samples were manually extracted from the fruit by pressing through cheesecloth followed by filtration, and stored at -20°C pending analysis. After thawing to room temperature, SSC was measured using a digital refractometer (PR-1, Atago, Tokyo, Japan), while acidity was determined by titrating 1 mL of juice with 0.1N NaOH to pH 8.1, using phenolphthalein as the indicator. Titratable acidity was converted to a citric acid equivalent.

Organic acid content was analyzed using a Dionex Bio-LC chromatograph (Dionex, USA). Samples were filtered through a 0.45 μm Millipore filter and diluted (x1000) with pure water. The detector was equipped with an electrochemical conductivity meter. Bio-LC conditions during analysis of organic acid were as follows; the column was a Ionpac® ICE-AS6; the mobile phase was 0.4mM heptafluorobutyric acid; the injection volume was 0.5 μL; the flow rate was 0.9 μL· min^{-1} and column temperature 28 °C.

2.3. Statistical Analysis

Analyses of variance and Duncan's multiple range tests were performed to compare data and separate means using the SAS program. Differences were considered significant where P= 0.05.

III. RESULTS AND DISCUSSION

3.1. Fruit Size

Transverse diameter tended to be longer in control relative to bagged fruit from 125 to 155 DAA (Figure 2), and was smallest in fruit covered with black printed paper from 125 to 185 DAA. Longitudinal length was also smaller in fruit covered with black printed paper from 125 DAA to harvest (Figure 2). However, there were significant differences in fruit size between the gray paper treatment and the control. Fruit size differences were probably due to variations in temperature between control and covered fruit during fruit growth and development. Bagging is already known to affect the size and weight of apple [9], banana [10], and loquat [8] when compared with uncovered controls. Temperature in fruit bags was higher in the black printed paper compared with gray paper and the ambient control (Figure 6). Thus, fruit sizes may be affected by internal temperature within fruit bags during growth and maturation.

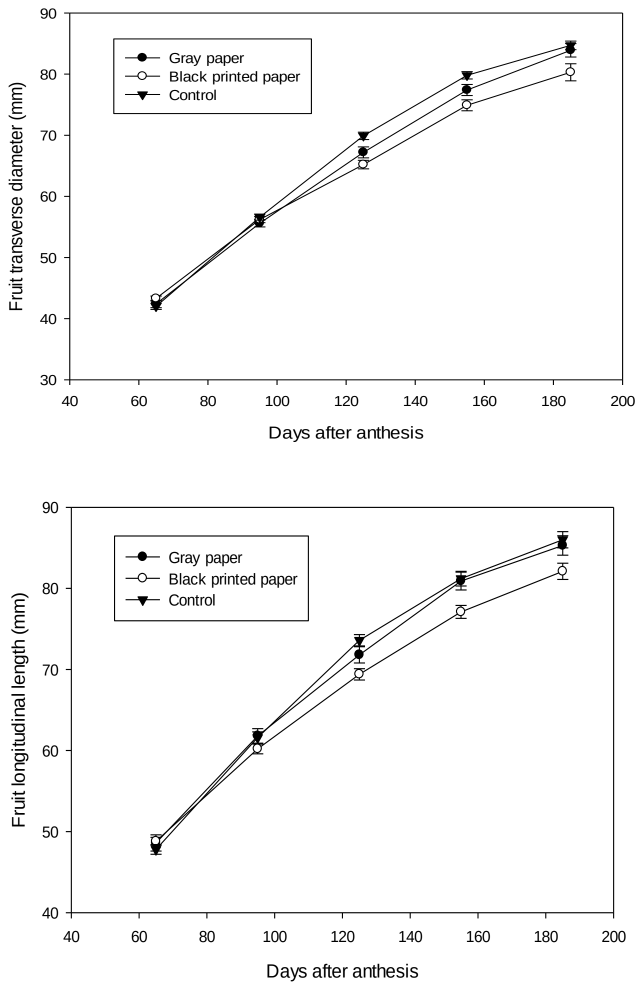

Figure 2: Changes in fruit growth during maturation in bagged and non-bagged 'Shiranuhi' [(*C. unshiu x C. sinensis*) x *C. reticulata*] mandarin fruit. Vertical bars represent standard error (n=10 trees).

3.2. Fruit Quality during Fruit Growth, Maturation and Storage

There was no difference in fruit juice SSC between the control and bagging treatments during development and maturation (Figure 3). Changes in SSC have been shown to be positively correlated with maturation processes [11], translocation of photosynthates to fruit [12], cumulative solar radiation [13], osmotic potential [14], and differential sink strength at enzyme level [15]. However, there was little effect on SSC in bagged loquat fruit [8], or in response to bag type in longan [16]. Our results similarly show that ‘Shiranuhi’ SSC was not affected by fruit bagging during growth, maturation and storage.

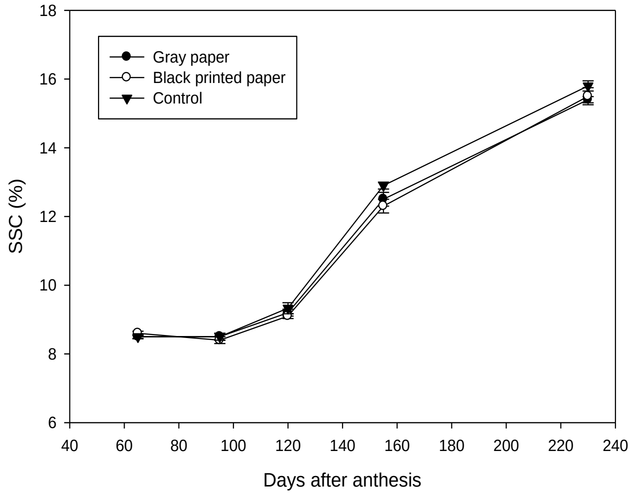

Fig. 3: Change in soluble solids content during maturation of bagged and non-bagged ‘Shiranuhi’ [(*C. unshiu x C. sinensis*) x *C. reticulata*] fruit. Vertical bars represent standard error (n=10 trees).

However, titratable acidity was 0.2~1.5% higher in the control compared with bagged fruit from 95 to 230 DAA (Figure 4) and lowest in fruit covered with black printed paper at 95 DAA. The differences in acid content among control and bagged samples were higher at 95 compared with 125, 155 and 230 DAA. Variations in acid content between bagged and control fruit may be associated with higher temperatures in fruit bags during summer, a period that coincides with rapid fruit development.

Organic content acid was highest in the control at 125 DAA (Table 1). Citric and malic acids were 1.8±0.05% and 0.15±0.01% for gray paper, 1.7±0.10% and 0.15±0.01% for black printed paper, and 2.1±0.07% and 0.20±0.01% for control, respectively, at 125 DAA. Both acids were significantly higher in control as compared with bagged fruit (Table 1). Citric acid, the major organic acid in citrus, generally decreases with fruit maturity. However, malic and oxalic acids are higher in ‘Shiranuhi’ than in satsuma mandarin fruit [17]. Our results suggest that organic acid content in bagged and control fruit was apparently affected by temperature with the higher temperature in fruit bags contributing to accelerated fruit pulp maturation. Therefore, we may conclude that the higher temperature within fruit bags affects cell growth and maturation through increased respiration of fruit juice sacs. Bagging treatments did not affect SSC but decreased organic acid content in pear [7]. These results suggest that citric and malic acids may be degraded by the higher temperature in fruit bags. Further studies on temperature effects on synthesis and degradation of organic acids in ‘Shiranuhi’ mandarin fruit are needed.

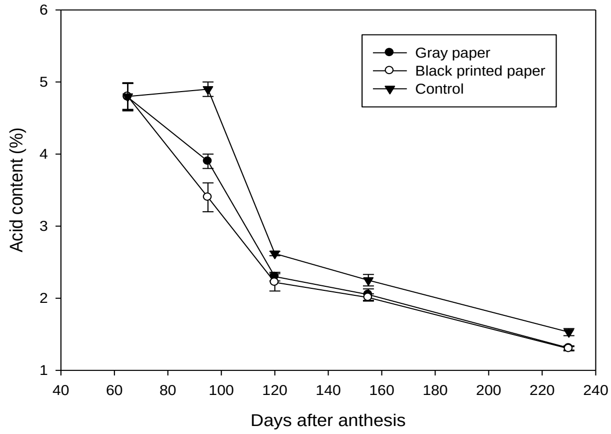

Fig. 4: Change in acid content of fruit during maturation of bagged and non-bagged ‘Shiranuhi’ [(*C. unshiu x C. sinensis*) x *C. reticulata*] mandarin fruit. Vertical bars represent standard error (n=10 trees).

Table 1: Citric and malic acid contents in bagged and non-bagged ‘Shiranui’ mandarin fruit at 125 days after anthesis.

Treatments	Citric acid content	Malic acid content
Gray paper	[z]1.8±0.05b[x]	0.15±0.01b
Black printed paper	1.7±0.10b	0.15±0.01b
Control	2.1±0.07a	0.20±0.01a
Significance	*	*

[z] Mean±standard error (n=10 trees).
[x] Mean separation within columns by Duncan’s multiple range test at P = 0.05.
* Significant at P = 0.05.

Acid content was lower in bagged than in control fruit from 30 to 90 DAS during fruit storage and highest in the control from harvest to 90 DAS (Figure 5). No differences in acid content were observed between the bagging treatments during fruit growth, maturation and storage. However, it was observed that some of the fruit covered with black printed paper sometimes suffered from sunburn at the height of summer (data not shown).

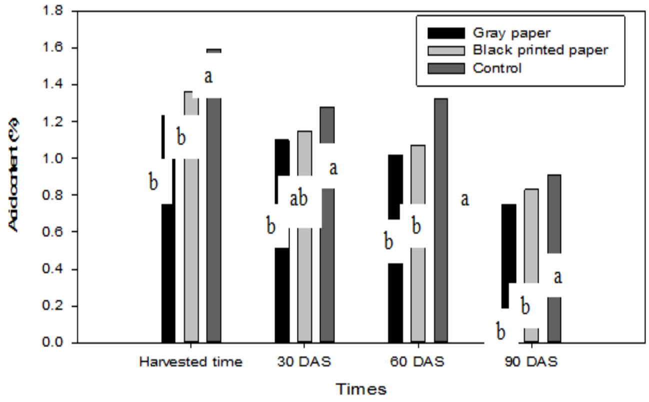

Figure 5: Effects of cover with paper bags on acid content during growth and storage of ‘Shiranuhi’ mandarin fruit. Columns labeled with the same letter are not significantly different at P = 0.05.

3.3. Temperature in Fruit Bags and Ambient Control

Temperature means were 26.6 °C, 27.1 °C and 26.1 °C in July, 27.4 °C, 27.9 °C and 26.9 °C in August, 22.6 °C, 23.0 °C and 22.4 °C in September, 17.2 °C, 17.6 °C and 17.0 °C in October, 11.9 °C, 12.2 °C and 11.2 °C in November, 8.5 °C, 8.8 °C and 8.4 °C in December, 5.5 °C, 5.9 °C and 5.3 °C in January, 6.7 °C, 6.9 °C and 6.6 °C in February, 7.7 °C, 7.7 °C and 7.7 °C in March, 13.6 °C, 13.4 °C and 14.3 °C in April and 16.7 °C, 16.7 °C and 19.3 °C in May for the gray paper, black printed paper and ambient control, respectively (Figure 6A). Differences in mean temperature between fruit bags and the control ranged from 0.3-0.7 °C from July to February. Mean temperature was highest in black printed bags from July to February and higher than the control in the gray paper bags during fruit growth and maturation. Variations were clearest during daytime when temperature was in the order: black printed paper>gray paper>control. Overall, temperature was significantly higher in the black printed and gray papers than in the control. For example, on August 1, it was 45.3 °C for the black printed paper, 41.9 °C for the gray paper and 39.7 °C for the control at 4:00 pm (Figure 6B). No differences in temperature were observed at the start of storage to 60 DAS (Figure 6A). But, mean temperature was highest in the control at 90 DAS with outside temperature increasing. Differences in mean temperature between paper bags and the control was 2.6 °C at 90 DAS.

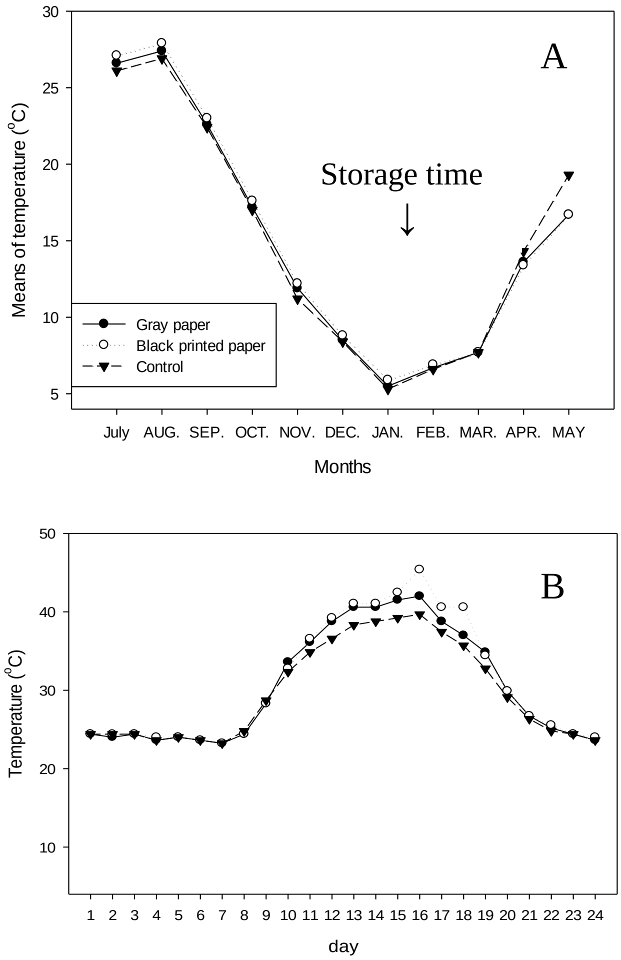

Figure 6: Change in mean monthly (A) and diurnal temperature for August 1 (B) within bags used to cover 'Shiranui' mandarin fruit (treatments) and control (ambient) conditions.

The 'Shiranuhi' mandarin fruit presented in Figure 7 shows how bagging from 50 DAA to 90 DAS improved fruit surface color. The fruit surface was lighter in bagged fruit than in the control. Our observations are in agreement with Xu *et al.* [8] and Seo *et al.* [18] who report that bagging improved fruit surface lightness in loquat and pear, respectively. However, the color from green to red for value of fruit peel at harvest was highest in the control (Figure 7). This result suggests that change in fruit peel color was also affected by the higher temperature associated with fruit bagging. However, the percentage of decay at 90 DAS was about 6.0 times higher in the control (data not shown). Further studies are required to evaluate on the treatment times and bag type for improvement of fruit quality.

In conclusion, we recommend that fruit bagging be applied during growth and maturation, and storage as part of crop management in order to lower acidity and reduce fruit decay in top-grafted 'Shiranuhi' mandarin trees. Our results show that bagging with gray paper is most suitable for maintaining the quality of the 'Shiranuhi' mandarin fruit.

Figure 7: Peel texture and shape of bagged and non-bagged 'Shiranuhi' [(*C. unshiu x C. sinensis*) x *C. reticulata*] mandarin fruit. (Left: control, middle: gray paper, Right: black printed paper).

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Doo-Gyung Moon, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2564

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Sung-Gap Han, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-730-4172

Chun-Hwan Kim, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2540

Chang-Kyu Lim, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea, +82-64-741-2550

Jae-Ho Joa, National Institute of Horticultural and Herbal Science, Rural Development administration, Jeju 63240, Republic of Korea,
+82-64-741-2581