Effects of Calcium Application on Fruit Quality of Pitaya

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Summary

Pitaya is one of the most important commercial cactus fruit. Pitaya fruits are easy to get injury during postharvest handling and storage. Pre-harvest and postharvest calcium treatments have been used to maintain flesh firmness and extend shelf life of many fruits. The aim of this study was to evaluate the effects of calcium treatments on maintaining pitaya fruit quality during cold storage.

Pitaya fruits were treated with different concentrations of calcium chloride solution at pre-harvest or postharvest and then stored at 5℃. Fruit pulp firmness increased after storage but calcium treatments did not increase it. Calcium treatments did not reduce skin injury during cold storage. In some cases, calcium treatment even increased skin injury level. Calcium contents in the pulp were not effectively increased by calcium treatments. Total soluble solid and titratable acid were reduced after cold storage, and calcium treatments did not have consistent effects on them. Peel thickness was also reduced after storage. Fruits bagged with PE bags during cold storage reduced weight loss, but increased skin injury.

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Introduction

Pitaya (*Hylocereus undatus* Britt.& Rose), native to Latin America (Le Bellac and Vaillant, 2011; Zee *et al*., 2004), is one of the most important commercial cactus fruit in the world (Ortiz-Hernández *et al*., 2012).

Pitaya fruit is a non-climacteric fruit, having low respiration and ethylene production during maturity and storage time, and generally they are sensitive to chilling injury (Zee *et al*., 2004). Pitaya fruits harvested at close to full color maintained market quality for at least 2 weeks at 14℃ or 1 week at 20℃ (Nerd *et al*., 1999). Pitaya fruits harvested at full color stage can be stored at low temperature up to 6℃ (Le Bellec *et al*., 2006). The fruits stored at 6℃ maintained eating quality for at least three weeks but became worse rapidly when transferred to room temperature (Nerd *et al*., 1999).

Pre-harvest and postharvest calcium treatment has been used to maintain flesh firmness and extend shelf life of many fruits (Casero *et al*., 2009; Ghani *et al*., 2011; Manganaris *et al*., 2006; Sams *et al*., 1999). The aim of this study was to evaluate the effect of pre-harvest and postharvest calcium treatments on maintaining pitaya fruit quality during cold storage.

Materials and methods

1. Pre-harvest calcium treatment

White flesh pitaya (*Hylocereus undatus*) plants, grown in Taichung District Agricultural Research and Extension Station, Taiwan, were used in this study. Pre-harvest calcium treatments were conducted at 1~2 days after anthesis by the use of calcium chloride solution sprayed to the whole fruit peel. Forty fruits, ten fruits as one replicate, were sprayed with 100 mM calcium chloride solution, and another forty fruits were sprayed with 200 mM calcium chloride solution. Tween 20 (0.1%; v/v) was added to each calcium solutions. The control fruits were sprayed with deionized water. At 1 week after the first spray, fruits were sprayed again. After the second spray, fruits were covered immediately with paper bags. Half of fruit of each treatment were harvested at 29 day after anthesis. The other fruits were harvested at 36 days after anthesis. After harvest, fruits were transported to the laboratory immediately. Ten fruits of each treatment were analyzed on the harvest day. The other fruits were packed in corrugated boxes and stored at 5℃, and were taken for evaluation after 6 weeks of storage.

Postharvest calcium treatment

White flesh pitaya (*Hylocereus undatus*) plants grown in Horticultural Research Station of National Chung Hsing University, Taiwan, were used in this study. Fruits were covered immediately with paper bags at 1~2 days after anthesis. Fruits were harvested at 35 days after anthesis when reached commercial maturity. After harvest, fruits were transported to the laboratory immediately. After measurement of fresh weight, ten fruits were vacuumed (-250 mm Hg) with 100 mM calcium chloride solution for 10 minutes, another ten fruits were dipped with 100 mM calcium chloride solution. The control fruits were dipped with deionized water. Five fruits of each treatment were bagged by polyethylene bag. The other fruits were not bagged. Five non-treated fruits were analyzed on the harvest day. All of treated fruits were packed in corrugated boxes and stored at 5℃, and were taken for evaluation after 5 weeks of storage.

2. Measurement and analysis

(1) Parameters of measurement

Fresh weight (FW) was measured by weight scale on the harvest day before storage. After storage, fruits were measured again before evaluation of fruit quality. The weight loss was then calculated.

Fruits were cut in cross-section and flesh firmness was measured with a fruit pressure tester (FT 011, FACCHINI).Peel thickness was measured with vernier caliper (CD-6BS, Mitsutoyo) at two points on the fruit equator without scales.

The total soluble solid (TSS) of fruit juice was measured with a digital handheld Refracmeter (PAL, P-1, Atago) and titratable acid was determined by titration with 0.1 N NaOH, end point pH 8.2, using a Radio Titrab 840 autoburette. The pH of fruit juice was measured with a glass electrode pH meter.

Skin injury level was scored on whole fruit peel; no injury =0, 1~20% injury =1, 21~40% injury =2, 41~60% injury =3, 61~80% injury =4, 81~100% injury = 5. Skin injury caused by chilling and pathogens were all included.

Frozen dry samples of peel and pulp were used. One gram dry sample was completely incinerated and ash samples were diluted by adding deionized water up to 25 ml. Taking 0.1 ml of the diluted solution and 3.9 ml deionized water and 1.0 ml 5 % LaO_3 were added. After vortex, the calcium contents were determinate by the Atomic Absorption Spectrophotometer Systems (Z-2000, Hitachi High-Technologies Corporation).

(2) Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) using SAS version 9.3 and mean separation was conducted using Least Significant Difference test at $p \leq 0.05$.

Results

1. Pre-harvest calcium treatment

Fruit pulp firmness decreased after 6 weeks of storage in the 1st harvest fruits, but increased in the 2nd harvest fruits (Table 1). Calcium treatment did not improve fruit firmness. Peel thickness and titratable acid decreased after 6 weeks of cold (5℃) storage (Table 1; Table 2). Calcium treatment did not reduce skin injury (Table 3). Calcium contents in pulp increased after storage and calcium treatment did not increase calcium contents in peel and pulp (Table 4).

Table 1. Effects of pre-harvest calcium treatment on weight loss, flesh firmness and peel thickness of pitaya fruit at harvest and after 6 weeks of cold (5℃) storage.

Treatment			Weight loss (%)	Firmness (kg)	Peel thickness (mm)
100 mM $CaCl_2$	1st harvest[z]	at harvest	-	1.19 ±0.15 a	3.36±0.16[y]abc
		after storage	10.97±0.92[y]ab[x]	0.89±0.08 ef	2.44±0.34 f
	2nd harvest	at harvest	-	0.76±0.07 g	3.54±0.25 ab
		after storage	10.14±1.07 bc	1.04±0.09 cd	2.42±0.13 f
200 mM $CaCl_2$	1st harvest	at harvest	-	1.19±0.06 a	3.08±0.26 cd
		after storage	11.46±1.17 a	0.95±0.08 de	2.32±0.36 f
	2nd harvest	at harvest	-	0.86±0.09 efg	3.60±0.36 a
		after storage	10.02±0.96 c	1.06±0.10 bcd	2.89±0.36 de
Water	1st harvest	at harvest	-	1.15±0.16 ab	3.06±0.37 cd
		after storage	11.02±1.08 ab	1.04±0.08 cd	2.52±0.42 ef
	2nd harvest	at harvest	-	0.82±0.07 fg	3.21±0.09 bcd
		after storage	10.17±1.02 bc	1.17±0.07 ab	2.36±0.18 f

[z]1st harvest: fruits were harvested at 29 days after anthesis.
2nd harvest: fruits were harvested at 36 days after anthesis.
[y]Mean±standard deviation.
[x] Mean separation within columns by Least Significant Difference test at p≤0.05

Table 2. Effects of pre-harvest calcium treatment on total soluble solid, titratable acid and pH of pitaya fruit at harvest and after 6 weeks of cold (5℃) storage.

Treatment			Total soluble solid (°Brix)	Titratable acid (%)	pH
100 mM $CaCl_2$	1st harvest[z]	at harvest	13.56±0.74 cd	0.92±0.07[y] a[x]	4.46±0.06 e
		after storage	13.48±0.78 d	0.24±0.02 cd	5.38±0.08 a
	2nd harvest	at harvest	15.30±0.69 a	0.55±0.07 b	5.03±0.06 d
		after storage	14.62±1.03 abc	0.32±0.02 cd	5.27±0.10 bc
200 mM $CaCl_2$	1st harvest	at harvest	13.42±0.91 d	0.96±0.18 a	4.45±0.06 e
		after storage	12.94±0.74 d	0.21±0.02 d	5.38±0.08 a
	2nd harvest	at harvest	15.11±1.00 a	0.57±0.07 b	4.98±0.15 d
		after storage	14.69±0.75 ab	0.32±0.01 c	5.20±0.10 c
Water	1st harvest	at harvest	13.27±0.97 d	0.87±0.17 a	4.41±0.07 e
		after storage	13.29±0.69 d	0.26±0.05 cd	5.36±0.07 ab
	2nd harvest	at harvest	15.31±0.95 a	0.53±0.08 b	5.01±0.13 d
		after storage	13.98±1.06 bcd	0.25±0.02 cd	5.34±0.07 ab

[z]1st harvest: fruits were harvested at 29 days after anthesis.
2nd harvest: fruits were harvested at 36 days after anthesis.
[y]Mean±standard deviation.
[x] Mean separation within columns by Least Significant Difference test at $p \leq 0.05$

Table3. Effects of pre-harvest calcium treatment on skin injury of pitaya fruit after 6 weeks of cold (5℃) storage

Treatment		Skin injury
100 mM $CaCl_2$	1st harvest[z]	1.20±0.45[y]
	2nd harvest	0.70±0.27
200 mM CaCl2	1st harvest	1.60±0.42
	2nd harvest	1.10±0.65
Water	1st harvest	1.20±0.57
	2nd harvest	0.40±0.42

[z]1st harvest: fruits were harvested at 29 days after anthesis.
2nd harvest: fruits were harvested at 36 days after anthesis.
[y]Mean±standard deviation. Skin injury level of whole fruit peel; no injury =0, 1~20% injury =1, 21~40% injury =2, 41~60% injury =3, 61~80% injury =4, 81~100% injury = 5.

Table 4. Effects of pre-harvest calcium treatment on calcium contents in pitaya fruit at harvest and after 6 weeks cold (5℃) storage

Treatment			Calcium contents (%)	
			Peel	Pulp
100 mM $CaCl_2$	1st harvest[z]	at harvest	1.054±0.141[y] a[x]	0.070±0.004 a
		after storage	0.955±0.059 abc	0.051±0.004 b
	2nd harvest	at harvest	0.939±0.058 abc	0.039±0.003 de
		after storage	0.845±0.164 c	0.043±0.008 cde
200 mM $CaCl_2$	1st harvest	at harvest	0.895±0.022 bc	0.042±0.010 cde
		after storage	0.864±0.070 bc	0.050±0.009 b
	2nd harvest	at harvest	0.976±0.048 ab	0.037±0.002 e
		after storage	0.899±0.059 bc	0.046±0.002 bcd
Water	1st harvest	at harvest	0.870±0.155 bc	0.039±0.005 de
		after storage	0.928±0.027 bc	0.047±0.004 bc
	2nd harvest	at harvest	0.887±0.092 bc	0.037±0.005 e
		after storage	0.802±0.083 d	0.047±0.004 bc

[z]1st harvest: fruits were harvested at 29 days after anthesis.
2nd harvest: fruits were harvested at 36 days after anthesis.
[y]Mean±standard deviation.
[x] Mean separation within columns by Least Significant Difference test at $p \leq 0.05$

2. Postharvest calcium treatment

Bagging treatment reduced fruit weight loss. All bagged fruits had lower weight loss than non-bagged fruits (Table 5). Compared to pre-treatment, fruit pulp firmness increased after storage. Calcium treatment did not increase fruit pulp firmness. Bagging had the effect of increasing peel thickness. Total soluble solid of all treated fruits decreased after storage, compared to pre-treatment fruits. Skin injury appeared earlier and more severe in bagging treatment fruits (Table 6). Vacuum treatment with 100mM calcium treatment slightly increased calcium contents in the peel, but not in the pulp (Table 7).

Table 5. Effects of postharvest calcium vacuum and dipping treatment on fruit characteristics of pitaya after 5 weeks of cold (5℃) storage.

Treatment	Weight loss (%)	Firmness (kg)	Peel thickness (mm)
Dipping water	6.77±0.38[z]ab[y]	0.96±0.17 bc	1.73±0.39 c
Dipping water +bagging	0.34±0.22 c	0.90±0.16 cd	2.75±1.22 ab
Vacuum water	7.21±0.65 a	1.07±0.17 abc	2.08±0.32 bc
Vacuum water +bagging	0.41±0.28 c	1.14±0.15 ab	3.34±0.50 a
Dipping 100mM $CaCl_2$	6.17±0.74 b	1.17±0.06 a	2.17±0.48 bc
Dipping 100mM $CaCl_2$ + bagging	0.38±0.20 c	1.06±0.09 abc	3.25±0.74 a
Vacuum 100mM $CaCl_2$	7.23±0.74 a	1.13±0.13 ab	2.43±0.48 bc
Vacuum 100mM $CaCl_2$ + bagging	0.41±0.14 c	1.09±0.18 ab	2.26±0.10 bc
Pre-treatment	-	0.79±0.13 d	2.29±0.36 bc

Treatment	Total soluble solid (°Brix)	Titratable acid (%)	pH
Dipping water	13.0±1.3 c	0.49±0.05 a	5.32±0.11 a
Dipping water + bagging	14.1±0.7 bc	0.47±0.10 a	5.28±0.19 a
Vacuum water	14.2±1.1 bc	0.48±0.10 a	5.36±0.04 a
Vacuum water + bagging	13.5±0.8 bc	0.50±0.08 a	5.32±0.05 a
Dipping 100 mM $CaCl_2$	13.9±1.1 bc	0.53±0.07 a	5.34±0.06 a
Dipping 100 mM $CaCl_2$ + bagging	14.7±1.2 ab	0.55±0.03 a	5.30±0.06 a
Vacuum 100 mM $CaCl_2$	13.2±1.6 c	0.48±0.08 a	5.37±0.12 a
Vacuum 100 mM $CaCl_2$ + bagging	13.4±0.7 bc	0.53±0.10 a	5.34±0.08 a
Pre-treatment	15.7±1.4 a	0.46±0.07 a	5.25±0.12 a

[z]Mean±standard deviation.

[y]Mean separation within columns by the Least Significant Difference test at $p \leq 0.05$.

Table 6. Effects of postharvest calcium vacuum and dipping treatment on skin injury of pitaya fruit after cold (5℃) storage.

Treatment	Storage		
	3 weeks	4 weeks	5 weeks
Dipping water	0.00±0.00	0.40±0.55	0.60±0.55
Dipping water + bagging	0.40±0.55	0.80±0.84	2.20±0.45
Vacuum water	0.00±0.00	0.20±0.45	1.40±0.55
Vacuum water + bagging	0.20±0.45	0.60±0.55	2.00±1.00
Dipping 100mM $CaCl_2$	0.00±0.00	0.00±0.00	0.60±0.55
Dipping 100mM $CaCl_2$ + bagging	0.40±0.55	1.40±0.55	2.60±0.89
Vacuum 100mM $CaCl_2$	0.00±0.00	0.20±0.45	1.20±1.10
Vacuum 100mM $CaCl_2$ + bagging	0.40±0.55	1.60±0.55	3.00±1.22

[z]Mean±standard deviation. Skin injury level of whole fruit peel; no injury =0, 1~20% injury =1, 21~40% injury =2, 41~60% injury =3, 61~80% injury =4, 81~100% injury = 5.

Table 7. Effects of postharvest calcium vacuum and dipping treatment on calcium contents in pitaya fruit after 5 weeks of cold (5℃) storage

Treatment	Calcium contents (%)	
	Peel	Pulp
Dipping water	0.511±0.090[z]ab[y]	0.022±0.007 a
Dipping water + bagging	0.388±0.033 b	0.020±0.007 a
Vacuum water	0.448±0.123 ab	0.018±0.004 a
Vacuum water + bagging	0.516±0.120 ab	0.021±0.003 a
Dipping 100 mM $CaCl_2$	0.449±0.101 ab	0.021±0.002 a
Dipping 100 mM $CaCl_2$ + bagging	0.392±0.066 b	0.019±0.003 a
Vacuum 100 mM $CaCl_2$	0.572±0.118 a	0.021±0.006 a
Vacuum 100 mM $CaCl_2$ + bagging	0.529±0.116 a	0.024±0.005 a
Pre-treatment	0.559±0.104 a	0.019±0.009 a

[z]Mean±standard deviation.

[y]Mean separation within columns by the Least Significant Difference test at $p \leq 0.05$.

Discussion

The firmness of red flesh pitaya (*H. polyrhizus*) fruit was increased by pre-harvest calcium treatment (Ghani *et al*., 2011). The firmness of red flesh pitaya fruit slices treated at high calcium chloride concentration (7.5 g L^{-1}) increased in the 4 min dipping treatment but reduced as the durations of dipping were extended to 8 and 12 min (Chuni *et al*., 2010). In the current study, firmness of mature white flesh pitaya (*H. undatus*) fruit increased after storage (Table 1). However, pre-harvest calcium splay was not effective in increasing fruit flesh firmness.

Calcium treatment had no significant effects on total soluble solid and titratable acid of red flesh pitaya (Ghani *et al*., 2011). Calcium treatment also did not cause any significant effects on color, pH, titratable acidity and ascorbic acid content of fresh cut red flesh pitaya fruit (Chuni *et al*., 2010). In this study, total soluble solid and titratable acid decreased during storage (Table 2; Table 5), and calcium treatments did not have significant effects on them.

Pitaya could be maintained market quality for at least 3 weeks at 6℃, 2 weeks at 14℃, and 1 weeks at 20℃ (Nerd *et al*., 1999). In this study, pitaya can be stored for 3~4 weeks at 5℃ (Table 6).

Generally, calcium treatments have been shown to alleviate chilling injury of many horticultural commodities (Wang *et al*., 2004). The chill-induced damage increased progressively during cold storage of cactus pear and became much more extensive during the simulated marketing period (Schirra *et al*., 1997). Although pre-storage calcium treatments were reported to maintain quality and storage life of fruit and vegetables, however, some cultivars of fruits do not tolerate calcium treatments, which may lead to peel injury (Schirra *et al*., 1997). In this study, the skin injury of pitaya fruits appeared as small blown spot on peel and then extend as storage proceeded.

The efficiency of pre-harvest calcium applications depends on many parameters, including: time of application, formula, growth conditions and cultivar properties (Manganaris *et al*., 2006). Pre-harvest calcium chloride application increased fruit calcium contents, especially in fruit peel of red flesh pitaya (Ghani *et al*., 2011). Postharvest calcium chloride treatment also increased calcium content in red flesh pitaya fruit (Awang *et al*., 2011). In this study, it was found that the calcium content in pitaya fruit peel was higher than that in the flesh (Table 4; Table 7). Calcium contents in peel might be increased by pre-harvest and postharvest calcium treatments, but calcium contents in pulp were less affected by the calcium treatment (Table 4; Table 7).

Vacuum infiltration of calcium was found to be an effective treatment for tomato to extend shelf life (Senevirathna *et al*., 2010). Pressure infiltration with 12% calcium chloride was an effective method for increasing calcium content in apple fruit tissues (Conway and Sams, 1983). There were significant improvements in storability of peach fruit resulting from the calcium chloride dipping treatment with polyethylene bags (Lysiak *et al*., 2008). The calcium chloride treatment for peach fruits improved firmness and maintained the soluble solids content. Polyethylene bags also minimized weight loss. In this study, polyethylene bags significantly reduced weight loss of pitaya fruit during cold storage and total soluble solid and titratable acid were not affected (Table 5). However, skin injury was increased in bagged fruits, compared to non-bagged fruits (Table 6). Mold infection was more severe in the bagging treatments.

In summary, total soluble solid, titratable acid and peel thickness of pitaya fruit decreased, but pulp firmness increased after cold storage. Postharvest calcium treatment is an effective method for increasing calcium content in peel of pitaya fruits. However, calcium treatment did not effectively increase fruit pulp firmness and reduce skin injury. Polyethylene bags can minimize weight loss of pitaya fruit during cold storage, but mold infection was increased by the bagging treatment.

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鈣施用對紅龍果果實品質之影響

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關鍵字：紅龍果、鈣處理、果實品質、冷藏

摘要：紅龍果是一個重要商業栽培的仙人掌果。紅龍果很容易在採收後貯運過程中損壞。採前和採後鈣處理經常被使用來保持果實硬度及延長果實儲架壽命。本研究旨在評估鈣處理在維持紅龍果貯藏期間品質之影響。於採收前和採收後使用不同濃度的氯化鈣溶液處理紅龍果果實，然後貯蔵於 5℃。貯蔵後果肉硬度增加，但鈣處理並無增加果肉硬度之效果。鈣處理無法降低果皮冷藏期間之傷害，有時甚至增加其傷害程度。鈣處理也無法有效的增加果肉鈣含量。冷藏後果實之總可溶性固形物及總可滴定酸均降低，而鈣處理對兩者並無一致之影响。貯蔵後之果皮厚度也降低。果實套 PE 袋雖可以降低冷藏期間之鮮重損失，但會增加果皮傷害程度。

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