Quality of Cactus Stems (Opuntia ficus-indica) During Low-Temperature Storage

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ABSTRACT

The quality of cactus stems (*Opuntia ficus-indica*) during storage at low temperature was evaluated. Cactus stems of commercial size (selections COPENA F-1 and COPENA V-1) were harvested manually, packed in wooden crates, selected for visual defects, and stored at 5°C, 10°C, and 20°C. Periodically, they were sampled for quality evaluation; measured variables were: color (hue angle), weight loss (%), bending force, texture (as fibrousness), ascorbic acid content, decay, and chilling injury. Color (hue angle) on the day of harvest was 125 (this value is within the green-color area) and did not show marked changes during storage. Weight loss for both selections averaged 12.6% after 9 days at 20°C, 13.8% after 21 days at 10°C, and 14.4% after 21 days at 5°C. The force applied to bend the cactus stems (bending force) decreased during storage, whereas texture showed a variable behavior. Ascorbic acid content decreased during storage at the studied temperatures. Chilling injury was manifested after 15 days at 5°C, and a low incidence of decay was observed. Main quality changes that affected storage life of cactus stems were weight loss and chilling injury.

Key Words: **Opuntia ficus-indica**, storage, quality, cactus stems.

INTRODUCTION

Mexico has a total area dedicated to growing cactus stems (nopalitos) of 10,000 ha with a production of about 600,000 tons (Flores and Olvera, 1995). After harvesting, cactus stems are marketed in different ways: packed in cylindrical packs, in wooden crates, or in bulk. Usually, they are destined to local markets where they are sold within three days with adequate quality.

However, for marketing to distant places, the quality of cactus stems must be maintained.

Studies about storage of cactus stems are scarce. Ramayo et al. (1978) reported that *Opuntia inermis* stored at 10°C had a weight loss of 10% after 18 days and 20% after 28 days. They observed chilling injury development on cactus stems stored at 10°C after 22 days (4%) which increased to 8% after 28 days. They concluded that decay was the main cause of storage losses on cactus stems, which reached 15% after 15 days and 54% after 28 days. In a second study, these researchers applied a fungicide dip (benomyl at 500 ppm) on cactus stems to reduce decay during storage at 10°C. A reduction of decay to 3% after 22 days and 9% after 28 days was observed.

Cantwell et al. (1992) in a study of cactus stems of Opuntia ficus-indica and Opuntia inermis packed in vented polyethylene bags reported that cactus stems maintained a good visual

quality for 2 weeks at 10°C and for 3 weeks at 5°C. They did not observe decay, but cactus stem curved inward after 2 weeks at 20°C. Other results were that chilling injury developed after 3 weeks at 5°C, tritatable acidity decreased on cactus stems at 10°C and 20°C and maintained or increased at 5°C. Cantwell (1995) reported that decay is usually avoided with an appropriate harvesting technique.

Rodriguez-Felix and Cantwell (1988) determined an ascorbic acid content of 7S18 mg/100g on cactus stems of different varieties and developmental stages. Ascorbic acid content during storage of cactus stems has not been reported.

The objective of this work was to evaluate the quality of cactus stems (Opuntia ficus-indica), with spines, packaged in wooden crates during storage at low temperatures.

MATERIALS AND METHODS

Cactus stems of *Opuntia ficus-indica* selections COPENA F-1 (F-1) and COPENA V-1 (V-1) of commercial size (about 20 cm) were used in this study. They were manually harvested in June at a commercial planting in Hermosillo, Sonora.

Harvested cactus stems were transported to the laboratory, selected for visual defects (mainly harvesting damage) and size uniformity. Then, they were packed in wooden crates and stored at 5°C (85S90% R.H.), 10°C (80S90% R.H.); and 20°C (65S70% R.H.). Periodically, they were sampled for quality evaluation.

Measured variables were:

- **Color** S measured on 25 cactus stems for each sampled period in a MiniScan Hunter Lab Colorimeter Model MS/B-25006 using tristimulus colorimetry. The following variables were measured: L (brightness), L0 = black, L50 = gray and L100 = white; a = green to red with values from S60 (green) to +60 (red); and b values (blue-to-yellow area) with values from S60 (blue) to +60 (yellow). Results were expressed as hue angle and calculated as arc tan b/a.
- Weight loss S Weight was periodically recorded on 15 cactus stems (replicates) using an OHAUS balance. Results were expressed as percentage of weight loss, calculated based on the initial weight of cactus stems.
- Bending force S measured on 15 cactus stems (replications) using a Penetrometer Chatillon DFG-50 and a circular plate of 5.3 cm of diameter and 0.5 cm wide. A compression force was applied to each cactus stem placed in vertical and horizontal positions until it was bent 2 cm. Results are the average of three measurements (tip and both sides) and were expressed as Newtons, representing the force required to bend the cactus stems 2 cm. This distance was selected on preliminary trials, which corresponds to the cactus stems break-up distance on the day of harvest.
- Texture, as fibrousness S measured on 10 cactus stems as the maximum shear force on an Instron 1132 Universal Texturometer using a Warner Bratzler shear cell with a head speed of 100 mm/min. Results were expressed as Newtons required to shear the cactus and are the average of nine determinations (three on the base, three on the middle, and three on the tip of the cactus stem).

- Ascorbic acid content S measured in triplicate, each consisting of an extract from five cactus stems. The extract was obtained by homogenizing 30 g of cactus stems in 150 ml of extracting solution (30 g of phosphoric acid, 80 ml of acetic acid in 1 l of water), which was injected into a Varian HPLC using a weak-anion exchange column and an external standard (L-ascorbic acid). Equipment conditions were: flow rate, 1.5 ml/min.; mobile phase, acetronitrile; 0.05 M KH_2PO_4 (75:25, w/w); ultraviolet detection at 268 nm; room temperature, 22° to 26°C. Dithiothreitol was used to reduce dehydroascorbic acid to L- ascorbic acid (Donner and Hicks, 1981).
- Decay and chilling injury S These variables were evaluated visually on cactus stems. Results were expressed as percentage.

RESULTS AND DISCUSSION

Color

On the day of harvest, color (reported as hue angle arc tan b/a) was similar for cactus stems of both selections with values around 125 (Figure 1). These values are within the green-color area.

This variable did not show significant changes on cactus stems from both selections during storage at 10°C and 20°C. However, a significant change on color was observed on cactus stems of both selections after 21 days of storage at 5°C. This can be related to chilling-injury development of cactus stems that began after 15 days at this temperature. Cactus stems showed severe symptoms of chilling injury after 21 days, which affected their color.

Weight Loss

This variable increased significantly during storage of cactus stems of both selections at the temperatures used in this study (Figure 2). After 9 days at 20°C, cactus stems from F-1 showed values of 11.8%, and those from V-1 13.8%. Cactus stems from F-1 (larger and thinner) began to curve inward after 3 days and V-1 after 9 days, affecting their visual appearance. Additionally, wilting symptoms began to appear on cactus stems after 3 days (5%) for F-1, and after 9 days (12%) for V-1.

After 21 days at 10°C, weight loss reached about 15% on cactus stems from both selections. At this storage period (21 days) cactus stems began to show wilting symptoms and cactus stems curving inward was observed after 24 days. Similar weight-loss values as those at 20°C were reached after 15 days at 10°C on F-1 and after 18 days on V-1.

A significant weight loss was observed after 6 days of storage at 5°C, then increased significantly during storage reaching values of 18.7% after 21 days on cactus stems of V-1 and 10.1% on F-1. We did not observe cactus stems curving inward at this temperature, nor wilting symptoms.

Bending Force

On the day of harvest the force required to bend the cactus stems was 30 N for F-1 and 21.8 N for V-1 (Figure 3), such force decreased significantly after 7 days at 20°C, showing a 50% reduction for both selections.

At 10°C, cactus stems of F-1 showed a significant decrease in the force required to bend them after 7 days of storage (19.0 N), this force was similar afterwards and decreased significantly after 28 days (10.6 N). The force required to bend cactus stems of V-1 was similar from 0 to 7 days of storage (21.7 and 19.3 N, respectively), decreased significantly after 14 days (12.6 N) and showed no changes afterwards.

The force to bend cactus stems from F-1 was similar for 0 and 7 days of storage at 5°C (30.9 and 30.2 N, respectively), and decreased significantly after 14 days (24.6 N). Whereas, the force required to bend V-1 cactus stems decreased significantly during storage, reaching 6.7 N after 21 days.

Fresh cactus stems were turgid and required a greater force to be bent 2 cm than stems that had been stored. Cactus stems that lost weight and became flexible (elastic) required less force to be bent.

Fibrousness

Texture as fibrousness (measured as the maximum force to shear a tissue) had a variable behavior during storage with values ranging from 15 N to 23 N on cactus stems of F-1 and from 11 to 31 N on those of V-1 (Figure 4). Fibrousness had similar values on cactus stems of both selections. There are no published data related to texture of cactus stems. Asparagus is a fibrous vegetable, similar to cactus stems. Sanchez-Pineda et al. (1994) reported a fibrousness (as maximum shear force) of 30 N at the bud and the middle part of the spear, and 50 N at the base of the spear for asparagus cultivar Desto. Comparing these values with those obtained on cactus stems, fibrousness of cactus stems is lower than fibrousness of asparagus. Sharma and Wolfe (1975) related sensory evaluation with fibrousness of asparagus and concluded that a maximum peak force greater than 62 N is considered unacceptable.

Ascorbic Acid Content

This variable is reported as total ascorbic acid (includes L-ascorbic and dehydroascorbic acid). Initial ascorbic acid content was similar on cactus stems from both selections: about 12 mg/100g fresh weight (Table 1). Rodriguez-Felix and Cantwell (1988) reported an ascorbic acid average content of 9.8 mg/100 g in cactus stems of Opuntia ficus-indica at commercial maturity by using a spectrophotometric method.

Table 1. Ascorbic Acid Changes in Cactus Stems (Opuntia ficus-indica) During Storage

Storage Time (days)	COPENA F-1			COPENA V-1		
	5°C	10°C	20°C	5°C	10°C	20°C
0	12.1[al]	12.1[a]	12.1[a]	11.9[al]	11.9[a]	11.9[a]
7	12.1[a]	-	7.5[b]	11.9[a]	-	9.0[b]
14	-	9.7[b]	-	-	8.0[b]	-
21	9.2[b]	-	-	9.7[b]	-	5.9[c]
28	-	7.3[c]	-	-	5.6[a]	-

[1]Data within a given column followed by different letters are significantly different at the 5% level.

Ascorbic acid content decreased significantly to 7.5 mg/100 g for cactus stems from F-1 and to 9.0 mg/100 g for those of V-1 after 7 days of storage at 20°C. These values represented 62% and 76% of their initial ascorbic acid content, respectively.

Ascorbic acid content decreased significantly to 9.7 and 8.0 mg/100 g fresh weight in cactus stems after 14 days of storage at 10°C for F-1 and V-1, respectively. These values represented an 80% and 67% of initial ascorbic acid content, respectively.

After 7 days of storage at 5°C, cactus stems showed values similar to those of the day of harvest. However, it decreased significantly after 21 days of storage to values of 9.2 and 9.7 mg/100 g of fresh weight for F-1 and V-1, respectively. These values represent 76% and 82% of initial content for cactus stems from F-1 and V-1 selections, respectively.

Chilling Injury

This physiological disorder appeared after 15 days at 5°C with values of 10% and 14% for cactus stems from F-1 and V-1, respectively (data not shown). In this study, cactus stems packed in wooden crates showed chilling injury earlier than those studied by Cantwell et al. (1992), who reported this damage after 3 weeks at 5°C in cactus stems packed in vented polyethylene bags. According to Ben-Yehosua et al. (1983), packing in polyethylene bags has been shown to reduce chilling injury in lemon and bell-pepper fruits.

At 10°C, chilling injury was manifested after 21 days with values of about 6% for cactus stems from both selections. These values are similar to those reported by Ramayo et al. (1978).

Decay

There was no incidence of decay of cactus stems stored at 20°C because their storage life was limited to 9 days due to weight loss. Decay developed after 18 days at 5°C (4%) and after 24 days at 10°C (2%) (data not shown). Comparing our results with those obtained by Ramayo et al. (1978a), who reported that decay began at the cut stem end after 10 days at 10°C (21%), it can be observed that we had a lower incidence of decay and it began later during storage. This decay reduction during storage can be related to the selection of cactus stems made previous to storage, which discards damaged cactus stems. Our results agree with Cantwell (1995), who stated that decay during storage is usually avoided if cactus stems have not been damaged.

CONCLUSIONS

Color changed significantly during storage at 5°C (after 21 days) and it was associated with chilling injury development.

Weight loss increased during storage, reaching the highest values (13%) at the highest temperature (20°C).

The force required to bend the cactus stems decreased during storage of cactus stems at any storage conditions.

Fibrousness (maximum shear force) of cactus stems varied from 14.7 N to 31.2 N, showing a variable behavior during storage.

Ascorbic acid content of *Opuntia ficus-indica* COPENA F-1 and COPENA V-1 decreased during storage at rates directly related to temperature.

Chilling injury was manifested after 15 days at 5°C and after 21 days at 10°C.

Cactus stems showed a low percentage of decay during low-temperature storage at 5°C and 10°C.

According to these results, the best storage temperature for cactus stems contained in wooden crates is 10°C.

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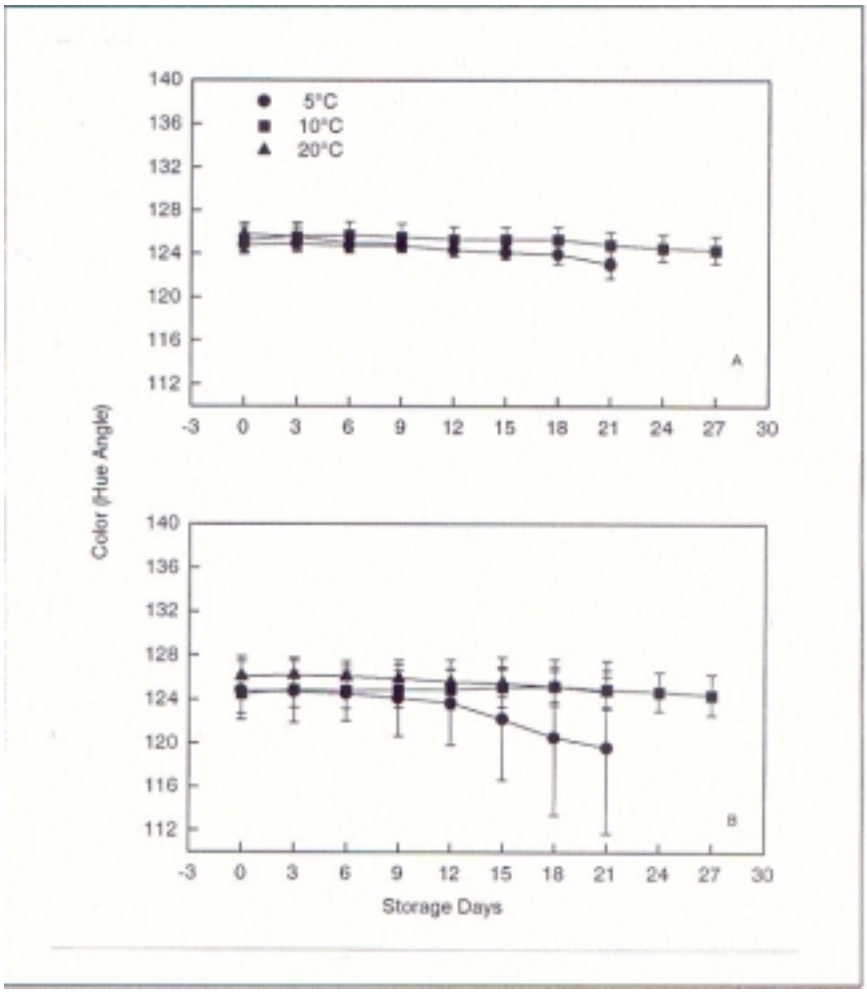

Figure 1. Color (hue angle) of Cactus Stems (Opuntia ficus-indica) During Storage.
A: Selection COPENA F-1; B: Selection COPENA V-1

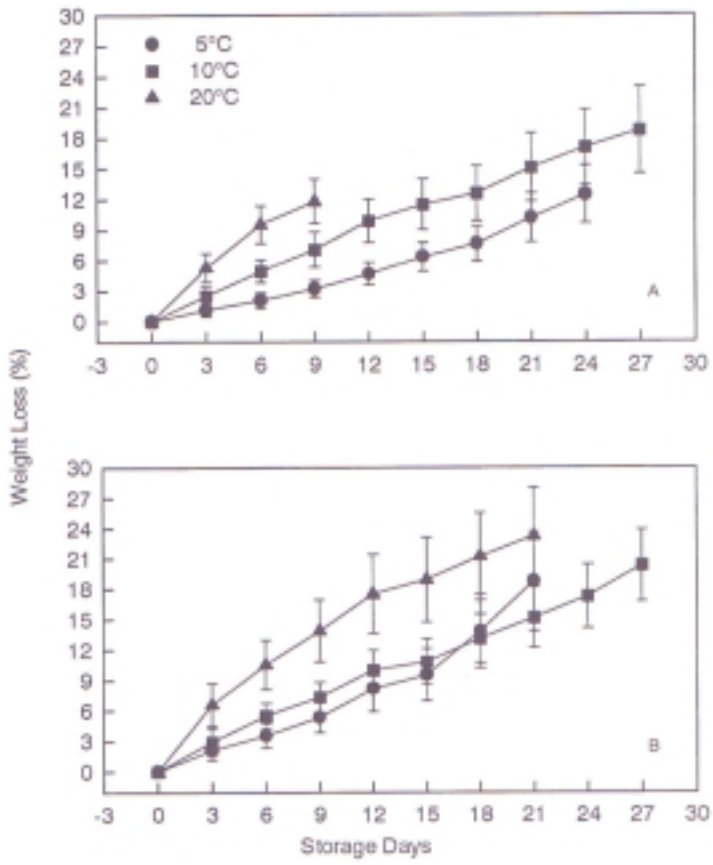

Figure 2. Weight Loss of Cactus Stems (Opuntia ficus-indica) During Storage.
A: Selection COPENA F-1; B: Selection COPENA V-1

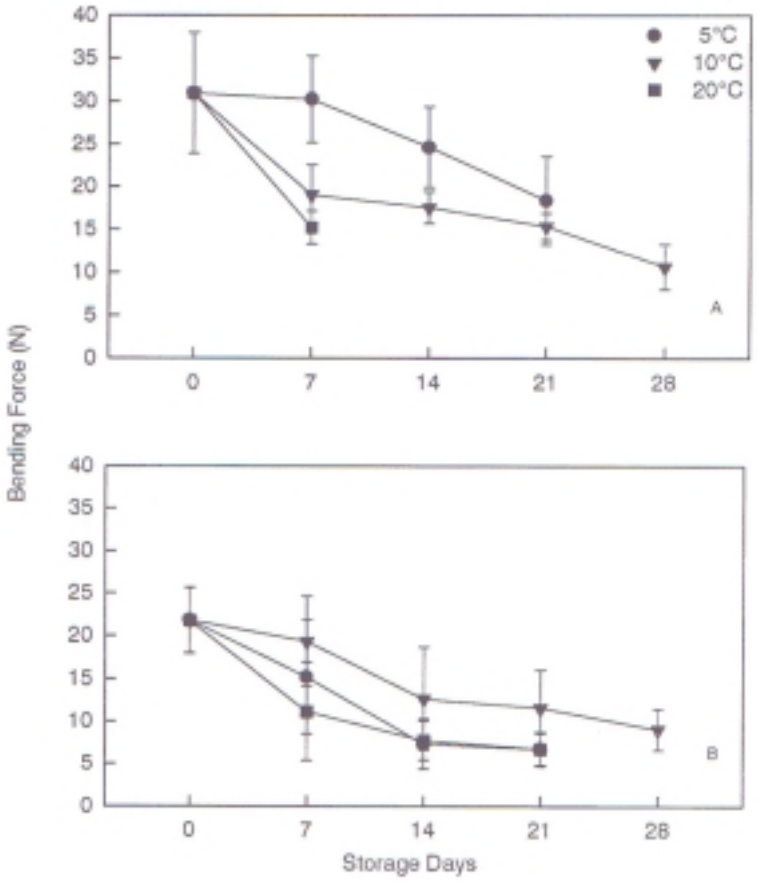

Figure 3. Bending Force[a] Changes of Cactus Stems (Opuntia ficus-indica) During Storage.
A: Selection COPENA F-1; B: Selection COPENA V-1.
[a]The force required to bend each cactus stem placed
in vertical and horizontal positions until it bent 2 cm.

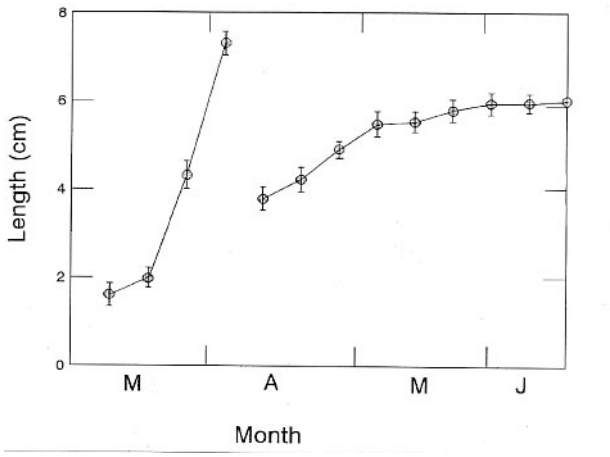

Figure 4. Texture (as fibrousness)[a] Changes of Cactus Stems (Opuntia ficus-indica) During Storage
A: Selection COPENA F-1; B: Selection COPENA V-1
[a]Maximum force to shear cactus stems.