QUALITY AND POSTHARVEST PHYSIOLOGY OF "NOPALITOS" AND "TUNAS"

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INTRODUCTION

The objective of this paper is to provide an overview of quality and postharvest aspects of "Tunas" (fruits) and "Nopalitos" (vegetables) produced by the Prickly Pear Cactus (Opuntia spp.). Most of the data reported here are from studies of nopalitos and tunas produced at the School of Agriculture of the University of Sonora near Hermosillo. Laboratory analyses were carried out at the C.I.A.D. (Research Center in Foods and Development, Hermosillo) and the Mann Laboratory, Univ. California, Davis, and are described in detail in the references cited.

QUALITY AND POSTHARVEST ASPECTS OF NOPALITOS

Nopalitos, the tender prickly pear stems, also called "Cactus leaves", are a traditional vegetable in Mexico and a specialty vegetable in the U.S. This vegetable is not a leaf but rather the young rapidly-growing flattened stems or cladodes of the Prickly Pear Cactus ("Nopal"). The vestigial true leaves, often subtended by spines, are present in the early stages of nopalito growth, but usually begin to abscise by the time the nopalitos reach commercial size. Good quality nopalitos are fresh-looking, turgid with a brilliant green color. After trimming and chopping, the nopalitos may be eaten as a fresh or cooked vegetable, resembling green beans somewhat in flavor.

Nopalitos are mostly water (92%) and carbohydrates including fiber (4-6%), with a little protein (1-2%), and minerals, principally calcium (1%). They also contain moderate amounts of Vitamin C (10-15 mg/100g) and the Vitamin A precursor, B-carotene (about 30 ug/100g) (Rodríguez-Felix and Cantwell, 1988). Table 1 compares the composition of nopalitos with two other green vegetables, lettuce and spinach. While the carotenoid and vitamin C levels are intermediate between those of spinach and lettuce, the nutritional contribution of nopalitos can be significant, especially in arid areas. Tender nopalitos can be readily and abundantly produced under high temperatures with little water, conditions unfavorable for the production of most green leafy vegetables.

Because the prickly pear plant is a CAM plant (opens its stomates during the night to fix carbon dioxide as malic acid which is then converted into sugar during the day), the acid content of the nopalitos may fluctuate greatly during the day and affect their flavor. Figure 1 shows the diurnal variation in titratable acid content of nopalitos of Opuntia ficus-indica of commercial size (20 cm). The chemical composition of nopalitos

Table 1. The composition of nopalitos, head lettuce and spinach.

Component	Nopalitos	Lettuce	Spinach
Water, %	91.8	95.5	90.7
Protein, %	1.1	1.0	3.2
Lipid, %	0.2	0.2	0.3
Crude Fiber, %	1.1	0.5	0.9
Total Carbohydrate, %	4.5	2.1	3.8
Ash, %	1.3	0.5	1.8
Calcium (mg/100g)	90	19	99
Vitamin C (mg/100g)	11	4	28
Carotenoids (μg/100g)	30	19	55

Data for nopalitos from Rodriguez-Felix and Cantwell, 1988; Data for lettuce and spinach from USDA Agric. Hdbk. 8-11, 1984.

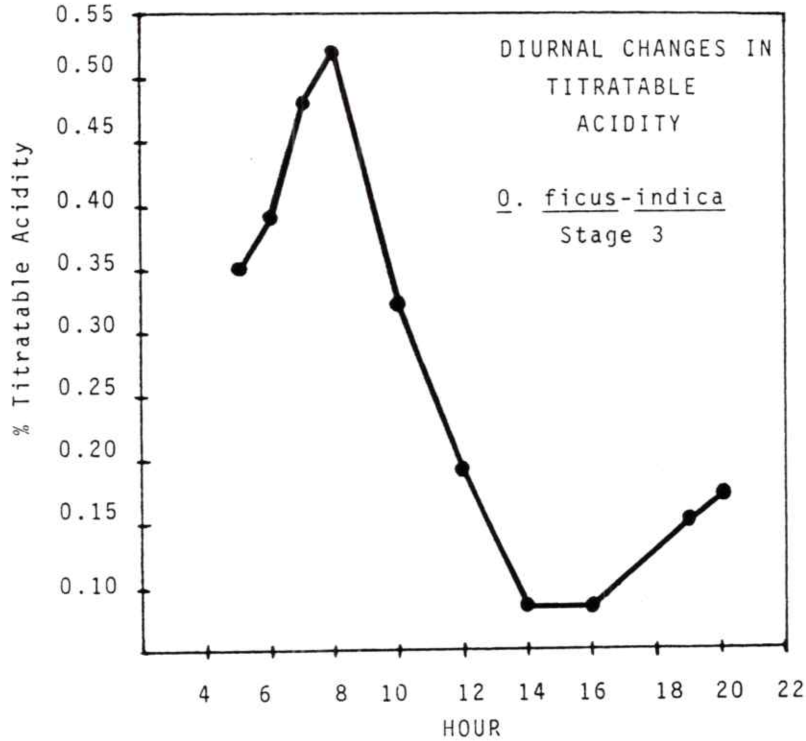

FIGURE 1. Diurnal changes in titratable acidity of 20 cm nopalitos of <u>Opuntia ficus-indica</u> (from Rodriguez and Cantwell, 1988).

varies depending upon the species, cultural conditions and the stage of development (Camarillo and Grajeda, 1981; Retamal et al., 1987; Robles-Contreras et al., 1991; Rodríguez-Felix and Cantwell, 1988). Table 2 illustrates how irrigation frequency will have little effect on titratable acid and soluble solids content until extreme conditions are established (i.e., very limited rainfall or a single initial irrigation).

The acid content of nopalitos may also be modified by postharvest storage temperatures. Figure 2 shows changes in titratable acidity of young (10 cm) and commercial size (20 cm) nopalitos which have been harvested in the morning or afternoon and stored at 20C or 5C. Storage at low temperature maintains or increases acid content, whereas storage at 20C results in a decrease in acid content.

Nopalitos are harvested commercially when they are from 17 to 20 cm long (6-9 inches) by cutting at the articulation with the "mother cladode". In Mexico they are collected in baskets or stacked in cylindrical packs about 1 meter tall for transport to market, where they are commonly cleaned (spines and vestigial leaves cut off and the sides are trimmed) prior to sale (Bautista-Castañon, 1982). Considerable heat from respiration is generated by the nopalitos in the center of these packs which is related to rapid decreases in visual quality and abscission of the small leaves. These conditions also favor decay organisms but since the nopalitos are generally marketed within 2-3 days, this is usually not a problem. Nopalitos produced in California or exported from Mexico are usually packed in 10 to 15 kg wooden or fiber boxes.

Storing nopalitos at 5-10C (41-50F) significantly reduces their respiration rate (Figure 3), increasing postharvest shelf life from less than 1 week at 20C to 3 weeks at 5C (Cantwell et al., 1991). After 3 weeks at 5C, however, nopalitos may begin to show signs of chilling injury, principally a bronzing or unattractive surface discoloration. Chilling injury is important also because, if severe enough, the nopalitos will deteriorate rapidly when removed from storage and marketed at ambient temperatures (Ramayo-Ramírez et al., 1978). Before the visual symptoms of chilling injury appear, changes in the respiration and ethylene production rates have been noted (Cantwell et al., 1991). Decay at the cut stem end may be a problem if nopalitos are stored for longer than 2 weeks. This is usually avoided by insuring that they have not been damaged when cut from the mother cladode. Recent research has focussed on improving the shelf life of cleaned and diced nopalitos, which are increasingly popular for their convenience, but which are also more perishable. Reducing brown discoloration at the cut surfaces and preventing fluid (mucilage) loss are problems in the handling of this product (Rodríguez-Felix, personal communication).

QUALITY AND POSTHARVEST ASPECTS OF TUNAS

The prickly pear fruit, tuna, is an oval or pear-shaped berry, consisting of a thick fleshy skin (30-40% fruit weight) surrounding a juicy pulp containing many hard-coated seeds (5-10% pulp weight). Each Opuntia species or type produces fruits of different

Table 2. Production and composition of nopalitos from plants under different irrigation regimes.

Irrigation Regime	Production Kg/20 plants	Water %	Soluble Solids %	Titratable Acidity %
Every 15 days, 8 cm	19	94.9	4.43	0.56
Every 20 days, 8 cm	17	94.5	4.21	0.51
Every 30 days, 8 cm	18	94.1	4.43	0.59
Every 45 days, 8 cm	19	94.3	4.11	0.65
Initial Irrigation of 15 cm	18	94.2	4.65	0.66
Rainfall only (10 cm)	11	93.5	5.19	0.94

Data collected from the second production cycle from Robles-Contreras *et al.*, 1991; All nopalitos harvested at 9:00 AM.

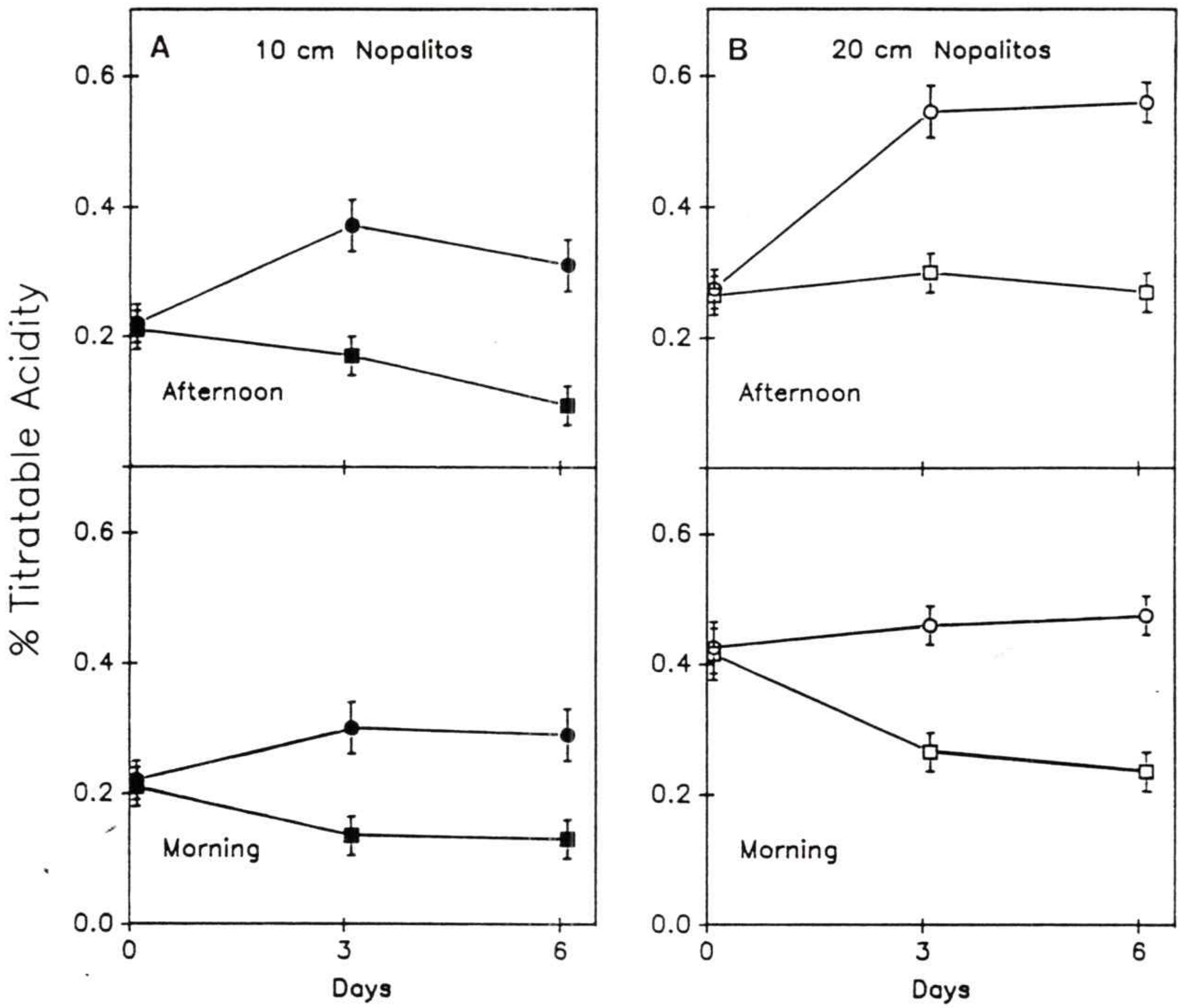

FIGURE 2. Changes in titratable acid content of 10 cm (A) and 20 cm (B) nopalitos (O. ficus-indica) harvested in the morning (lower graphs) and afternoon (upper graphs) and stored at 5C (circles) and 20C (squares) for 6 days (from Rodriguez, 1986).

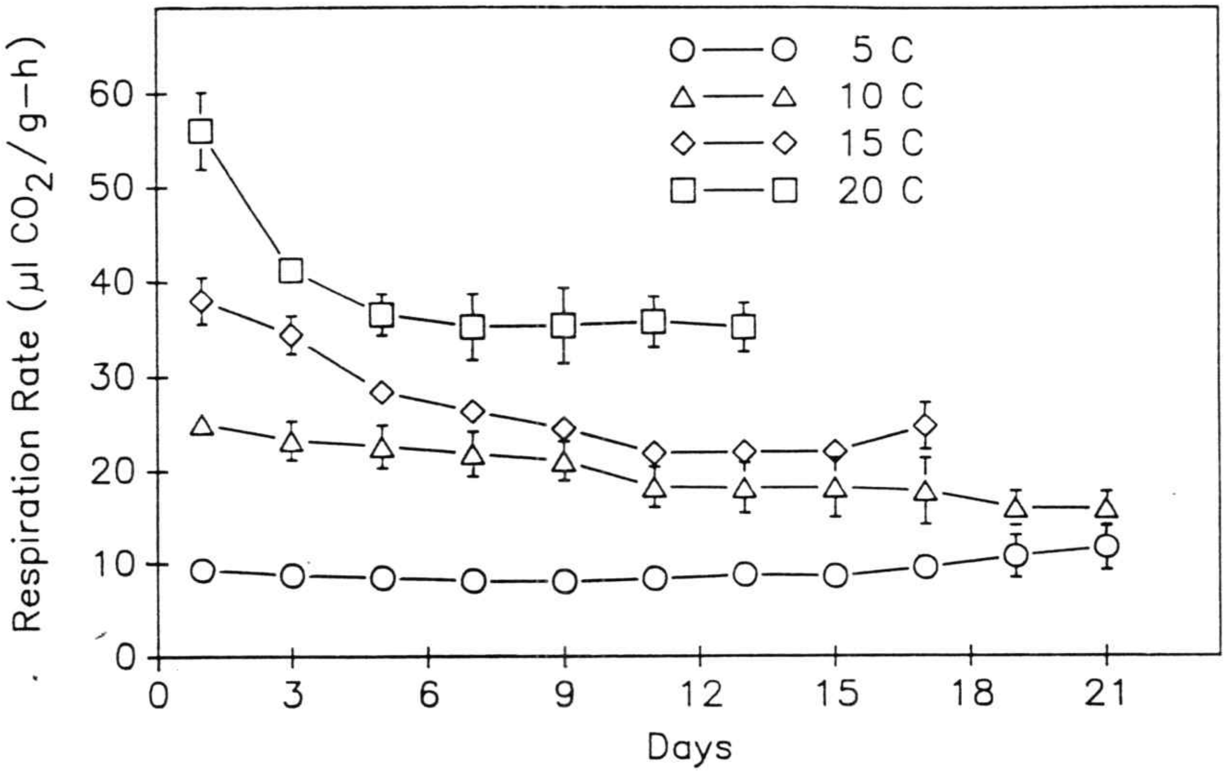

FIGURE 3. Respiration rates of 20 cm nopalitos (<u>O. ficus-indica)</u> stored in the dark at 4 temperatures (from Cantwell et al., 1991).

colors with slightly different delicate flavors. The major components of the fruit pulp are water (85%) and carbohydrates (10-15%) with important amounts of Vitamin C (25-30 mg/100g). Table 3 compares the composition of tunas (O. amyclaea, Tuna Blanca) with oranges and papayas.

Changes in the physical characteristics and chemical composition of fruits from a selection of Tuna Blanca ("White" Tuna; refers to the very pale-green almost white pulp) are shown for various stages of growth and ripening (Table 4). For commercial handling the stage of maturity or ripeness at harvest is very important to fruit quality and several external indices are used, including 1) fruit size and fullness, 2) external color changes, 3) abscission of the glochids (tufts of very small spines), 4) fruit firmness, and 5) flattening of the floral cavity.

Stages of development and ripening for Tuna Blanca types can be described as follows: 1) Mature-green fruits are well developed with a light green peel; 2) Ripening fruits begin to show color change on the peel, from about 25 to 75% yellow, and the glochids begin to fall off; these are the fruits of most interest commercially; 3) Ripe fruits have 95 to 100% pale yellow peel color and are noticeably softer and damage easily during harvest; and 4) Overripe fruits may show an increasing intensity of the yellow peel color with small rusty-brown discolored areas beginning to form;

Compositional changes which correspond to the stages described above for the Tuna Blanca are shown in Figure 4 for both the pulp and the peel of the fruit. Figure 4a and b show that soluble solids, although generally useful as an approximation of sugar content does not necessarily correlate well with sugar content (determined from an alcohol extract of the pulp by a colorimetric method). In other research (Lakshminarayana et al., 1979) soluble solids have correlated more closely with sugar content. In all tuna types there are considerable changes in pulp sugar levels during the last stages of development and ripening. Harvesting the fruit early in the ripening process, therefore would reduce fruit sweetness.

Titratable acid content is higher in the peel than in the pulp, and the pulp contains very little acid at any stage of development (Figure 4c). In many fruits the total and soluble pectin contents change during ripening. In the case of Tuna Blanca total pectin was very low in the pulp and did not change, whereas it was higher in the peel and decreased with ripening (Figure 4d). The percent of soluble pectin, however remained relatively constant during ripening (Martínez-Olea, 1986). The number of fruits per cladode (10 to 30) did not affect fruit size or composition, nor did the orientation of the producing cladode (Montiel-Rodríguez, 1986).

Tunas are nonclimacteric fruits (Lakshminarayana et al., 1979) and this behavior is illustrated in Figure 5 where respiration declines with time and is not different for fruits harvested at different stages of ripeness. Their ethylene production rate is also very low, is similar for fruits harvested at 3 stages and although it increases in the postharvest

Table 3. The composition of Tuna, Orange and Papaya fruit pulp.

Component	Tuna	Orange	Papaya
Water,%	85.0	87.8	88.7
TotalCarbohydrate,%	11.0	11.0	10.0
CrudeFiber,%	1.8	0.5	0.8
Lipid,%	0.1	0.1	0.1
Protein,%	0.5	0.4	0.6
Ash,%	1.6	0.4	0.6
Calcium(mg/100g)	60	40	20
VitaminC(mg/100g)	30	50	50
VitaminA(IU)	50	200	1100

Data from M. Hernández *et al.*, 1980 (Valor Nutritivo de los Alimentos Mexicanos, INN) and USDA Agric. Hdbk. 8-9, 1982.

Table 4. Physical and compositional changes in Tunas (*Opuntia amyclaea*, Copena 18) during development and ripening.

Stage of Develop ment	Weight (g)	Pulp (%)	Firm- ness (lb-f)	Soluble Solids (%)	Titra- table Acidity (%)	pH	Vit. C mg/ 100g
Immature	86	44	9.8	7.4	.08	5.18	12
Mature-Green	102	57	8.2	8.7	.04	6.09	18
Intermediate	105	63	6.0	10.1	.03	6.18	18
Ripe	112	65	5.3	11.5	.02	6.29	26
Overripe	108	75	4.8	12.5	.02	6.38	28

Date from Montiel-Rodriguez, 1986.

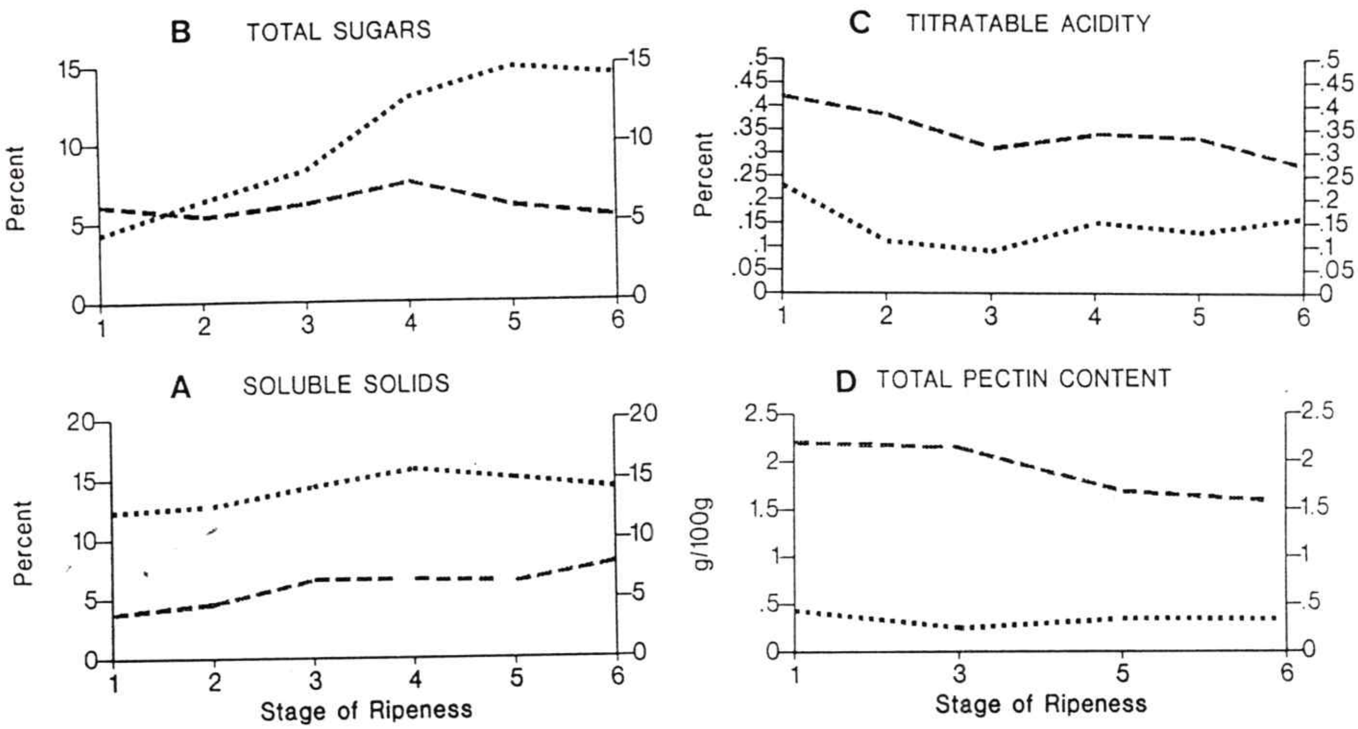

FIGURE 4. Changes in the soluble solids (A), total sugar (B), titratable acidity (C) and total pectin (D) of the pulp (····) and peel (--) of Prickly pear fruits (<u>Opuntia amyclaea</u>, Copena 1) harvested at different stages of ripeness (from Martinez-Olea, 1986).

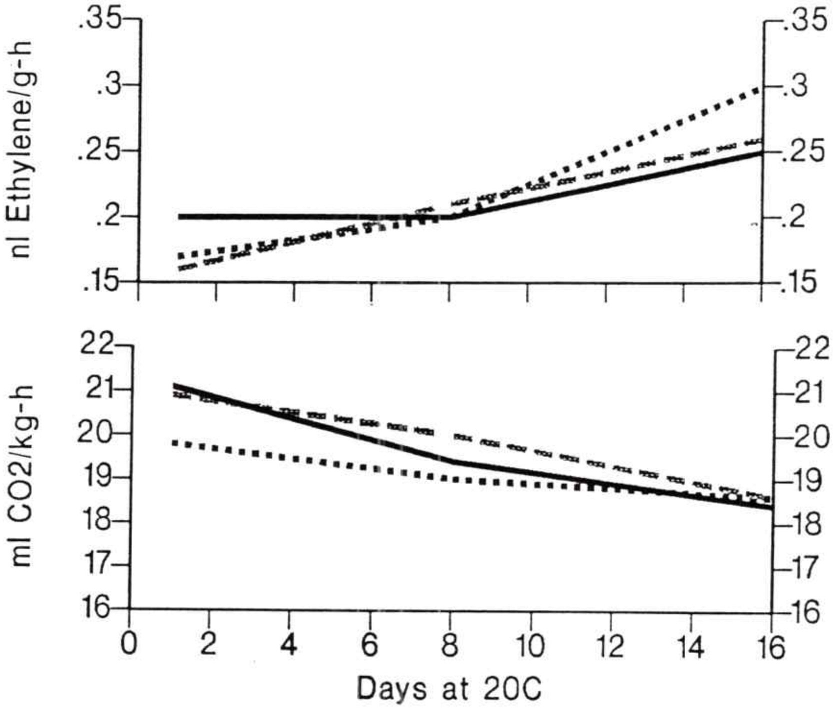

FIGURE 5. Respiration and ethylene production rates of Prickly pear fruits (<u>Opuntia amyclaea,</u> Copena 18) harvested Mature-green (——), Ripening (– –), and Ripe (····) and stored at 20C for 16 days (Cantwell, unpublished).

period, remains at very low levels. The behavior of tunas can be compared to that of other common fruits (Table 5), leading to the conclusion that their physiological activity is relatively low.

Another characteristic of nonclimacteric fruits is that their lack of starch as a carbohydrate reserve so there is no significant increase in sugar content after harvest. In ripe fruits from 3 selections of Tuna Blanca (Copena 1, 16 and 18) soluble solids of the pulp increased by <1% during storage at 20C for 1 month. This small increase in soluble solids could have been due to hydrolysis of complex carbohydrates other than starch. Chávez-Franco and Saucedo-Veloz (1985) also showed an increase in soluble solids for one type of Tuna if stored at 18C. Alvarado y Sosa (1978), however, showed a slight decline in soluble solids and sugars of Tuna fruits after two weeks storage at 20C. The sugar content in the tuna is essentially determined at the time of harvest, and whatever the change after harvest, it is relatively small. Firmness decreased over 1 month at 20C, but again the changes were small in comparison to firmness changes which occur in other fruits at that temperature.

The perishability of Tunas lies, therefore, not in their physiology, but principally in physical damage to the peel and stem-end during harvest. In Mexico the fruits are most commonly twisted off the stem, and depending upon the skill of the harvester this may lead to varying degrees of damage. Damage from finger pressure to the peel shows up later during the postharvest period as discolored areas which subsequently dry out and produce an unsightly appearance. Damage at the stem end is more serious, however, since it will lead to attack by numerous pathogens and result in fruit decay (Guzman, 1982). In the storage experiment at 20C described above, 59% of all fruits were damaged at the stem-end at harvest and 70% of the fruits had stem-end decay after 1 month; peel rots were present in less than 18% of the fruits. In addition to a very careful harvest, fruits are sometimes cut from the cladode with a small amount of stem attached, which subsequently dries and falls off. In some Opuntia species, however, large subtending spines makes this technique impossible. Traditionally fruits have been stored under ambient conditions by harvesting with pieces of cladode attached or by harvesting the entire cladode; again this is not practical as a commercial practice.

Recent efforts at the Faculty of Engineering of the University of Guanajuato (Lara-López and Manríquez-Yepez, 1985; Lara-López, personal communication) have resulted in several designs for selective and nonselective fruit harvesters. These harvest aids result in a level of damage to the fruits which is similar to that obtained with careful hand harvesting (Cantwell, unpublished data). In the central highland areas of Mexico, dew is present in the mornings and this prevents the small spines (glochids) from flying around during harvest, but in the very dry desert areas of the north, no dew is formed and the small spines are a major problem during harvest. The difficulties associated with the harvest of Prickly Pear fruits have limited their utilization, especially industrialization, and the development of useful harvest aids is critical.

Table 5. Maximum respiration and ethylene production rates of selected fruits at 20°C.

Fruit	$\mu l\ CO_2/g\text{-}h$	$nl\ C_2H_4/g\text{-}h$
Avocado*	150	100
Strawberry	80	0.1
Mango*	60	40
Banana*	50	5
Apple*	30	100
Orange	15	0.1
Cactus fruit	20	0.2

Data were compiled from numerous publications.

* Denotes climacteric fruits

Water loss during postharvest handling of Tuna fruits is important because it decreases appearance; fruits must lose 5% or more of their fresh weight before visual appearance is affected. Fruits for export from Mexico or those produced in California for distant markets are waxed to improve their visual quality and reduce postharvest weight loss. Other techniques to reduce water loss include the use of polyethylene liners in the boxes such as those used for bananas (Cantwell, 1986). Storage at lower temperatures (5C) reduces water loss by reducing the vapor pressure deficit (Cantwell, 1986; Chessa and Barbera, 1984). Tunas are chilling sensitive and storage at 5 to 7.5C (41 to 45F) is generally recommended for a storage life of about 3 weeks, although Chávez-Franco and Saucedo-Veloz (1985) have reported chilling damage to Tuna Blanca types if stored below 10C.

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