DOCUMENTOS ANEXOS

CONSULTORIA B-025

HORTSCIENCE 32(4):702–704. 1997.

Postharvest Heat Conditioning Effects on Early Ripening 'Gialla' Cactus Pear Fruit

M. Schirra
C.N.R.–Istituto per la Fisiologia della Maturazione e della Conservazione del Frutto delle Specie Arboree Mediterranee, 09170 Oristano, Italy

M. Agabbio
Dipartimento di Scienze Ambientali e Agroalimentari e Biotecnologie Agroalimentari, Facoltà di Agraria, Università di Sassari, 07100 Sassari, Italy

S. D'Aquino
C.N.R.–Istituto per la Fisiologia della Maturazione e della Conservazione del Frutto delle Specie Arboree Mediterranee, 09170 Oristano, Italy

T.G. McCollum
U.S. Department of Agriculture, Agricultural Research Service, U.S. Horticultural Research Laboratory, 2120 Camden Road, Orlando, FL 32803

Additional index words. chilling injury, decay, ethanol, ethylene, *Opuntia ficus-indica*, quality, respiration, storage

Abstract. **The influence of postharvest heat conditioning at 38 °C for 24, 48, or 72 hours on ripe 'Gialla' cactus pear [*Opuntia ficus-indica* (L.) Miller] fruit produced by the spring flush was investigated during 21 days of storage at 6 °C and 90%–95% relative humidity (RH) followed by 7 days at 20 °C and 70%–75% RH (simulated marketing). Conditioning for 24 to 72 h reduced by 50% the severity of chilling injury (CI) on cactus pears following exposure to cold storage. Treatment for 24 to 72 h was also effective in reducing decay, with conditioning for 24 h being the most effective. Overall visual quality was better in heat-conditioned compared with control fruit. Mass loss was significantly reduced by all heat conditioning treatments. Respiration rate was not affected by heat treatment. Ethylene evolution was lower in fruit heat-conditioned for 48 or 72 h than for 0 h. Conditioning for 72 h resulted in the highest fruit ethanol levels. The influence of conditioning on juice pH, titratable acidity, soluble solids concentration and ascorbic acid was negligible. Prestorage heat treatment provides some measure of CI and decay control without detrimental effects to visual quality of early ripening cactus pear fruit and may offer an alternative to fungicide treatments.**

Cactus pears are tropical fruits highly susceptible to chilling injury (CI) when exposed to temperatures below 10 °C (Chessa and Barbera, 1984). Without refrigeration, fruit senesce rapidly and become susceptible to infection by microorganisms, especially *Penicillium* spp., *Alternaria* spp., and rots caused by some strains of yeasts and bacteria. Visual symptoms of CI on cactus pears include small dark spots, irregular red brownish areas, superficial bronzing, and rind pitting. Chilling injury only affects the peel but the fruit become unsuitable for sale. The symptoms of CI are often accompanied by the development of off-flavors and increased susceptibility to pathogens, especially when fruits are removed to nonchilling temperatures. Recommended storage temperatures for cactus pears range from 6 to 8 °C at 90% to 95% RH, depending on cultivar and harvesting period (Gorini et al., 1993). Refrigeration trials with intermittent warming gave contradictory results (Chessa and Schirra, 1990; Testoni and Eccher Zerbini, 1990).

Prestorage heat treatment of various horticultural products under high humidity has been shown to reduce susceptibility to pathogens (Barkai-Golan and Phillips, 1991; Couey, 1989), to increase fruit resistance to CI (Wang, 1993), to improve postharvest fruit quality (Klein and Lurie, 1992), and to delay ripening and senescence in climacteric fruit (Paull, 1990; Porrit and Lidster, 1978).

This paper describes an attempt to extend the storage life of early-ripening cactus pear fruit using cold storage preceded by heating for various periods, as a possible alternative to agricultural chemicals applied to control microrganisms.

Received for publication 25 Apr. 1996. Accepted for publication 4 Dec. 1996. The Authors contributed equally to this study. Research supported by Mi.R.A.A.F. Special Grant: "Sviluppo e Miglioramento della Frutticoltura da Industria, della Frutticoltura da Consumo Fresco e dell'agrumicoltura–Sottoprogetto 5–Tropicali e Subtropicali". Paper 590. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Materials and Methods

The experiment was performed on 'Gialla' cactus pear fruit obtained from the first flower flush (spring flush), in 1993. Ripe fruit were harvested from an experimental orchard located near Sarroch in the southern part of Sardinia (39° 03' lat. north) in the last week of September. Freshly harvested fruits were placed in plastic boxes (about 20 kg per box) and transported within 2 h to the laboratory in Oristano. Upon arrival, fruit were sorted and those of medium size (120 ± 20 g) and uniform color and which were defect-free were randomized into four experimental units (groups) of three replications (two boxes of 50 fruit per replication). One group was transferred to storage at 6 °C and 90% to 95% RH, with a complete air change inside the room every hour. The remaining three groups were placed into separate plastic containers in a controlled heating room at 38 °C. Relative humidity inside the containers was >90%, maintained by placing 10 L of water on the floor of the containers and forcing air into the sealed chambers 1 h every 8 h by pumps (airflow 5 $L \cdot min^{-1}$). Air temperature and humidity of the heated chambers were recorded simultaneously by a portable drum instrument (type TIG-1TH Thermohygrograph; LSI, Milan, Italy). After 24 (24COND), 48 (48COND) or 72 h (72COND), fruits were removed from the respective heated chambers and immediately transferred to storage at 6 °C and 90% to 95% RH. The fruit were not waxed or treated with postharvest fungicides.

After 21 days of cold storage, and an additional 7 days at 20 °C and 70% to 75% RH (simulated marketing), fruit were inspected for CI and decay. The extent of CI on each fruit was evaluated subjectively on the basis of the extent of brown staining of the rind, from 0 = no injury to 4 = severe injury, when fruit would be rejected and a weighted average (chilling index, Cx) was calculated (McCollum et al., 1993). Overall visual quality was evaluated by an informal test panel of three using a hedonic scale of 9 = excellent, 7 = good, 5 = fairly good, 3 = poor, and 1 = very poor, and an average visual score was calculated.

Physiological (respiration rate and ethylene evolution) and chemical characteristics [pH, titratable acidity, soluble solid concentration (SSC), ethanol, and ascorbic acid] were determined at harvest and after simulated marketing. Respiration rate and ethylene evolution by freshly harvested fruit were determined after holding at room temperature (20 °C ± 1 °C) for 24 h.

All analyses were performed according to the procedures described previously (Schirra et al., 1996). Experiments were repeated in 1995 with the same experiment design with the addition of determining mass loss.

A split-plot design was used to evaluate the main effects (year and treatment) and interaction (year × treatment). Data were processed for analysis of variance by means MSTAT-C

Table 1. Influence of prestorage heat treatment at 38 °C on chilling injury, expressed as an index (Cx), decay and visual quality of 'Gialla' cactus pear fruit after 21 days at 6 °C plus 7 days at 20 °C[z].

Time at 38 °C (h)		Quality attribute[y]		
		Cx	Decay (%)	Visual quality
0		1.91 a	8.9 a	2.2 b
24		0.99 b	1.2 b	4.7 a
48		0.95 b	4.0 ab	5.2 a
72		1.06 b	4.9 ab	4.4 a
Source	df	Mean square and significance		
Year (A)	1	3.59**	53.7[NS]	9.67**
Error	4	0.034	31.12	0.43
Treatments (B)	3	1.26***	62.35*	10.36***
A × B	3	0.36*	23.59[NS]	0.54[NS]
Error	12	0.07	13.95	0.36

[z]Values are the means of 3+3 replicate analyses (1993 and 1995 seasons).
[y]Mean separation within columns at $P \leq 0.05$ by Duncan's multiple range test.
[x]Quality rating 1 = very poor, 9 = excellent.
[NS],*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

(Michigan State Univ. microcomputer program, 1991). Mean comparisons were performed by Duncan's multiple range test at $P \leq 0.05$ where appropriate.

Results and Discussion

Heat damage was absent in 24COND and 48COND in 1993 and 1995, while 72COND in 1993 produced serious lesions in the form of irregular and extended eruptions of the pulp on about 7% of the fruit after 14 days of storage (data not shown). These symptoms were detected only occasionally in 1995 (<1%) and were much less severe. The susceptibility of cactus pear fruit to heat damage in 1993 may have been related to a very hot and dry season during fruit growth and ripening, followed by several days of rain before harvest.

Incidence of CI was very low after 14 days of storage at 6 °C (data not shown). CI, expressed as Cx, increased rapidly as storage continued, especially when fruit were kept at 20 °C, but to a lesser extent on heat-treated fruit (Table 1). All heat treatment duration were equally effective in reducing CI. The significant year by treatment interaction was a result of more CI in 1995 compared with 1993. Symptoms appeared as widespread, irregular brown spots, extending to various degrees over the whole surface of the fruit. Beneficial effects of high temperature conditioning in reducing CI have been reported with other fruits (Lurie and Klein, 1991; McCollum et al., 1993; Woolf at al., 1995).

No important treatment-dependent differences were detected in decay during cold storage (data not shown). By the end of simulated marketing, decay rose to 8.9% in nontreated fruit. In comparison to control fruit, decay percentage was less in 48 and 72COND fruit and significantly less in 24COND fruit (Table 1). Among pathogens, *Penicillium* spp., were the most frequent; *Botritis*, *Alternaria*, and bacterial infections were also present (data not shown).

After 14 days of storage, fruit appearance, when free of disorders and diseases, was judged to be good in all cases, with minimal differences among treatments. By the end of storage at 6 °C, overall appearance had worsened, which was more pronounced in nonconditioned than in conditioned fruit (data not shown). Keeping fruit at 20 °C following storage led to rapid deterioration in visual quality in all samples, but to a larger extent in untreated fruit (Table 1).

No significant differences among treatments were detected in fruit mass after 14 days at 6 °C (Fig. 1). At 21 days, heat-conditioned fruit had lost significantly less mass than had control fruit. By the end of simulated marketing, mass loss was lowest in 48COND and 72COND, intermediate in 24COND, and highest in nontreated fruit.

Respiration rate was not affected by year or treatment (Table 2). Ethylene evolution from 48COND and 72COND fruit was significantly lower than from controls, while 24COND was intermediate. The significant year × treatment interaction effect on ethylene evolution could be attributed to an unusually high ethylene evolution rate in 24COND fruit in 1993. Previous studies with cactus pears from the late crop revealed that 24COND suppressed respiration during simulated marketing, but did not affect the pattern of ethylene evolution compared with nontreated fruit (Schirra et al., 1996). In our study, heat treatment had no influence on cactus pear respiration rate while ethylene evolution was suppressed by 48COND or 72COND, indicating a different physiological response to heat treatment of the first compared to second (induced) crops.

Ethanol at <2 mg/100 mL was detected in the juice of freshly harvested cactus pears (Table 2). Ethanol increased sharply during simulated marketing in 72COND fruit. At harvest, mean values for juice were: pH, 6.30 ± 0.02; titratable acidity, 0.13 ± 0.002%; SSC, 13.7 ± 0.12%; and ascorbic acid, 31.3 ± 0.96 mg/100 mL, respectively. Differences due to treatments and storage duration were negligible (data not shown).

Prestorage conditioning reduced CI and decay and resulted in better external cactus pear fruit appearance. Beneficial effects of heat treatments were also detected in fruit mass loss during simulated marketing.

Postharvest heat conditioning may represent a possibility of extending the postharvest life of early-ripening cactus pears by 4 weeks, thus keeping cactus pears on the market in a period when fruit from the second, induced, crop are not still available (Barbera et al., 1991, 1992), but without requiring the use of chemical treatments.

Literature Cited

Barbera, G., F. Carimi, and P. Inglese. 1991. The reflowering of prickly pear (*Opuntia ficus-indica* (L.) Miller): Influence of removal time and cladode load on yield and fruit ripening. Adv. Hort. Sci. 5:77–80.

Barbera, G., F. Carimi, and P. Inglese. 1992. Past and present role of the indian-fig prickly pear (*Opuntia ficus-indica* (L.) Miller, cactaceae) in the agriculture of Sicily. Econ. Bot. 46:10–20.

Barkai-Golan, R. and D.J. Phillips. 1991. Postharvest heat treatment of fresh fruits and vegetables for decay control. Plant Dis. 75:1085–1089.

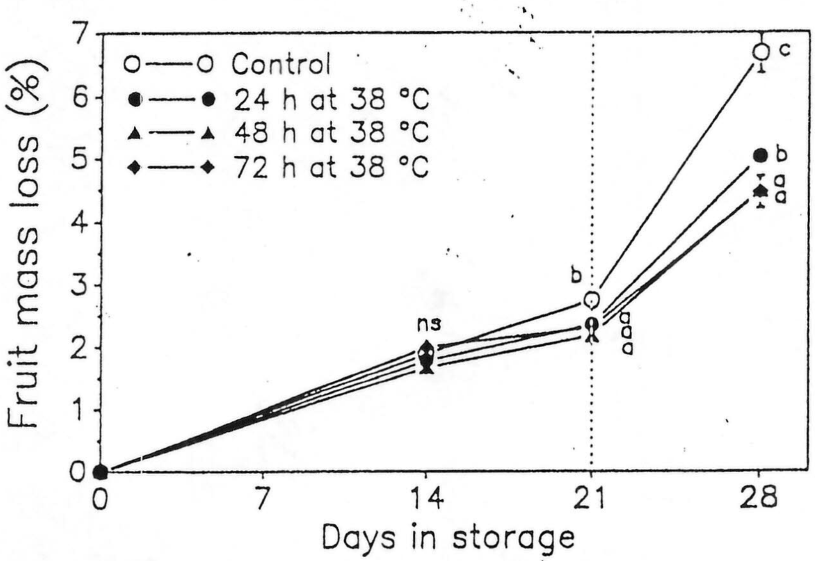


Fig. 1. Effect of temperature conditioning on fruit mass loss of early ripening 'Gialla' cactus pear fruit stored for 21 days at 6 °C plus 7 days at 20 °C.

Table 2. Influence of prestorage heat treatment on respiration rate, ethylene evolution and ethanol content in the juice of 'Gialla' cactus pear after 21 days at 6 °C plus 7 days at 20 °C.[z]

Time at 38 °C (h)		CO_2 production ($mg\cdot kg^{-1}\cdot h^{-1}$)	Ethylene ($\mu L\cdot kg^{-1}\cdot h^{-1}$)	Ethanol (mg/100 mL)
			At harvest	
		21.9	0.58	1.65
			21 days at 6 °C + 7 days at 20 °C	
0		49.4 a	1.25 a	4.7 b
24		44.6 a	1.03 ab	5.8 b
48		41.6 a	0.70 b	4.8 b
72		47.6 a	0.61 b	28.3 a
Source	df		Mean square and significance	
Year (A)	1	548[NS]	0.34[NS]	3.68[NS]
Error	4	356	0.17	1.94
Treatments (B)	3	70.3[NS]	0.53[**]	809.6[***]
A × B	3	90.9[NS]	0.38[*]	6.94[NS]
Error	12	51.3	0.09	3.79

[z]Values are the means of 3+3 replicate analysis (1993 and 1995 seasons).

[y]Mean separation within columns at $P \leq 0.05$ by Duncan's multiple range test.

[NS],[*],[**],[***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Chessa, I. and G. Barbera. 1984. Indagine sulla frigoconservazione dei frutti della cv "Gialla" di Ficodindia. Frutticoltura 8:57–61.

Chessa, I. and M. Schirra. 1990. Cactus pear cv. 'Gialla': Intermittent and constant refrigeration trials. Proc. Intl. XXIII Hort. Congr. Florence (Italy). 1:689 (Abstr. 2514).

Couey, H.M. 1989. Heat treatment for control of postharvest diseases and insect pests of fruits. HortScience 24:198–202.

Gorini, F., A. Testoni, R. Cazzola, F. Lovati, M.G. Bianco, I. Chessa, M. Schirra, M. Budroni, and G. Barbera. 1993. Aspetti tecnologici: Conservazione e qualità di fico d'india e avocado. Inf. Agrario. XLIX(1):89–92.

Klein, J.D. and S. Lurie 1992. Heat treatments for improved postharvest quality of horticultural crops. HortTechnology 2:316–320.

Lurie, S. and J.D. Klein. 1991. Acquisition of low-temperature tolerance in tomato by exposure to high temperature stress. J. Amer. Soc. Hort. Sci. 116:1007–1012.

McCollum, T.G., S. D'Aquino, and R.E. McDonald. 1993. Heat treatment inhibits mango chilling injury. HortScience 28:197–198.

Paull, R.E. 1990. Postharvest heat treatments and fruit ripening. Postharvest News Infor. 1:355–363.

Porrit, S.W. and P.D. Lidster. 1978. The effect of pre-storage heating on ripening and senescence of apples during cold storage. J. Amer. Soc. Hort. Sci. 103:584–587.

Schirra, M., G. Barbera, S. D'Aquino, T. La Mantia, and R.E. McDonald. 1996. Hot dips and high-temperature conditioning to improve shelf quality of late-crop cactus pear fruit. Trop. Sci. 36:159–165.

Testoni, A. and P. Eccher Zerbini. 1990. Conservazione del fico d'india in atmosfera normale e controllata. Annali I.V.T.P.A. Milano, Italy XXI:131–137.

Wang, C.Y. 1993. Approaches to reduce chilling injury of fruits and vegetables. Hort. Rev. 15:63–95.

Woolf, A.B., C.B. Watkins, J.H. Bowen, M. Lay-Yee, J.H. Maindonald, and L.B. Ferguson. 1995. Reducing external chilling injury in stored 'Hass' avocados with dry heat treatments. J. Amer. Soc. Hort. Sci. 120:1050–1056.

Trop. Sci. 1996, **36**, 159–165

Hot dips and high-temperature conditioning to improve shelf quality of late-crop cactus pear fruit

M. Schirra, G. Barbera, S. D'Aquino, T. La Mantia* and R.E. McDonald†*
CNR – Istituto per la Fisiologia della Maturazione e della Conservazione del Frutto delle Specie Arboree Mediterranee, 09170 Oristano, Italy. *Istituto di Coltivazioni Arboree, Università di Palermo, Italy. †USDA, ARS, US Horticultural Research Laboratory, 2120 Camden Rd., Orlando FL 32803, USA

Abstract *The response of late-crop cactus pear (*Opuntia ficus-indica *Mill.) to postharvest hot water dip treatments (5 min at 55°C) with or without thiabendazole fungicide (1000 ppm) and high-temperature conditioning (24 h at 38°C), or both in combination, was investigated over 4 weeks of storage at 6°C and one additional week at 20°C (simulated shelf life). All treatments reduced cold- and rot-induced losses without causing heat injury or detrimental effects to fruit firmness, flavour, taste or peel appearance. The combined treatments did not significantly reduce chilling injury and decay with respect to treatments applied separately. Fruit respiration and ethylene production rate were minimally affected by postharvest treatments. Treatments had only a slight effect on pH, total soluble solids, acetaldehyde and ethanol in the juice during refrigeration or shelf life. Ascorbic acid levels were generally lower in all fruit following simulated shelf life. Prestorage dipping of the fruit in water at 55°C for 5 min or conditioning at 38°C under saturated humidity for 24 h appear to be effective in improving the quality of cactus pears during marketing and could reduce the need for postharvest fungicides.*

Keywords: *Opuntia ficus-indica*, chilling injury, decay, ethanol, ethylene, quality, respiration, storage, heat treatment.

Introduction

The cactus pear, *Opuntia ficus-indica* (L.) Mill. (Cactaceae), has long been cultivated in the Mediterranean region. Despite the recent market downturn for many other Mediterranean fruit crops, the cactus pear industry in Sicily has flourished (Barbera *et al.* 1991). Cultivation now covers about 2500 ha, intensively managed (Basile 1990). The cactus pear's domestic marketing season opens in mid-August and closes in November/December, when prices are notably higher because of waning supplies and the delivery of higher quality fruits. The latter are the result of what is called *scozzolatura*, a special management technique which involves removal of the flowers and cladodes that appear at the end of natural bloom in spring. This causes a flush of new floral and vegetative buds that lead to a new, or 'late', crop about 2 months later in the season (Portolano 1967).

Accepted 11 January 1995

The cactus pear could be cultivated in other semi-arid areas, where it might be an alternative to more demanding crops or to the abandonment of farming. It requires low energy inputs (Baldini *et al.* 1982), a moderate water demand (Barbera 1988), shallow tilling even at planting, reduced and easy pruning and only occasionally needs pesticide treatments.

Little is known of the physiological processes controlling the ripening of the cactus pear (Moreno-Rivera *et al.* 1979; Barbera *et al.* 1992) and its postharvest response (Lakshminarayana and Estrella, 1978; Lakshminarayana *et al.* 1979). The fruit is very susceptible to chilling injury, like other tropical and sub-tropical fruit species (Paull 1990), which limits low-temperature storage. However, without refrigeration cactus pears deteriorate in a few days as a result of rapid aging and parasitic infections. Established storage systems employ low temperatures, high humidity and fungicides, which achieve a certain lifespan, but result in excessive product losses (Gorini *et al.* 1993). Although use of a controlled atmosphere has given some benefits to fruit quality (Testoni and Eccher Zerbini 1990), intermittent warming has produced contrasting results (Chessa and Schirra 1990; Testoni and Eccher Zerbini 1990). More recent studies (Schirra *et al.* unpublished results) have shown that prestorage high-temperature conditioning can notably reduce postharvest losses. The present study concerns the response of cactus pear to conditioning and hot water dip treatments.

Materials and methods

Late-crop cactus pears of cv. 'Gialla' (*O. ficus-indica* Mill.) were harvested during the second week of November 1993 from a single lot of a commercial orchard at Santa Margherita Belice, Sicily. Freshly harvested fruits were transported by ship and truck to the laboratory at Oristano at ambient temperature (15–20°C) within 36 h, sorted to eliminate defective samples, selected by colour, size and appearance, and placed in plastic boxes (40 fruit per box). They were then divided into three lots of six boxes each and subjected to the following different dip treatments: water at 25°C; water at 55°C; and 1000 p.p.m. thiabendazole (TBZ) suspension in water at 55°C. Dip time was 5 min and water temperature was continuously monitored to keep it within ±1·0°C at the 55°C setting. The dip temperature and time were selected after preliminary tests.

After treatment each lot was divided into two subgroups and left to dry for 3 h at ambient temperature (20°C). Three subgroups were immediately transferred to a ventilated storage room at 6°C and 90–95% relative humidity (RH). The remaining three subgroups were placed in a plastic container inside a heat-controlled room at 38±1·5°C; a moisture-saturated atmosphere was created inside the containers by placing 10 litres of water on the floor and circulating forced air into the sealed chambers every 8 h. After 24 h the fruit were moved to the cold store containing the first three subgroups. After 4 weeks all six subgroups were removed from cold storage and kept at 20°C and 70–75% RH for 1 week to simulate market conditions (shelf life).

The fruit were inspected after 2 and 4 weeks, immediately upon removal from cold storage and after the week of simulated shelf life to assess the percentage of fruit showing mould decay and chilling injury. Each fruit was evaluated subjectively for rind pitting and brown staining. The amount of peel surface affected by chill injury was rated as 0 (no injury), 1 (trace of injury), 2 (slight injury), 3 (moderate injury) or 4 (severe injury). To obtain a weighted average for a chilling index the number of fruit in each rating was multiplied by the designated number and an average was taken. Overall visual quality was evaluated on fruit without infection or physiological defects by an informal taste panel of three technicians using a scale of 9 (excellent), 7 (good: fresh, limit of marketability), 5 (fair: fairly fresh, limit of edibility) and 3 (poor: old, not fresh, when fruit would be rejected) and an average visual score calculated.

Physiological and chemical parameters were determined at harvest, after 4 weeks' storage and at the end of shelf life. Respiration rate was measured by taking at random five fruit from each subgroup and placing them in 3·8 litre plastic jars mounted in groups of four inside the storage rooms, three of which were used for the respiratory rate and the fourth used as an air blank. The air stream from each jar, metered through XPR precision tube flow meters (Aalborg Instruments, New York) was passed through two gas dispersion tubes connected in series (double trap) containing 0·1N barium hydroxide and 0·2% barium chloride solution. Carbon dioxide output was recorded titrimetrically. The jars were sealed after CO_2 analysis and, after 2 h incubation, the atmosphere was agitated five times with a syringe. A 2 ml sample of headspace atmosphere was withdrawn with a gas-tight glass syringe and analysed for ethylene by gas chromatography as described by Schirra (1992). Ethylene concentrations were calculated by comparison with peak heights from injections of authentic standard. Immediately after ethylene analysis, the fruit were peeled and the pulp homogenized with a Waring commercial blender. Seeds were removed by filtering through a domestic sieve and the fluid was centrifuged (6000 rpm for 10 min at 4°C) to give a juice. The pH was determined with an expandable ion analyser (EH 940, Orion Research), total soluble solids as °Brix (Abbe refractometer 10460, American Opt. Corporation), ascorbic acid by the 2,6-dichloroindophenol method (AOAC 1980), and ethanol and acetaldehyde by gas chromatography of juice headspace (Schirra 1992).

The analysis of variance (ANOVA) and Duncan's multiple range test for comparison of means were performed with the data.

Results

Chilling injury

A higher incidence of chill injury was recorded in control fruits than in treated fruits during low-temperature storage (Table 1). The stress engendered under low-temperature storage was more evident on transfer to simulated shelf life, where many fruit, still apparently sound in storage, developed typical visible symptoms. The post-shelf life injury index was at least double that recorded after cold storage. Symptoms appeared as diffused and irregular brown spots extending over the entire fruit surface.

Heat treatments significantly reduced injury, to varying extents. The 55°C hot water dip (HW) diminished injury by almost 60% by the end of cold storage and by 30% at the end of shelf life. Hot TBZ at 55°C (HTBZ) delayed the onset of chill injury by about 2 weeks, but the injury at the end of cold storage did not differ significantly from that seen with HW

Table 1. Influence of postharvest treatments on chilling injury, decay and visual rating of 'Gialla' cactus pear fruit

Storage conditions	Chilling injury index	Decay by mould (%)	Visual rating
2 weeks at 6°C			
5 min water dip at 25°C	0·70a	3·3a	8·3d
5 min water dip at 55°C (HW)	0·07b	0·0a	8·9ab
5 min 1000 p.p.m. TBZ dip at 55°C (HTBZ)	0·00b	0·0a	9·0a
24 h conditioning at 38°C (HA)	0·13b	2·2a	8·7c
HW + HA	0·10b	1·5a	8·7c
HTBZ + HA	0·07b	0·8a	8·8abc
4 weeks at 6°C			
5 min water dip at 25°C	0·97a	11·3a	6·8d
HW	0·37c	0·0c	8·1a
HTBZ	0·50bc	0·0c	7·7abc
HA	0·77ab	5·1b	7·4c
HW + HA	0·50bc	2·3bc	7·6bc
HTBZ + HA	0·23c	1·5bc	8·0ab
4 weeks at 6°C + 1 week at 20°C			
5 min water dip at 25°C	1·97a	48·0a	5·1d
HW	1·40b	3·7bc	5·7bc
HTBZ	1·23b	0·0c	6·2a
HA	1·50b	12·1b	5·5c
HW + HA	1·27b	8·9bc	5·9ab
HTBZ + HA	1·37b	1·5bc	6·1ab

Mean separation by Duncan's multiple range test at the 5% level of probability. Means in each column with each storage time followed by a common letter are not significantly different.

alone. Postharvest hot air treatment (HA) significantly reduced chilling injury with an efficacy similar to that of HW or HTBZ. No significant benefit was observed in HW + HA or in HTBZ + HA treatments compared with treatments applied separately.

Rot development

Rot incidence was about 3% in control fruit after 2 weeks' storage and increased to about 11% after week four. The transfer of fruit to simulated shelf life resulted in an increase of rot to 48%. The hot water dip was very effective in preventing the onset of rot throughout cold storage and in reducing rot growth in shelf life simulation. HTBZ treatment fully controlled rot throughout storage and simulated shelf life. HA significantly controlled rot development but was less effective than the HW or HTBZ treatments. The HW + HA and HTBZ + HA treatments in cold storage showed no significant differences from HA alone. *Penicillium* spp., especially *Penicillium italicum*, were the most frequent pathogens recorded, followed to a much lesser extent by *Botrytis* and *Alternaria* spp.

Overall visual appearance

By the end of storage week two, the fruit with no physiological or pathological disorders were rated as excellent, the mean score being above 8 in all cases. Fruit characteristics exhibited a decline, which varied depending on treatment, after cold storage. Peel appearance was rated good for all heat treatments. Simulated shelf life conditions had a devastating effect in all cases, the fruit being rated at the limit of edibility and scoring 5 in control and approaching 6 in the other cases.

Physiological response

On removal from storage, the respiration rate was significantly lower in the HTBZ treatments, higher in the HW treatment and intermediate in the other cases (Table 2). After 1 week of shelf life following storage sharp increases were recorded in all cases, the most pronounced being in the HTBZ + HA treated group. The lowest values were detected in HA and HW + HA and intermediate in the other treatments. At the end of cold storage the ethylene production rate was lower with HTBZ + HA treatment, higher in HTBZ treatment and intermediate in the other cases. At the end of shelf life, sharp increases were recorded in all samples, the extent being greater in the control and HA treatment and lower in the HW + HA treated fruit.

Chemical parameters

Ethanol levels remained undetectable throughout both cold storage and shelf life and only very low amounts of acetaldehyde were detected. There were no significant differences in cold storage and shelf life for pH and total soluble solids. Ascorbic acid levels were lower in control fruit and, to a lesser extent, in HW treated fruit after 1 week of simulated shelf-life following storage.

Table 2. Influence of postharvest treatments on 'Gialla' cactus pear fruit stored at 6°C plus 1 week at 20°C (simulated shelf life)

Storage conditions	Respiration rate (mg CO_2/kg/h)	Ethylene production rate (ml/kg/h)	pH	Total soluble solids (°Brix)	Ascorbic acid (mg/100 ml)
Harvest	32·7	0·57	6·58	13·4	32·5
4 weeks at 6°C					
5 min water dip at 25°C	15·5ab	0·43ab	6·25c	13·1a	33·4ab
HW*	16·6a	0·39abc	6·27c	13·0a	35·0a
HTBZ	12·5c	0·52a	6·44b	13·3a	34·6a
HA	15·2ab	0·36bc	6·48ab	12·7a	33·4ab
HW + HA	14·5b	0·38abc	6·52a	12·7a	31·3b
HTBZ + HA	10·1d	0·26c	6·30c	13·0a	30·9b
4 weeks at 6°C+ 1 week at 20°C					
5 min water dip at 25°C	73·0b	2·12a	6·41b	12·6a	22·7b
HW	68·9b	1·88b	6·45ab	12·6a	27·2ab
HTBZ	75·9b	1·66c	6·40b	13·1a	31·3a
HA	37·8c	2·15a	6·50a	12·9a	30·5a
HW + HA	37·4c	1·55c	6·42b	12·7a	31·7a
HTBZ + HA	98·2a	1·95b	6·24c	12·5a	30·5a

Harvest data are included only to provide a comparison with the other measurements.
Mean separation by Duncan's multiple range test at the 5% level of probability. Means in each column with each storage time followed by a common letter are not significantly different.
*For abbreviations see Table 1.

Discussion

The results show that the conditioning of fruits at 38°C for 24 h in a humidity-saturated atmosphere effectively reduced losses from cold injury and rots; similar results occurred on early crop cactus pears (Schirra *et al.* unpublished data). Prestorage hot dip treatments were slightly more effective than HA conditioning in reducing cold injury and decay and in maintaining fruit appearance throughout storage. Hot water was also instrumental in removing glochids, small (4–5 mm), barbed spines associated with the areolas on the fruit surface. Because of their structure and composition (Pritchard and Hall 1975), glochids can cause numerous microlesions in the skin, resulting in rapid fruit aging and making the fruit susceptible to infection by micro-organisms. Hot water treatment has the advantage of ensuring removal of these spines without the inevitable skin damage caused by 'brushing', a technique employed before marketing. When combined, HA and HW did not lead to consistent improvements over individual applications. Thiabendazole inhibited the onset of chilling injury throughout cold storage and sharply reduced its development during shelf life. A similar effect has been reported with citrus fruit (Schiffmann-Nadel *et al.* 1975). The reason for the lower ascorbic acid values in control fruit during shelf life is not clear. It may be that the other treatments delayed the oxidation of ascorbic acid to dehydroascorbic acid.

Conclusions

Prestorage dipping of late-crop cactus pear fruit in water at 55°C for 5 min or conditioning for 24 h at 38°C under saturated humidity appear to be effective methods for improving the shelf quality.

Acknowledgements

We thank the Ministero delle Risorse Agricole, Alimentari e Forestali for financial support.

References

AOAC (1980) *Official methods of analysis*, 13th ed. Washington DC: Association of Official Analytical Chemists.

Baldini E., Alberghina O., Bargioni G., Cobianchi D., Jannini B., Tribulato E. and Zocca A. (1982) Analisi energetiche di alcune colture arboree da frutto. *Rivista di ingegneria agraria.* 13, 113–118, 191–199.

Barbera G., Carimi F., Inglese P. and Panno M. (1992) Physical, morphological and chemical changes during fruit development and ripening in three cultivars of prickly pear, *Opuntia ficus-indica* (L) Miller. *Journal of Horticultural Science* 67, 307–312.

Barbera G., Carimi F. and Inglese P. (1991) Past and present role of the Indian fig prickly-pear (*Opuntia ficus-indica* (L) Miller Cactaceae), in the agriculture of Sicily. *Economic Botany* 46, 10–20.

Barbera G. (1988) Ricerche sull'irrigazione del fico d'india. *Frutticoltura* 8, 49–55.

Basile F. (1990) Indagine economico-agraria sulla produzione del fico d'india in Italia. Istituto di Economia e Politica Agraria, Facoltà di Agraria dell'Università di Catania.

Chessa I. and Schirra M. (1990) Prickly pear cv. 'Gialla': intermittent and constant refrigeration trials. *Proceedings of the 23rd International Horticultural Congress.* 1, 689 (Abstract No. 2514).

Gorini F., Testoni A., Cazzola R., Lovati F., Bianco M.G., Chessa I., Schirra M., Budroni M. and Barbera G. (1993) Aspetti tecnologici: Conservazione e qualità di fico d'india e avocado. L. *Informatore Agricolo* 49, 89–92.

Lakshminarayana S, Alvarado L. and Perez F. (1979) The development and postharvest physiology of the fruit of prickly pear (*Opuntia amyclaea* Tenore). *Tropical Foods* **1**, 69–93.

Lakshminarayana S. and Estrella I.B. (1978) Postharvest respiratory behaviour of tuna (prickly pear) fruit (*Opuntia robusta* Mill.). *Journal of Horticultural Science* **53**, 327–330.

Moreno-Rivera M.A., Alvarado y Sosa L. and Lakshminarayana S. (1979) Preharvest respiratory trend of the fruit of prickly pear (*Opuntia amyclaea* T.). *Proceedings of the Florida State Horticultural Society* **92**, 235–237.

Paull R.E. (1990) Chilling injury of crops of tropical and subtropical origin. In: *Chilling injury of horticultural crops* (C.Y. Wang ed.), pp.17–36. Boca Raton, FL: CRC Press.

Portolano N. (1967) La fruttificazione del fico d'india. *L'Italia Agricola*. **104**, 739–741.

Pritchard H.N. and Hall J.A. (1975) The chemical composition of glochids from Opuntia. *Canadian Journal of Botany* **54**, 173–176.

Schiffmann-Nadel M., Chalutz E., Waks J. and Dagan M. (1975) Reduction of chilling injury in grapefruit by Thiabendazole and Benomyl during long-term storage. *Journal of the American Society Horticultural Science* **100**, 270–272.

Schirra M. (1992) Behaviour of 'Star Ruby' grapefruits under chilling and non-chilling storage temperature. *Postharvest Biology and Technology* **2**, 315–327.

Testoni A. and Eccher Zerbini P. (1990) Conservazione del fico d'india in atmosfera normale e controllata. *Annali dell'Istituto Sperimentale per la Valorizzazione Tecnologica dei Prodotti Agricoli.* Grafiche Pavoniane Artigianelli Milano, Italy **21**, 131–139.

Storage trials of cactus pear [*Opuntia ficus-indica* Miller (L.)] fruit with 'non-conventional' methods.

M. Schirra

C.N.R. - Istituto per la Fisiologia della Maturazione e della Conservazione del Frutto delle Specie Arboree Mediterranee, Nuraxinieddu, 09170 Oristano, Italy.

Summary

Various physical and chemical approaches have been investigated singly or in combination to improve fruit shelf-quality of cactus pears. The maximum benefit is achieved when fruit is of top quality, harvested when properly ripe and free of defects. Moreover, packaging lines, storage facilities, transit systems and marketing channels must be kept clean and sanitised so as not to frustrate efforts made to keep fruit quality high. What follows is an account of the most important results obtained in a research project with cactus pears carried out in Italy. Special attention is focused on 'non-conventional' technologies such as prestorage heat treatments (high temperature conditioning under saturated atmosphere and hot water dip treatments), applied separately or in combination with fungicides, to prevent or alleviate chilling injury and minimise rot development in fruit during cold storage and shelf-life.

Keywords: Cactus pear, heat treatments, thiabendazole, chilling injury, rots, storage.

Cactus pear [*Opuntia ficus-indica* (L.) Mill.] fruits represent a very important food source in satisfying the nutritional needs of populations of various countries, especially those in South America such as Bolivia, Brazil, Chile, Columbia and Mexico (Pimienta Barrios 1993). Cactus pear fruits may be used in a wide range of products made in the home, in small enterprises or on the industrial scale such as jams, gelatine, syrups, dry fruit, candies and juice concentrate. The nutritional, medicinal and human health properties of cactus pears are factors that could contribute to an increase in cactus pear consumption (Hegwood 1990). In Peru and Spain certain species of *Opuntia* are used as hosts of cochineal insects (*Dactylopius coccus* Costa) from which a red dye highly appreciated by pharmaceutical, cosmetics, food and textile industries is extracted. Recently, the possibility of using seed oil from cactus pears and in producing ethanol and antioxidants from cladodes has been pointed out.

In Italy, cactus pears are grown primarily for the fresh market. Sicily is the main producing region, with approximately 95% of national production (over 60,000 tonnes) on about 8,000 intensively managed hectares (Basile and Foti 1997). Only three cactus pear cultivars are cultivated in Italy: the 'Gialla' cultivar, also known as 'Sulfarina' or 'Nostrale', representing approximately 90% of total cactus pear production, Rossa (8%) and Bianca (2%) (Barbera et al. 1991). The cactus pear's domestic marketing season opens in mid-August with fruits of the spring flush of flowers and closes in November-December with fruits of the second crop which is the result of what is called *scozzolatura*, a special management technique consisting of the removal of the flowers and cladodes that appear at the end of the natural bloom in spring. This causes a flush of new floral and vegetative buds that lead to a new, or 'late,' crop about two months later in the season (Barbera et al. 1991).

The postharvest life of Italian cactus pear fruits is relatively short. Fruits kept at room temperature deteriorate rapidly as a result of ageing and microbial moulds and rots, especially *Penicillium* spp which exploits micro-wounds caused by glochids during fruit handling and by the fruit's high sugar content. Conversely, low storage temperature favours the development of postharvest disorders known as chilling injury (Cantwell 1995). The susceptibility of fruits to chilling injury depends on cultivar, environmental growth conditions and fruit age. Investigations carried out at our laboratory (D'hallewin et al., unpublished data) showed that 'Bianca' cactus pears were more sensitive to low temperature than fruits of 'Rossa', while 'Gialla' cactus pears showed intermediate susceptibility. Fruits of the spring flush are found to be much more susceptible to chilling injury and weight loss, but less sensitive to rot decay than fruits of the second induced flush of flowers and cladodes. Mature-green fruits are more susceptible to decay but less prone to chilling injury than ripe fruits (Schirra et al., unpublished data). Fruits should be harvested when the umbilical crown is still slightly green so that they can withstand a certain storage and marketing period. To reduce damage during harvesting and limit postharvest decay caused by wound pathogens, it is advisable to leave a small piece of cladode at the fruit edge cut. The subsequent exposure of fruits to room temperature (curing) is recommended to favour the drying of the piece of cladode and its detachment during handling and packaging. Fruit brushing to remove glochids (small barbed spines associated with the areolas on the fruit surface) negatively affects keeping quality and increases susceptibility to decay (Testoni and Eccher-Zerbini 1990).

Established storage conditions for cactus pears grown in Italy are 5-8°C and 90-95% relative humidity with adequate ventilation of refrigerated rooms for a storage life of approximately 30 days (Testoni and Eccher-Zerbini 1990; Gorini et al.

1993). These conditions are found to be the best compromise in limiting CI and decay development and reducing respiration and transpiration rates. When storage continues beyond these limits, losses from rot and chilling injury increase sharply, especially when the fruits are once again subjected to room temperature. Compared to continuous storage at 6°C, intermittent warming (IW) to 8°C for 4 days every 10 days at 2°C reduced CI of 'Gialla' cactus pears after 6 weeks of refrigeration plus 1 week at 20°C (Chessa and Schirra 1992). On the other hand, storage at a cycles of 3 weeks at 2°C followed by 1 week at 8°C significantly reduced decay development in comparison to continuous storage at 5°C or 8°C, but to a lesser extent than storage at controlled atmosphere (CA) (2%O_2, 5%CO_2 or 2%O_2, 2%CO_2) which has been shown to extend storage life of fruits to approximately 45 days (Testoni and Eccher-Zerbini 1990; Di Cesare et al. 1993). Some beneficial effects of cold stored fruits were also achieved by fruit packaging (Piga et al. 1996). However, there are still many problems connected with CA storage, packaging and IW. Two of these are the lack of suitable storage facilities in most producing countries and its high cost, which makes it unfeasible for fruits of this species.

Over the last few years much attention has been devoted to developing or improving 'non-conventional' methods such as heat therapy for postharvest protection of cactus pear fruits. In particular, it has been shown (Schirra et al. 1996) that postharvest treatments with hot water (HWT) (5 min dips at 55°C), 1000 ppm hot thiabendazole (HTBZ) (5 min dips at 55°C), and hot air treatment (HAT)(24 h at 38C) significantly reduced cold- and rot-induced losses in late-crop cactus pear fruits during 4 weeks of storage at 6°C plus an additional week at 20°C of simulated marketing period (SMP), without causing heat injury or detrimental effects to fruit firmness, flavour, taste and peel appearance (Schirra et al. 1996). HWT and HTBZ were also instrumental in removing glochids, which are known to cause numerous micro-lesions in the skin, resulting in rapid fruit ageing and making the fruits susceptible to infection by micro-organisms. HWT has the advantage of ensuring the removal of these spines without the inevitable skin damage caused by 'brushing' prior to marketing. The combined treatments HWT+HAT or HTBZ+HAT did not produce any additional advantages compared to their individual applications. Physiological response of fruits (respiration and ethylene production rate) was only slightly influenced by treatments. The effect of treatments on pH, TSS, acetaldehyde and ethanol in the flesh was negligible. Ascorbic acid levels were generally lower in all fruits following simulated shelf-life.

Beneficial effects of HAT (38°C for 24 to 72 h) before storage (21 days of storage at 6°C and 90-95% RH plus one week SMP) have also been demonstrated with cactus pears produced by the spring flush (Schirra et al. 1997a). So far, HAT resulted in better external fruit quality and remarkably reduced the severity of fruit weight loss, chilling injury and decay of cactus pears with respect to untreated fruits following SMP, with conditioning for 24 hours being the most effective in decay control.

Preharvest sprays with 2% calcium chloride ($CaCl_2$) solution 10 weeks after full bloom delayed the appearance of the typical colour of ripe fruits, significantly inhibited pathogen development after 42 days of storage plus 3 additional days of SMP but significantly promoted the appearance of chilling injury (CI) during SMP while decreased the rate of fruit weight loss during SMP (Schirra et al., 1997b). The combined treatments ($CaCl_2$+HAT) did not exhibit advantages in mould decay control as compared to HT applied separately.

Postharvest dip treatments with TBZ mixtures at room temperature effectively reduced the expression of CI in cactus pears in addition to its fungicidal properties (Gorini et al., 1993). However, the effectiveness of this fungicide in CI and decay control may be greatly improved when applied at 50-52°C (unpublished data). Moreover, the combination of fungicide and hot water made it possible to use much lower levels (200 mg/l) of TBZ than the recommended doses (1000 mg/l) of fungicide at room temperature.

It was concluded that the use of fungicides is still needed to maintain the postharvest quality of cactus pear fruit. However, the positive synergistic effects of hot water and TBZ, when applied together, may pave the way to a saving on fungicides and a reduction of the costs of processing wastewaters, which could be discharged from packing or storage facilities.

References

Barbera, G., Carimi, F. and Inglese, P. (1991). Past and present role on prickly pear *Opuntia ficus-indica* (L) Miller in the agriculture of Sicily. *Econ. Bot.* 46, 10-20.

Basile, F., Foti, V.T. 1997. Economic features of cactus pear production in Italy. Acta Hortic. 438, 139-150.

Cantwell, M. 1995. Postharvest management of fruits and vegetable stems. In: *Agro Ecology, Cultivation and uses of Cactus Pear.* (G. Barbera, Inglese, P. and Pimienta Barrios E. *eds*). FAO Plant Production and Protection. Paper 132. 120-136.

Chessa, I. and Schirra, M. 1992. Prickly pear cv Gialla: intermittent and constant refrigeration trials. Acta Hort. 296, 129-137.

Di Cesare, L.E., Testoni, A. and Sansovini, G. 1993. Studio dei componenti volatili del fico d'india durante la conservazione normale e controllata. Industrie alimentari XXXII (Lugio-agosto), 725-730.

Hegwood, D.A. 1990. Human health discoveries with Opuntia sp. (Prickly pear) HortSci. 25: 1315-1316.

Gorini, F., Testoni, A., Cazzola, R., Lovati, F., Bianco, M.G., Chessa, I., Schirra, M., Budroni, M. and Barbera, G. 1993. Aspetti tecnologici: Conservazione e qualità di fico d'india e avocado. Inf. Agrario XLIX (1), 89-92.

Piga, A., D'Aquino, S., Agabbio, M. and Schirra, M. 1996. Storage life and quality attributes of cactus pears cv 'Gialla' as affected by packaging. Agricoltura Mediterranea 126: 423-427.

Pimienta Barrios, E. 1993. El nopal (*Opuntia* spp.): una alternativa Ecológica productiva para las zonas áridas y semiáridas. Ciencia 44: 339-350.

Schirra, M., Agabbio, M., D'Aquino, S. and McCollum, T.G. 1997a. Postharvest heat conditioning effects on early ripening 'Gialla' cactus pear fruit. HortScience 32: 702-704.

Schirra, M., Barbera, G., D'hallewin, G., Inglese, P. and La Mantia, T. 1997b. Response of cactus pear fruit to $CaCl_2$ preharvest treatments and prestorage heat conditioning. Journal Horticultural Science 72: 371-377.

Schirra, M., Barbera, G., D'Aquino, S., La Mantia, T. and McDonald, R.E. 1996. Hot dips and high temperature conditioning to improve shelf quality of late-crop cactus pear fruit (*Opuntia ficus-indica* L. Mill.). Tropical Science 36: 159-165.

Testoni, A. and Echer Zerbini, P. 1990. Conservazione del fico d'india in atmosfera normale e controllata. Annali I.V.T.P.A. Milano, Italy XXI, 131-137.

CACTUSNET
FAO INTERNATIONAL COOPERATION NETWORK ON CACTUS PEAR
N E W S L E T T E R
UNIVERSITÀ DEGLI STUDI DI REGGIO CALABRIA
UNIVERSIDAD DE CHILE

EDITORIAL

I am glad to present the fourth issue of the Newsletter of the CACTUSNET-FAO, which is devoted to "Postharvest and industrialization of cactus pear cladodes and fruits". This issue has been prepared in occasion of the Meeting held in Chile and organized by the Working Group on "Agroindustrial uses" chaired by Carmen Saenz of the Universidad de Chile.

Our idea was to make a document useful to readers, familiar with cacti or unaware of their management, who face problems of postharvest handling of cactus pear fruits and cladodes. We asked the authors to give practical guidelines and to update the knowledge available for cladode and fruit postharvest and industrialization, and we are grateful for their effort.

I wish to thank Carmen Saenz, co-editor of this issue, for her enthusiastic and creative participation to network activities.

I also wish to thank FAO for its support, and particularly we are indebted with Enrique Arias and Yoram Levtov who gave us their technical assistance in organizing the Meeting and in preparing the newsletter.

The improvement of postharvest handling of fruits and cladodes is an important step for any further development of the cactus pear industry, both in industrialized and developing countries. Consumers require well presented fruits and only cactus pear of first quality reach good prices in the European markets. Fruit appearance - color, firmness, absence of any wound - and fruit taste and flavor are highly demanded and more information is needed on the relationship between physical, external fruit characteristics and internal quality (taste, sweetness, consistence).

In many countries people are simply not aware on the potential uses of the fruits which cannot be sold fresh because of poor size or scanty appearance. In Italy we can estimate a 15% of unsold, wasted fruits, which are left in the field.

Much more research is needed, but the Mexican experience can be of a great importance for any cactus pear producing country, and the efforts made in this direction by scientists in Chile and Mexico could be the basis for an exploitation of the agroindustrial potential of the cactus pear fruits. Farmers and small scale agroindustry require this information.

Information on "Nopalitos" in the international literature is still very scarce, and many potential consumers do not hold even the basic knowledge for their management and preparation. We hope the information provided by the authors of the articles of this newsletter could support any small scale enterprise aimed to exploit the potential of this vegetable, which could be a treasure for arid areas worldwide.

Prof. Paolo Inglese
General Coordinator of the International Networkfor for Technical Cooperation on Cactus Pear CACTUSNET-FAO

CACTUSNET newsletter 1998

«Postharvest and industrialization of cactus pear cladodes and fruits»

CONTENTS

INDUSTRIALIZATION OF CACTUS PEAR (Opuntia spp.) PADS (*NOPALITOS*) 3
Joel Corrales-García

D'ARRIGO BROTHERS CACTUS PEAR PRODUCTION 5
Martin Thomas

ALTERNATIVES TO PROCESS CACTUS PEAR 8
Carmen Sáenz-Hernández

POSTHARVEST HANDLING OF CACTUS (*Opuntia* spp.) STEMS. 10
Armida Rodríguez-Félix and Mónica A. Villegas-Ochoa

STORAGE OF CACTUS PEAR [*Opuntia ficus-indica* Miller (L.)] FRUIT 13
Mario Schirra

Edited by Paolo Inglese and Carmen Sáenz-Hernández

Designed by Carmen C. Sáenz-Escobar

INDUSTRIALIZATION OF CACTUS PEAR (Opuntia spp.) PADS (*NOPALITOS*)

Joel Corrales-García
Depto. Ingeniería Agroindustrial
Universidad Autónoma Chapingo, Mexico CP 56230

Introduction

Tender cactus pear pads consumed as a vegetable are named nopalitos, and are an excellent food which has form part of the diet of the Mexican people since pre-Hispanic times. However, "nopalitos" is a highly perishable vegetable crop when handled and marketed fresh.

"Nopalitos" have a high content of moisture, which make them very succulent, but susceptible to attack by microorganisms, and thus they are difficult to preserve. Other components to consider are the gummy substances and mucilage whose presence causes problems for preserving, processing, stability and acceptance of the product by the consumer. Besides carbohydrates (sugars and cellulose) "nopalitos" also contain proteins, vitamins, pectic substances, saponines, organic acids and minerals (mainly calcium) (Rodríguez-Félix and Cantwell, 1988; Becerra *et al.*, 1969; Villarreal *et al.* 1961).

With industrial transformation nopalitos can be conserved for a long time, and thus they can be sold in far away markets, the supply can be extended to those months of the year in which yields are scarce, and also prices can be regulated. The variety of products that can be obtained with industrial transformation also makes diversification of markets possible. Moreover, industrialization offers the opportunity to give added value to the product, generate employment, and contribute income that benefits the producer communities and reduces emigration (Corrales-García, 1992).

Today, in Mexico there are companies that process "nopalitos", mainly for export, since domestic consumers prefer them fresh. The main processed products are "nopalitos" in brine and pickled "nopalitos", "nopalito" sauce, jam, and candied "nopalitos". By volume, the most important of these are "nopalitos" in brine and pickled "nopalitos".

With the idea of sharing the experiences which Mexico has had in industrial uses of "nopalito" as an excellent food, this paper gives a technical description of the alternatives of industrial transformations which have greater commercial potential.

Conditioning of raw "nopalitos" for later process

For all of the products mentioned above, the first steps in processing are reception and conditioning of the raw material, which should be of the best quality and dethorned by the grower (Figure 1).

Conditioning consists basically of scalding and washing. The purpose of scalding is to deactivate enzymes, destroy microorganisms, soften the tissues, and partially eliminate mucilage. The main factors to consider in this process are the time and temperature of scalding, as well as the addition of certain compounds that help to improve the results. These factors should be adjusted to the type and variety of the raw material. Washing with cold water, which implicates thermal shock, eliminates adhering pectins and mucilage and also fixes the green color characteristic of the product.

The "nopalitos" resulting from this conditioning is the material which can be used to obtain any of the different products: "nopalitos" in brine, pickled "nopalitos", jam, or candy.

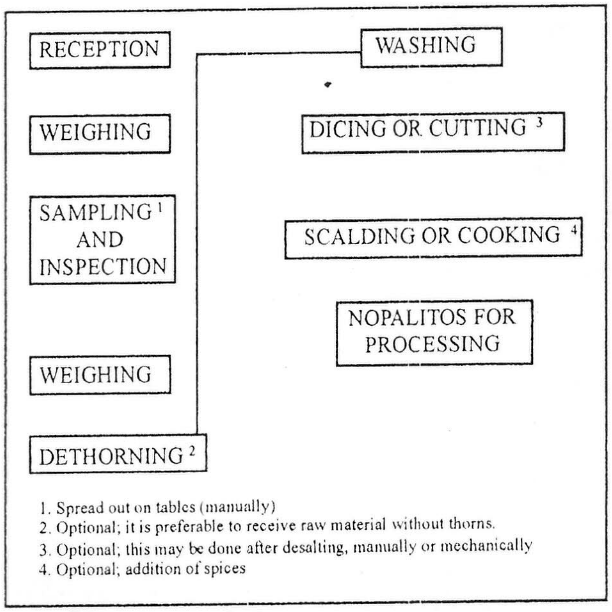


Figure 1. Flow diagram of conditioning of raw "nopalitos" for later process
Source: Corrales-García, 1992 (modified)

"Nopalitos" in brine

As can be seen in Figure 2, the conditioned "nopalitos" are salted in tanks at 12 %; approximating a proportion of 1.7 l of brine to a kilogram of "nopalitos". In these containers, the "nopalitos" may remain for 10 days to months, depending on the demand.

The saline solution must be maintained at a minimum concentration of 10%, by adding salt when necessary. Stirring should be done daily with a wooden paddle. The containers should be well covered to avoid contamination and discoloration of the product from light.

When salting is finalized, the product is taken to the process room where, it is desalted by washings. Later it is sorted, diced, and bottled in jars or packed in bags with a few spices and just covered with 2% brine. The bags are sealed, the jars are covered, and sterilized. They are then left to air dry before labeling. Finally, they are packed in cardboard boxes for commercialization. The product can also be sold by bulk without desalting.

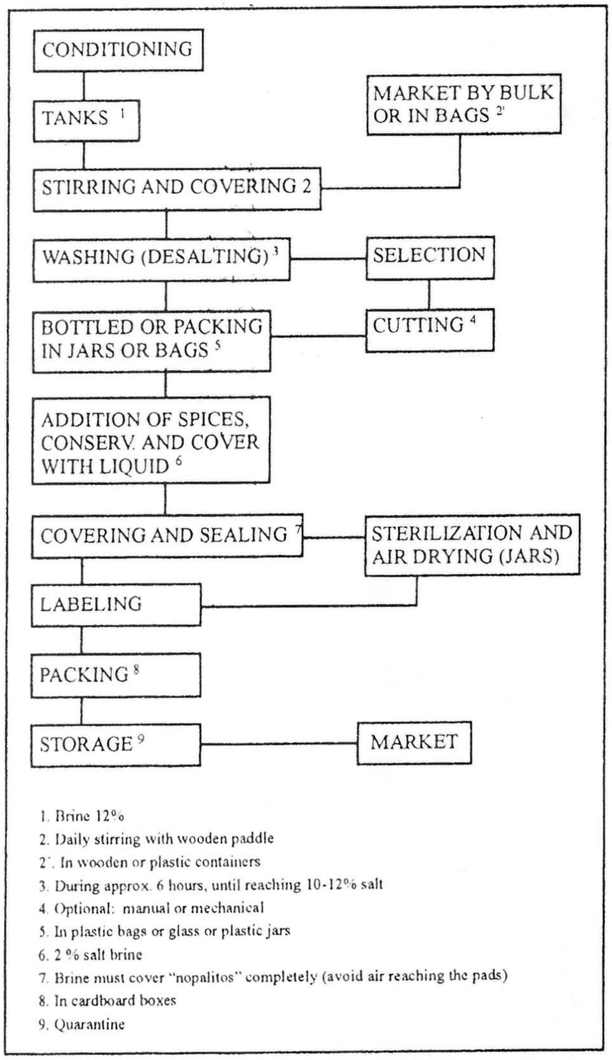
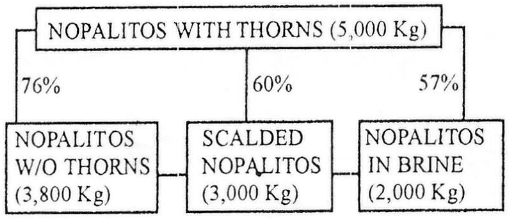


Figure 2. Flow diagram of processing "nopalitos" in brine
Source: Corrales-García, 1992 (modified)

Depending on the process and its control, the yield obtained in the pilot plant was approximately 57% of the weight of the cactus pear pads with thorns (Figure 3 and Table 1).

Because in Mexico, the principal destiny of the industrialized product is export, the following points are worth considering in order to guarantee more success:

- Implement a well-defined program and rigorous quality control for the different steps in the process, from the reception of the raw material. This implies selecting the pads at key points to sort out pads that are bruised or flawed.
- Avoid direct contact of the brine with metal (such as unpainted iron) to prevent problems of corrosion.
- When filling the tanks, the brine must be maintained at a minimum concentration of 10%, which should be verified constantly with a special salt meter, and salt should be added when necessary. Daily stirring during this period is very important to measuring a representative concentration of salt.
-The brine should completely cover the "nopalitos". To assure this, the "nopalitos" should be weighted down with a plastic or wooden screen.
- Light and extraneous material (dust, dirt, litter, water, insects, among others) are detrimental, and so the tanks should be well covered with canvas.



EQUIVALENT QUANTITIES

"Nopalitos"	Weight	No. Pads (X)
With thorns	1 Kg	10
Without thorns	1 Kg	13.16

Figure 3. Pilot plant yields of "nopalitos" in brine, and equivalent quantities of "nopalitos" with and without thorns .

EQUIVALENT PROCESS QUANTITIES	
Product	Approx. Quantitie[s]
Cylindrical packs (250-300 Kg)	8-10 (pieces)
Tender pads	25,000 "
Pads with thorns	2,500 (kg)
Pads without thorns	1,900 "
Cooked "nopalitos"	1,500 "
"Nopalitos" in brine for marketing	1,425 "

Table 1. Equivalent quantities of "nopalitos" for the process in brine

Pickled "nopalitos"

As can be observed in Figure 4, previously conditioned "nopalitos", can be used cut or diced (manually or mechanically). At the same time, the pickling mix is prepared: a mixture of vinegar (1.87- 2.0% acetic acid) with spices, aromatic herbs, and olive oil. The vinegar is heated to boiling, and the spices are added, either

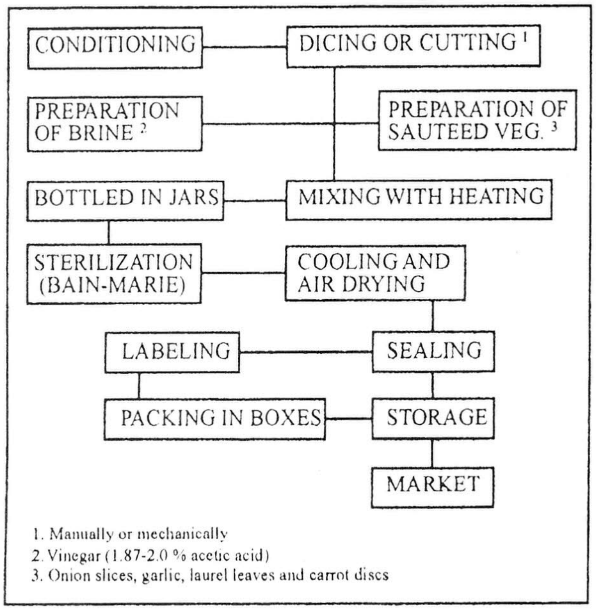


Figure 4. Flow diagram of the production process for pickled "nopalitos".
Source: Corrales-García, 1992 (modified)

directly or in a cloth bag. This mixture is boiled for five minutes to allow the vinegar to absorb the aromas. Separately, onion slices, garlic teeth, laurel leaves, and carrot discs are lightly fried in vegetable oil.
Immediately, the "nopalitos", vinegar, and sauteed vegetables are mixed. This mixture is then bottled in jars, which are then sterilized in bain-marie (filled covered jars are boiled in water). The sterilized jars are cooled, sealed and labeled. Finally, the jars are packed in cardboard boxes and stored for the quarantine period, and shipped to market.

"Nopalitos" Jam
The previously conditioned material is chopped (manually or mechanically) and is cooked for a second time, preferably in copper pots which help to eliminate gums and mucilage and also to maintain the characteristic green color. The well-cooked "nopalitos" are ground in a blender (industrial or home use). The liquefied "nopalitos" are weighed to monitor yield and to calculate the amounts of additives to be used. After that, they are boiled adding sugar gradually. Before all of the sugar is added, pectin, sodium benzoate, and citric acid are added in specified proportions. The mixture is boiled, with constant stirring to prevent sticking, until a concentration of 65 °Brix degrees is reached. The pectin should be dissolved in syrup (one gram of pectin in 10 ml of syrup) before adding.
With a minimum of 65 °Brix, the product is bottled hot (85 °C). The jars must be previously washed and sterilized. After filling, the jars are covered and then cooled by immersion in water. The jars may also be sterilized in bain-marie for five to 30 minutes, cooling immediately afterward. If it does not gel adequately, the proportion of pectin/citric acid may be increased, or degumming can be made more efficient during cooking by adding copper sulfate (1%). To prevent the loss of green coloring, which commonly occurs at the neck of the jar, a vacuum can be created (in an exhauster) before closing the jar, or permitted antioxidants can be added.
The jars are then dried so that they can be labeled; they are then packed in cardboard boxes, stored, and finally shipped to market.

REFERENCES

Becerra, R.H.; A. M. Garfunkel; R. A. González and S.S. Trevadan, 1969. Estudio teórico experimental sobre el aprovechamiento del nopal. Tesis Profesional. Fac. de Ciencias Químicas, Univ. Nal. Aut. de México
(UNAM).

Corrales-García, J. 1992. Perspectivas de industrialización de nopalito y tuna. In: S. Salazar y D. López (eds.) Conocimiento y aprovechamiento del nopal. Memorias de resúmenes del 5º Congreso Nacional y 3ero. Internacional. Univ. Aut. Chapingo, Chapingo, Edo. de México. 97-98 pp

Rodríguez-Félix, A. and M Cantwell. 1988. Developmental changes in composition and quality of cactus pear cactus cladodes (nopalitos). Plant Foods for Human Nutrition 38: 83-93.

Villarreal, F.; M.P. Rojas and G. Romero. 1964. Estudio químico sobre 6 especies de nopales (Opuntia spp). Ciencia Mexicana 22: 59-65.

D'ARRIGO BROTHERS CACTUS PEAR PRODUCTION

Martin Thomas
Supervisor of Cactus Pear Processing.
D'Arrigo Brothers
P.O. Box 850, 383 Market St. Salinas,
California 93902. U.S.A.

Current Developments
Seeking to more fully utilize the production from our fields has given rise to a new product line here at D'Arrigo Brothers. Occasionally, the most delicious fruit is too fragile for marketing; it is ripe upon arrival from the fields and will not survive the rigors of shipping, handling, and storage; it may have a thin peel; it may be soft, or bruise too easily. This fruit will be sold to the local markets at a discount in order to encourage fast turnover, and will seldom be available beyond a few miles from the packing facility. In this age of refrigeration we can juice and freeze this fruit for later use. However, without proper processing and heat treatment, problems of fermentation, souring, or pathogenic growths can be encountered regardless of the cleanliness of the juicing operations.
The initial cost of equipment for juicing and heat treating

by special construction, built by special design, each piece a prototype.

The dedication of financial resources, project commitment and mechanical expertise, has yielded success here at D'Arrigo Brothers, Castroville, California. This is where we receive, de-spine, clean, lightly wax, sort, label, and pack our Italian red cactus pears (*Opuntia ficus-indica*). This is now where we also process our delicious red-ripe fruit into cactus-pear puree. This is a new market, a new product, with newly developed equipment. Our workers in the cactus packing facility have been with us for many years, and now we are all enthused by a new way to extend the availability of this noble, traditional food. Actually, we are all quite excited, and we are pleased.

We have been processing cactus-pear puree in our own facility for more than a year, after having utilized co-pack facilities to evaluate and pilot our own design. (Figure 1) Our new installation has allowed us to obtain control on our process previously not possible. We have exceeded industry standards of food safety and process variance to such a degree that now, by examining production data, we know when and where our process can be adjusted to meet our product specifications. Our microbiological results can only be envied by other juicing operations, as we have non-detectable (<3cfu/g) coliforms, lactic acid bacteria, and E. coli. As well we have non-detectable (<10cfu/g) aerobics, yeasts, and molds. (At this time, for example, acceptable aerobic counts in the juice industry can go as high as 1,000 cfu/g). We have achieved these excellent results by extensive testing and product development, making use of food and beverage consultants, our own staff food scientists, sensory analysis, and extensive financial investment.

Here in the United States, fruit with many small seeds is considered less desirable than seedless fruit. For many potential consumers of cactus pear fruit, the quantity of seeds in the fruit is an insurmountable obstacle to their purchase of this commodity. Cultures in the U.S. with greater acceptance of seeded fruit are the principal consumers of whole cactus pears. This market has been expanded to include all fruit juice consumers as potential customers, by developing the cactus pear-puree. The possibilities of now reaching not only juice consumers, but also the ingredient market for formulators of such items as ice cream, confections, pastries and desert toppings has been realized. Not only is our cactus-pear puree used in these items, but the development of our new cactus-pear puree concentrate, a 65° Brix, vacuum-dehydrated product is now included as a flavoring ingredient in these items as well. Mixed drink flavorings using the cactus-pear puree are now available through a national restaurant wholesalers organization, in a 28 pound pail, frozen. We maintain a standardized 13 to 15° Brix, with pH<3.90, and titratable acidity (TA) as specified by our customers. All product is of course microbiologically tested, and released from Quality Control hold prior to shipment.

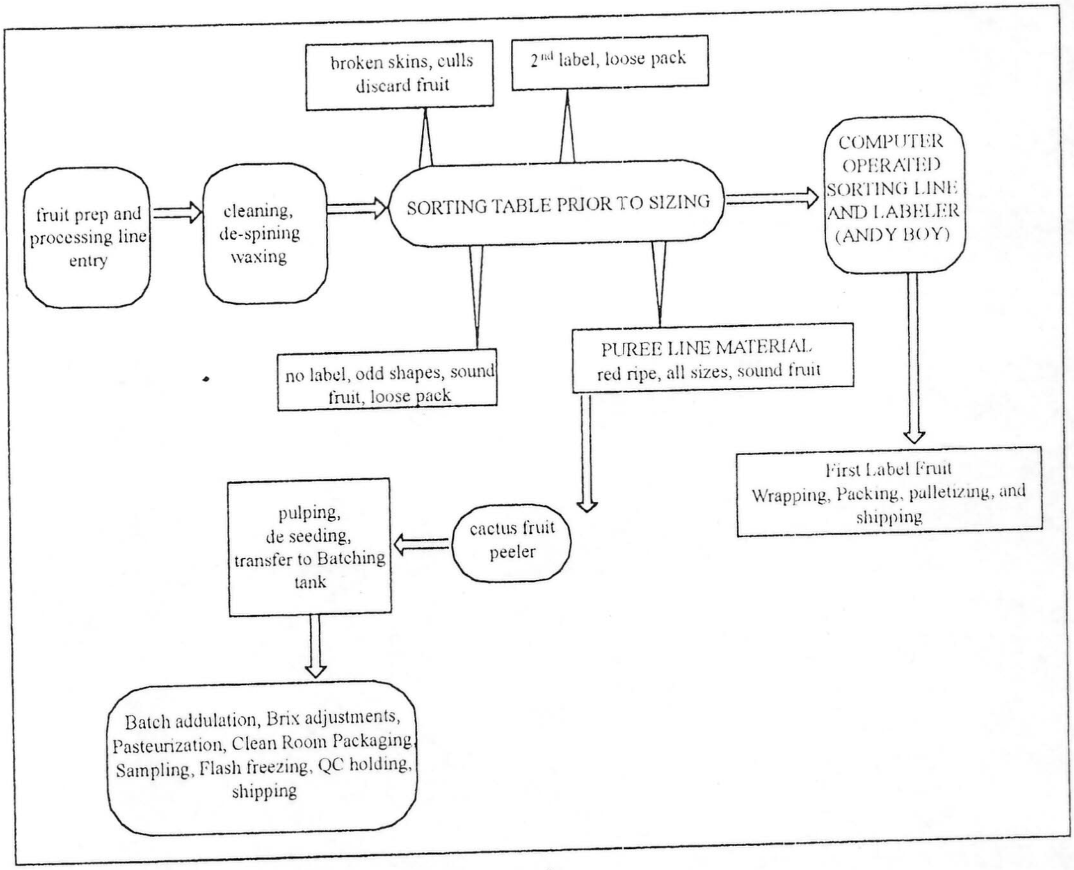


Figure 1. Packing and cactus-pear puree processing

We have been selling to these markets successfully, and with the addition of a newly developed automated cactus pear peeling machine, our marketing potential has expanded enormously. This upcoming season will be the first time we have been able to automate the peeling of the cactus fruit; the hand peeling has been a tremendous expense. The sense of expectation has been running high amongst our workers, for they all view the investment as an additional source of work-revenue for themselves. We will now be able to more fully utilize the fruit previously sold to the local markets, and the juicing, Pasteurization, and packaging of this fruit will add to our employees' income. The prospect of off-season work for our employees has improved worker morale. They are more eager to make the extra effort to maintain our increased standards of cleanliness on the fruit packing line, as all of the impressive stainless steel equipment for the cactus-pear puree line equipment shares the same building.

We have been able to pursue this new product line for a variety of reasons, and we are unique in having such an opportunity. The feasibility of sharing our Pasteurization equipment with other local commodities such as strawberries, raspberries, and other thin-skinned fruits or berries allows the financial investment to be justified. Sharing other resources has been integral to the success of this project as well. We share the microbiological and food chemistry laboratory with our Fresh Vegetable cutting and packaging operation. As well we share the skills of highly educated personnel on our staff including a mechanical engineer, food scientists, and microbiologist. Our success is of course shared as well. Another important return on this investment is the improvement in our packaged cactus pear fruit, due to the increased scrutiny by our fruit sorting personnel. We have re-vamped our entire fruit packing line to allow for the inclusion of this new product; new lighting, whole fruit treatment activity, improved fruit sizing and sorting equipment; all have been recently renovated, installed and validated. As well, we have improved our cactus fruit data acquisition, as necessitated by this new product. Our agricultural production department now receives far more detailed and accurate data from the production line regarding fruit quality and quantity. They now incorporate this information in their analysis of treatment effectiveness across various blocks and ranches for the improvement of field production.

Here in the processing and packaging facility we are aware of the nutritional benefits of cactus pears not because we read the glowing reports in the media, but because we eat them. As a traditional source of nourishment and a snack between meals, cactus fruit is unsurpassed. The fruit is eaten at room temperature during breaks in the employee break room, and employees are allowed to take home a small bag of cleaned, de-spined fruit at the end of each work day. We know, without needing any scientific validation, this fruit is wholesome and healthy, and satisfying.

Nutrition Facts
Cactus Pear Flesh
Serving Size 2 pears (152 g)

Amount Per Serving			
Calories	**80**	**Calories From Fat**	**10**
		%Daily Value*	
Total Fat	**1g**	**0%**	
Saturated Fat **0g**		**0%**	
Cholesterol	**0 mg**	**0%**	
Sodium	**25 mg**	**0%**	
Total Carbohydrate	**18 mg**	**6%**	
Dietary Fiber	**4 g**	**15%**	
Sugar	**12 g**		
Protein	**<1 g**	*based on 2,000 cal/day	
Vitamin A	2%	Vitamin C	25%
Calcium	4%	Iron	10%

I hope the cactus fruit growing community recognizes the tremendous advantage and opportunity shared by us all with this step forward in delivering a more versatile cactus pear product to the world marketplace. As the market grows for this traditional, drought resistance food source, the economy of many rural, inadequately irrigated areas of the world may share in heightened prosperity and turn to a crop which has so many uses including fruit and vegetable food, as well as fodder for their animals.

REFERENCES

For scientific documentation regarding the hypoglycemic properties of cactus products, I refer the reader to:

Castañeda, I. 1997. Journal of the Profess. Assoc. Cactus Develop.

For further details regarding the breeding program at D'Arrigo Brothers, and development of the cactus fruit-puree, one may reference the :

Journal of Professional Association of Cactus Development 1996, and 1997.
(Bunch, R. J.PACD-1996) and (Bunch, R. J.PACD-1997)

ALTERNATIVES TO PROCESS CACTUS PEAR

Carmen Sáenz-Hernández
Facultad de Ciencias Agrarias y Forestales
Universidad de Chile. Casilla 1004. Santiago, Chile

Introduction

Cactus pear, known since many centuries ago, has today few commercial alternatives for consumption. Both the fruit and the young cladodes (nopalitos) of the plants are a very good food, but just like many other vegetables they are perishable as a fresh commodity. Alternatives to process and increase its shelf-life are very appreciated in several countries where this crop is cultivated but they lack the knowledge about how it can be consumed different than fresh.

Chile is one of the countries that has many semiarid regions where the cultivation of cactus pear is present and could be a very interesting crop for their inhabitants if they had available different processes to transform the fruit and also the cladodes into other kinds of attractive foods. In the lasts years the FIA Foundation, that belonged to the Ministry of Agriculture, financed a Project where the researchers of the University of Chile studied several ways to process and use cactus pear fruit and also the cladodes of the plant. Some of the most important results of this project are presented in the following paragraphs together with the results of interesting experiences of other countries.

Fruit and nopalitos characteristics for processing

Cactus pear fruit has a similar composition to other fruits: a lot of water, very important element to the human life, moreover in the semiarid regions, sugar (as an energetic source) and minerals such as potassium, phosphorous and calcium. The caloric value of its pulp is about 50 Kcal/ 100 g, comparable to that of other fruits, such as apple, pear and orange.

The protein, fat, crude fiber and ash content are similar to other fruits. The acidity of the juice is often very low (Table 1).

Table 1. Technological characteristics of cactus pear pulp (g/100g)*

Parameter	% fresh fruit
Pulp and seeds	49.6
Peel	50.4
pH	6.37
Acidity (% citric acid)	0.06
°Brix (TSS)	14.06
Total solids	16.20
Pectin	0.17
Vitamin C (mg %)	20.33
ß - carotene (mg %)	0.53

* Sepúlveda and Sáenz (1990)

On the other hand, nopalitos are also high in water content (Table 2) and its way of consumption is less known compared with the fruit. In countries like Mexico people consume nopalitos as a legume in different dishes. One of the components of nopalitos is the dietary fiber, food component with a very important role in the human nutrition because of its capacity of preventing some diseases like colon diseases, obesity control and diabetes. There are some groups of experts that are working in this research nowadays (Sáenz, 1997; Pimienta, 1990; Gallardo *et al.* 1997).

Table 2. Chemical composition of cladodes (% dry matter)

Age	Protein	Fat	Ash	Crude fiber	FNE
(year)	(%)	(%)	(%)	(%)	(%)
1	5.4	1.29	18.2	12.0	63.1
2	4.2	1.40	13.2	14.5	66.7
3	3.7	1.33	14.2	17.0	63.7
4	2.5	1.67	14.4	17.5	63.9

Source: López et (1977) cited by Pimienta (1990)

Processing alternatives

It is important to make a difference in the possible alternatives to process fruit or nopalitos, because the characteristics of both materials are quite different. Table 3 shows different products that can be obtained from cactus pear fruit, cactus cladodes and by-products.

Alternatives for the fruit

Cactus pear fruit can be processed as a juice or nectar (with sugar added). The fruit presents several colors: orange, green, red or purple, then the beverages have a very attractive appearance. One of the characteristics that influence the shelf-life of the juice obtained is the low acidity of the great part of the cultivars; if the juice is not heat treated, fermentation appears after few days of obtained. The purple fruit is more easy to process than the green fruit due to the pigments present in them. The green fruit has chlorophyll and the purple fruit betalains. The first pigment is highly affected by the acid compared with the betalains that are much more stable with temperature and pH, the juice maintained the original color after a heating process (Sáenz, 1992).

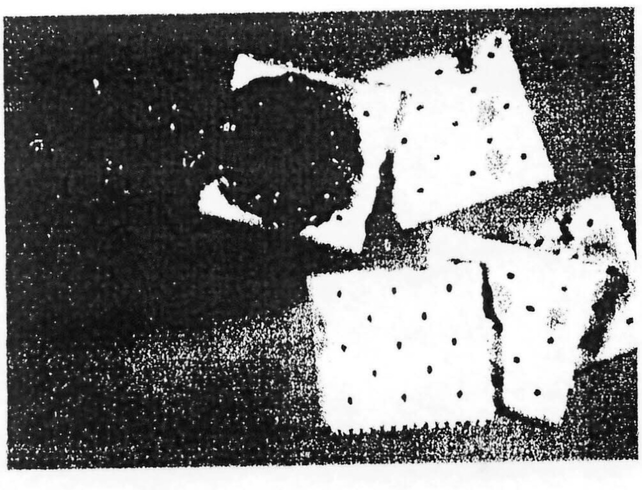
Nectars could be prepared with addition of other juices as pineapple juice (to lower the acidity), sugar and also some preservatives as sodium sorbate or sodium benzoate (maximum 1g/Kg); this product is also recommended to be heated (bottle pasteurized or other heat treatment). The consume of fruit juices is increasing in many parts of the world because they are considered as "liquid fruit" with all the characteristics of the fruit (sugar content, minerals and vitamins content and all the nutritional factors that are present in the fresh fruit).

Table 3. Some products and by-products from cactus pear fruit and cladodes

Cactus pear	Cladodes	By-products
	Products	
Juices and nectars	Pickles	Oil from seeds
Marmalades, gels and jams	Candy	Mucilage from cladodes
Dehydrated sheets	Marmalades	Pigments from the peel
Sweeteners	Flour	Dietary fiber from cladodes
Alcohol and wines	Alcohol	
Canned fruit		
Frozen fruit		

Marmalades or jams are other way to preserve the pulp of the fruit. The addition of sugar to the fruit pulp, in a ratio of 60:40; followed by a heat treatment is another old but sure way to preserve the fruit. For improving the viscosity of the product pectin can be added (1-1.25%). In order to increase the sensory characteristics of these products it was observed that the addition of citric acid or lemon juice and lemon peel is a practice that improves the taste and the latter also the viscosity of the marmalade (Sawaya et al., 1983).. It can be consumed with bread, or as a dessert. The addition of sodium sorbate or benzoate are allowed in doses not higher than 1g/Kg product. For this kind of product it is desirable to work with fruit with low content of mucilage.

A similar product are the gels that can be prepared with the fruit pulp and some gelling agent as carragenaan, this product can be prepared with different sugar proportion and this variable will determine the way of preserve the product with or without refrigeration. Proportion of sugar added less than 50% will obligatorily require refrigeration (Sáenz et al, 1996).



Dehydrated, canned and frozen fruit

Joubert (1993) studied the canning of different cultivars of *Opuntia ficus indica* from South Africa. Hand peeled fruits were caned in acidified sucrose syrup (20°Brix) at 100°C for 15 min, differences between cultivar firmness were observed and increased on addition of 0.25% $CaCl_2$ to the syrup; the processing of the fruit resulted in loss of texture, color and flavor.

As an alternative way to preserve the fruit, Sáenz *et al.* (1988) manufactured frozen fruit, using slices of 0.625 mm thick and quarters of peeled and unpeeled fruit. The freezing process was done in a fluid bed tunnel at -40°C; the product was stored at -20°C. The results achieved were not satisfactory due to the high drip, mainly in slices, when they were defrosted. This technology must be further studied and maybe the texture could be improved with the addition of sucrose.

Sepúlveda *et al.* (1996) developed fruit leather made with different proportions of cactus pear pulp and quince pulp; the better blend was 75:25 cactus pear: quince pulp. The blend was dehydrated in a force air tunnel in a thin layer until a moisture near 15-16%. This product can be done with other pulps and can be dehydrated with solar energy also.

Minimally processed fruit

In the last years many vegetables are presented to the consumers minimally processed (peeled, washed, cut, etc with or without a light process with acids or antioxidants) to increase the shelf-life of these perishable products. These vegetables stored at refrigeration temperatures (near 4-6°C) have 7 or 14 days of duration. The minimal process applied to the cactus pear fruit is an alternative that is being studied at present (Sáenz et al, unpublished data).

Alcoholic beverages and "cheese"

Another product is "Melcocha", made from boiling the peeled fruit and it is like taffy. When highly concentrated Melcocha is beaten and placed in rectangular recipients, usually of 1 Kg, when dried we obtain the "cheese". It is an older preservation procedure, with large application today, mostly in Mexico, prepared with the cottage industry procedures.

An alternative cottage industry use of cactus pears, is in the preparation of "colonche". The "colonche" is obtained through fermentation of the juice and pulp in wooden barrels; this procedure, as followed today, has certain imperfections that could be overcome, among which is the lack of selection of yeast, where the use of *Sacharomyces cereviseae* is recommended. The "colonche", a low-alcohol drink is mostly appreciated freshly fermented, as it turns acid very soon (Sáenz, 1995). Ripe cactus pear, from which the peel has been removed, may be fermented and made into a flavorsome "wine". Once again it is the red fruit the most successful in "wine" making (Flores, 1992).

Vinegar

The technology for obtaining vinegar is well known and it requires little infrastructure. A cactus pear vinegar can be obtained from the juice of fruit too.

Alternatives for the cladodes

Mexico can teach since many years ago how to consume the nopalitos. In the present Newsletter some of articles shows the interesting alternatives it has.

As it was mentioned in the first part of this article one of the possible interesting way of processing the cladodes is the use as dietary fiber. Some studies shows that the cladodes of 1-2 years contain over 40% dietary fiber (Sáenz et al, 1997).

This dietary fiber obtained as a flour from the cladodes can be blended with wheat flour to prepare cookies, or with other vegetables to prepare soups, or with milk and fruit taste to prepare desserts like caramel custard (Sáenz et al, unpublished data).

REFERENCES

Flores, A. 1992. Producción de vino y aguardiente de tuna, alternativa en el aprovechamiento del nopal. Ciencia y Desarrollo 17:56-68.

Gallardo, Y., Zambrano, M.L. & Hernandez, A.D. 1997. Determinación de las propiedades fisicoquímicas del nopal verdura. Memorias VII Congreso Nacional y V Internacional sobre conocimiento y aprovechamiento del nopal. Monterrey, México. p. 277-278

Joubert, E. 1993. Processing of the fruit of five prickly pear cultivars grown in South Africa. Int. J. Food Sci. and Technol. 28:377-387.

Pimienta, E. 1990. El Nopal tunero. 1ª ed. Universidad de Guadalajara, Jalisco, México. 246 pp.

Sáenz, C.; Pak, N.; Sepúlveda, E. & Lecaros, M. 1997. Caracterización de harina de cladodio de nopal. Memorias VII Congreso nacional y V Internacional sobre conocimiento y aprovechamiento del nopal. Monterrey, México. p. 302-303.

Sáenz, C. 1997. Cactus cladodes: a source of dietary fiber. Journal of the Profess. Assoc. on Cactus pear. 2

Sáenz, C. 1995. "Food Manufacture and by-products" p137-143. In: "Agro-ecology, cultivation and uses of cactus pear". Ed. by Barbera, G., Inglese, P. and Pimienta Barrios, E. FAO Plant Production and Protection Paper Nº 132. 216 pp.

Sepúlveda, E. & Sáenz, C. 1990. Chemical and physical characteristics of prickly pear (*Opuntia ficus indica*) pulp. Rev. Agroquim. Tecnol. Aliment. 30:551-555.

Sáenz, C.; Sepúlveda, E. and Moreno, M. 1996. Final Report to the Ministry of Agriculture (Chile). Project: "New technologies for processing nopal and cactus pear". 103 p. (Unpublished).

Sáenz, C., Sepúlveda, E. & Araya, E. 1988. Ensayos preliminares de obtención de tuna (*Opuntia ficus indica*) congelada. Resúmenes: VI Seminario Latinoamericano de Ciencia y Tecnología de. Alimentos. Bogotá, Colombia.

Sawaya, W.N., Khatchadourian, H.A., Safi, W.M. & Al-Hammad, H.M. 1983a. Chemical characterization of prickly pear pulp, *Opuntia ficus indica*, and the manufacturing of prickly pear jam. J. Food Technol. 18:183-193.

Sepúlveda, E., Sáenz, C. y Alvarez, M. 1996. Elaboración de láminas de fruta: tuna (*Opuntia ficus indica* (L) Mill) y membrillo (*Cydonia oblonga* Mill). Textos Completos. CICTA - 5. IX Seminario Latinoam. y del Caribe de Ciencia y Tec. de Alimentos. PSM Publicaciones Soporte Magnético. La Habana, Cuba. p.1-6.

POSTHARVEST HANDLING OF CACTUS (*Opuntia* spp.) STEMS.

Armida Rodríguez-Félix and Mónica A. Villegas-Ochoa
Centro de Investigación en Alimentación y Desarrollo, A.C.
Km. 0.6 Carr. a la Victoria, P.O. Box 1735. Hermosillo, Sonora 83000. Mexico.

Cactus pear (*Opuntia* spp.) originated in Mexico, and has been used as a food source since ancient mesoamerican civilizations. It is now an important crop in arid and semiarid lands of some American, European, Oriental and African countries (Pimienta and Muñoz, 1995). The cactus pear is cultivated as a food source for both humans and animals. Also, it is utilized in folk medicine, and field management such as windbreaks, control of soil erosion, and hedges (Inglese *et al.*, 1995). *Opuntia ficus-indica* (L.) Miller, the widely known cactus pear species, is grown in most of the producing countries for fruit and forage production. In Mexico, besides O. *ficus-indica,* other species that are important are *O. streptacantha* Lemaire, *O. lindhemeiri* Engel, *O. amyclaea* Tenore, *O. megacantha* Salm-Dick and *O. robusta* Wendland (Pimienta, 1993; Pimienta and Muñoz, 1995).

The tender young pads (vegetative portions) of *Opuntia* and *Nopalea* species, known as nopalitos, cactus pads, cactus stems, vegetable cactus or cactus leaf, have been a traditional fresh green vegetable in the Mexican diet for centuries. The Indian tribes that inhabited the semiarid regions prepared the cactus stems in different ways; cooked, roasted and dressed with meat of wild animals, or mixed with wild vegetables or seeds (Pimienta, 1993). The cactus pads are considered a specialty vegetable in the United States, where populations with a Mexican heritage, prepare them as a cooked green vegetable during the Lenten season, and as a marinated vegetable throughout the year (Russell and Felker, 1987; Cantwell, 1995). Actually, the tender cactus pear pads are used as an ingredient of a diversity of dishes including sauces, salads, soups, stews, snacks, beverages, and desserts (Vigueras and Portillo, 1995; Anónimo, 1997). The average per capita intake in Mexico is 6.4 kg (Flores, 1997).

In Mexico an estimated area of 3 million ha are densely occupied by wild cactus pear species, during the growing season (spring-summer) their young tender stems are gathered for home consumption. Commercial plantations are located in different areas, covering 10 500 ha, but the most important commercial production center is Milpa Alta, close to Mexico City. In the United States, *Nopalea cochenillifera* (L.) Salm-Dyck clone 1308 is produced in commercial plantations located in the States of California and Texas that cover 100 ha with an average yield of 50 ton/ha. Plantations for cactus pads production are established with 25 000 to 40 000 plants per ha, planted about 30-40 cm apart within rows and 80-100 cm between rows. Production starts in 2-3 months. The productivity of a commercial plantation varies depending on the plantation age, with yields of 3-5 ton/ha during the first two years, increasing to about 40 ton/ha after the third year, and can reach 80-90 ton/ha. The tender and young pads are harvested throughout the year, but the highest productivity is reached during springtime and the lowest during the winter season. An intensive production system using microtunnels is used in Mexico and South Texas to assure high yields and cactus stems production during the winter months (Mick, 1991; Pimienta, 1993; Flores, 1995; Flores, 1997). A small percentage of the crop in Mexico is exported to international markets, mainly the United States, in 1992 only 1 527 ton. were exported (Flores, 1997).

Quality and Nutritional Characteristics

Cactus leaves, the tender developing flattened stems of *Opuntia* and *Nopalea*, are typically oblong to spatulate-oblong shaped, in the early stages of growth have vestigial true leaves, subtended by spines (depending on the species) or spine-hairs. The tender cactus leaves of *Nopalea cochenillifera* variety 1308 are for the most part free of spines and spine-hairs. Good quality cactus pads are thin, fresh-looking and have a brilliant green color. Some undesirable quality characteristics are the thickening of the cuticle and an increase in the thickness of the pad. Before using the pad, the spines must be removed with a knife or a vegetable peeler, trimming the outside edges of the pads. The flesh is generally cut into small pieces or strips that may be eaten fresh or cooked in water until tender. Cactus leaves have a delicate slightly tart, green bean flavor. To some people they have a slight asparagus-like taste. Succulent but crispy, when they are cooked exude a slimy substance (as okra does). This is a complex carbohydrate known as mucilage, which is a carbohydrate reserve for the plant (Rodríguez-Felix and Cantwell, 1988; Mick, 1991; Pimienta, 1993; Sudzuki, 1995).

Like most vegetables, cactus pads are mostly water (92%), and carbohydrates, including complex carbohydrates and simple sugars (4-6%). Low in protein and fat (1% and 0.2%, respectively), a mineral content of 1%, comprised of calcium; a moderate amount of vitamin C (12.7 mg/ 100g fresh weight), and ß-carotene (the vitamin A precursor) of 12.9 mg/ 100 g fresh weight. Noticeable differences were found among different *Opuntia* species. *O. amyclaea* had the highest protein content, *O. inermis* had the highest vitamin C and ß-carotene content (Rodríguez-Félix and Cantwell, 1988). Water, protein, and mineral content of commercial cactus pads of *Nopalea cochenillifera* clone 1308 are similar to those of *Opuntia* species (Nerd *et al.*, 1997). The composition of cactus pads can vary according to the species, cultural conditions, and maturity. Cactus leaves can contribute significant calcium, vitamin C and provitamin A in the human diet, especially in arid areas (Pimienta, 1993; Cantwell, 1995).

Because the cactus pear is a CAM (crassulacean acid metabolism) plant, the acid content of cactus stems (20 cm long) changes during the day. The highest values are present in the morning (0.5% at 8:00 hrs) and they decreases to values of 0.1% in the afternoon (16:00 hrs), the pH varies from 5.2 at evening to 4.4 in the early morning. Cactus stems of smaller size (10 cm) had the same acidity whether harvested in the morning or afternoon (Rodríguez-Felix and Cantwell, 1988; Pimienta, 1993). The acid content of cactus pads increases during maturity and varies among species (Rodríguez-Felix and Cantwell, 1988). High acid content (100 mmol H^+ per kg fresh weight) imparts an undesirable sour taste affecting the cactus pad flavor and decreases consumer acceptability (Rodríguez-Felix and Cantwell, 1988; Pimienta, 1993; Nerd *et al.*, 1997).

Postharvest physiology

Harvest and Packing

Tender cactus stems (*Opuntia* sp.) are harvested commercially when they are 15 to 20 cm long and weigh about 90-100 g (Cantwell, 1995). Cactus leaves of *Nopalea cochenillifera* clone 1308, have been defined as commercially mature when they attain a length of 11-13 cm and a weight of about 40 g (Nerd *et al.*, 1997). Harvest is normally by hand, cutting with a knife the leaf at the base of the insertion, where the young cactus pad joins the supporting stem. Care is recommended to avoid damage at the cut stem end of young cactus leaves. Decay in this area during storage is one of the main quality problems during postharvest handling. Depending on the distance, various packing methods are practiced in Mexico.

1) To markets close to the production area of Milpa Alta, cactus leaves are packed in typical reed baskets called "colotes" and sold at the local market; or stacked in cylindrical packs of about 1 m in diameter and 1.70 m in height, containing approximately 3 000 cactus leaves and weigh 250 to 300 kg. The cylindrical packed cactus leaves are loaded in trucks and transported to the wholesale markets in Mexico City. They are stored at ambient temperature until they are sold. The marketing is completed within 1 to 3 days of harvest. They are often cleaned (trimmed of spines and small leaves) prior to sale. Cylindrical packed cactus leaves are not recommended for long term storage. Considerable heat from the respiration of the product is generated in the center of the packed

leaves, which cause a loss in appearance and favors the growth of decay organisms. Because of the short time these packs are stored, usually no postharvest problems occur. 2) To markets that are far away from the producing areas, including domestic and exportation markets, cactus pads are packed in 5 to 20 kg wooden boxes covered with paper, or fiberboard cartons, and are transported in refrigerated trucks (10°C) (Cantwell, 1995; Flores, 1995). Most common quality problems are decay at the cut stem end and wilting associated with weight loss.

Storage Conditions

Cactus stems have a moderate respiration rate, being higher (60 ml CO_2/g-h at 20°C) in small pads than in large pads (25 ml CO_2/g-h at 20°C), which is comparable to the respiration rate of topped carrots, head lettuce and celery. Ethylene production is low in cactus stems (0.2 nl/g-h at 20°C) (Cantwell *et al.*, 1992).

Cactus stems lose their bright shiny appearance and become dull with time following harvest (Cantwell *et al.* 1992). Shelf life of carefully harvested cactus leaves is about 1 week at 20°C, after that the vestigial leaves blacken and fall out and wilting appears affecting visual appearance. (Cantwell *et al*, 1992; Rodríguez and Villegas, 1997). Fresh cactus stems are turgid, but as they lose moisture they become more flexible (Rodríguez and Villegas, 1997). In a shelf life study of cactus pads that had not been carefully harvested, showed up to 53% decay after storage for 10 days at temperatures ranging from 15.6 to 21.1°C (50-60% R.H.) (Ramayo *et al.* 1978). Cactus stems of *Nopalea cochenillifera* maintain quality for 12 days at 20°C (Nerd *et al.*, 1997).

Refrigerated storage (5 to 10°C or 41 to 50°F) reduces respiration rate, and increases postharvest shelf life. Cactus stems packed in vented polyethylene bags (that retard water loss) maintain their visual quality for about two weeks at 10°C and for 4 weeks at 5°C (Cantwell *et al.*, 1992). Cactus stems packed in wooden crates and stored at 10°C (80-85% R.H.) show a 21% of decay at the cut stem end after 10 days (Ramayo *et al.*, 1978). If carefully harvested, the shelf life can be extended up to 21 days at 10°C (85-90% R.H) without developing decay, but begin to show signs of wilting due to moisture loss (Rodríguez y Villegas, 1997). Factors such as harvest, storage temperature and relative humidity, and packing method can affect the shelf life of cactus pads (Cantwell *et al.*, 1992; Cantwell, 1995; Nerd *et al.*, 1997; Rodríguez and Villegas, 1997).

Cactus leaves stored at low temperatures (below 10°C) are susceptible to chilling injury (CI), which is manifested as bronzing or unattractive surface discoloration and softening. Chilling injury susceptibility varies depending on species, maturity of cactus pad, and packing method. Cactus leaves of *Opuntia* sp. packed in vented polyethylene bags may begin to show signs of chilling injury after 3 weeks of storage at 5°C, whereas cactus stems packed in wooden crates stored at the same temperature (5°C) begin to show chilling injury at 15 days (Cantwell *et al.*, 1992; Cantwell, 1995; Rodríguez and Villegas, 1997). Cactus stems of *Nopalea cochenillifera* seem to be more susceptible to chilling injury during storage at low temperature (4°C) than those of *Opuntia* species. When not bagged, they develop CI symptoms after 7 days, but if stored in plastic bags an additional 4 days of storage is gained until CI symptoms appear (Nerd *et al.*, 1997)

Acidity of cactus stems changes during storage, depending on storage temperature. Storage at low temperature maintains or increases acid content, whereas storage at 20°C results in a decrease in acidity (Cantwell *et al.*, 1992; Cantwell, 1995; Nerd *et al.*, 1997). Vitamin C content of cactus stems decreases faster during storage at 20°C than during storage at 5°C (Rodríguez and Villegas, 1997).

For practical postharvest handling of intact cactus stems of *Opuntia* sp., it appears that storage between 5 and 10°C with high relative humidity (90-95%), maximizes shelf life and visual quality (Cantwell *et al.*, 1992). A storage temperature of 12°C and above is recommended for cactus leaves of *Nopalea cochenillifera* (Nerd *et al.*, 1997).

Minimally Processed Cactus Stems

Diced cactus leaves, whose spines have been removed, packed in plastic bags is a popular presentation in today's markets. Diced cactus leaves are more perishable that the corresponding intact product. The shelf life of diced cactus leaves is 1 to 2 days at 20°C. Refrigerated storage (5°C) increases their shelf life to 7 days. The main problems that limit shelf life of diced cactus leaves are brown discoloration at the cut surfaces, mucilage loss (fluid inside the bag) and a surface color change from brilliant green to brownish green which gives a cooked appearance. Washing trimmed and diced cactus leaves increases mucilage loss. Vacuum packing of diced cactus pads does not increase shelf life at refrigerated storage temperatures (Rodríguez-Felix and Soto-Valdez, 1992). Consumer acceptability of diced cactus pads decreases during refrigerated storage (Rodríguez-Felix *et al.*, 1997). To optimize the shelf life of diced cactus leaves, it is recommended to keep cut surfaces clean and dry, and to handle and store at low temperatures.

REFERENCES

Anónimo. 1997. Recetario de Cocina. XI Feria Nacional del Nopal Milpa Alta 97. Union Agrícola Regional de Productores de Milpa Alta. Fideicomiso Central de Abasto de la Ciudad de Mexico. Mexico. 30 pp.

Cantwell, M., A. Rodríguez-Felix, and F. Robles-Contreras. 1992. Postharvest physiology of prickly pear cactus stems. Scientia Horticulturae 50:1-9.

Cantwell, M. 1995. Post-harvest management of fruits and vegetable stems. In: Barbera, G., Inglese, P. and Pimienta-Barrios, E. (Eds.). Agro-ecology, Cultivation and Uses of Cactus Pear. FAO Plant Production and Protection Paper 132. Rome: FAO. 216 pp.

Flores, V. C. 1995. "Nopalitos" production, processing and marketing. In: Barbera, G., Inglese, P. and Pimienta-Barrios, E. (Eds.). Agro-ecology, Cultivation and Uses of Cactus Pear. FAO Plant Production and Protection Paper 132. Rome: FAO. 216 pp.

Flores, V., C. 1997. La producción de nopalito en Mexico. In: Vazquez, R., Gallegos, C., Treviño, N., and Diaz, Y. (Eds.). Memorias del VII Congreso Nacional y V Internacional Sobre Conocimiento y Aprovechamiento del Nopal. Monterrey, N.L., Mexico. pp. 28-38.

Inglese, P., G. Barbera, and T. La Mantia. 1995. Research strategies for the improvement of cactus pear (*Opuntia ficus indica*) fruit quality and production. J. Arid Environ. 29: 455-468.

Mick, R.J. 1991. Growing variety 1308 for year around nopalito production. In: P. Felker (Ed). 2nd. Annual Texas Prickly Pear Council Convention Proceedings. McAllen, Texas, USA. pp. 32-34.

Nerd, A., M. Dumotier, and Y. Mizrahi. 1997. Properties and postharvest behavior of the vegetable cactus *Nopalea cochenillifera*. Postharvest Biology and Technology 10: 135-143.

Pimienta, B.E. 1993. Vegetable cactus. In: J.T. Williams (Ed.). Chapman and Hall, London, England, pp. 177-192.

Pimienta-Barrios, E. and A. Muñoz-Urias. 1995. Domestication of Opuntias and cultivated varieties. In: Barbera, G., Inglese, P. and Pimienta-Barrios, E. (Eds.). Agro-ecology, Cultivation and Uses of Cactus Pear. FAO Plant Production and Protection Paper 132. Rome: FAO. 216 pp.

Ramayo, R., L., C. Saucedo, and S. Lakshminarayana. 1978. Prolongación de la vida de almacenamiento del nopal hortaliza *(Opuntia inermis* Coulter) por refrigeración. Chapingo, Nueva Epoca 10: 30-32.

Rodríguez-Félix, A. and Cantwell, M. 1988. Developmental changes in composition and quality of prickly pear cactus cladodes (nopalitos). Plant Foods for Human Nutrition 38: 83-93.

Rodríguez-Félix, A., and H. Soto-Valdez. 1992. Quality changes of diced nopal during storage in polyethylene bags. In: P. Felker and J. Moss (Eds.). 3rd. Annual Texas Prickly Pear Council Convention Proceedings. Kingsville, Texas. USA. pp. 22-25.

Rodríguez, F., A. and M.A. Villegas. 1997. Quality of cactus stems (*Opuntia ficus-indica*) during low temperature storage. J. Professional Assoc. for Cactus Development 2:

Rodríguez-Félix, A., M.D. Cano, M.A. Villegas, and V. Santos. Calidad sensorial y formas de consumo de nopal verdura. In: Vazquez, R.E., C. Gallegos, N. Treviño y Y. Diaz (Comp.). Conocimiento y Aprovechamiento del Nopal. Memorias del 7° Congreso Nacional y 5° Internacional . Monterrey, N.L., Mexico

Russell, Ch. E. and P. Felker. 1987. The prickly-pears (*Opuntia* sp., Cactaceae): A source of human and animal food in semiarid regions. Economic Botany 41(3): 433-445.

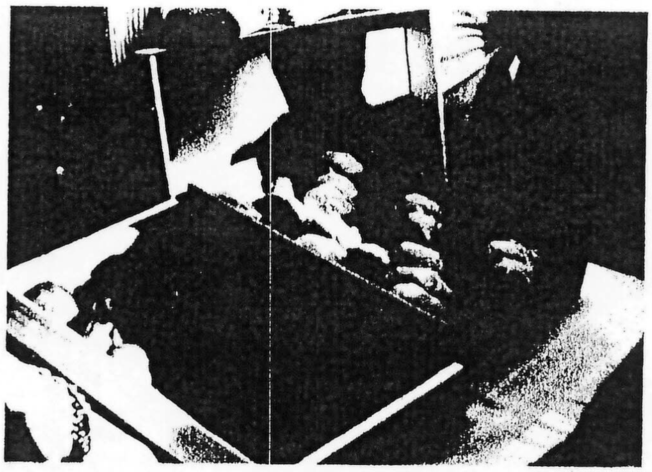
Sudzuki, H., F. 1995. Anatomy and morphology. In: Barbera, G., Inglese, P. and Pimienta-Barrios, E. (Eds.). Agro-ecology, Cultivation and Uses of Cactus Pear. FAO Plant Production and Protection Paper 132. Rome: FAO. 216 pp.

Vigueras, G., A.L. and L. Portillo, M. 1995. Recetario de Cocina, Cactaceas y Suculentas. Nakari, Sociedad Jaliscience de Cactologia, A.C. Guadalajara, Jal., Mexico. 37 pp.

STORAGE OF CACTUS PEAR [*Opuntia ficus-indica* Miller (L.)] FRUIT

Mario Schirra
C.N.R. - Istituto per la Fisiologia della Maturazione e della Conservazione del Frutto delle Specie Arboree Mediterranee, Nuraxinieddu, 09170 Oristano, Italy.

The cactus pear [*Opuntia ficus indica* (L) Mill. *Cactaceae*] is a species of great importance in subsistence agriculture in arid and semi-arid lands where its cultivation often represents an agricultural necessity and its consumption is an indispensable source of nutrition. It is evident that given such conditions the value attributed to the fruit is almost exclusively a function of its availability for a longer or shorter period of time and its nutritional value. Other quality indices, such as external appearance and organoleptic acceptance, are secondary (Barbera et al., 1991; Pimienta Barrios 1993). On the contrary, in countries with advanced economies the cultivation of this species represents a possible agricultural option and the fruit must appeal to the consumer, who expects fruit with excellent eating qualities, attractiveness and firmness, and possibly free of pesticide residues. A more effective grower-oriented promotional campaign could further stimulate the cultivation of this crop in semi-arid areas, where it may prove to be a viable alternative to more demanding crops and to the abandonment of farming. The positive economic performance of this species derives in part from its notably low demand for energy inputs (Baldini *et al.*, 1982). To this latter factor are to be added a moderate water demand (Barbera, 1988), shallow tilling even at planting, reduced and easily applied pruning, and, not least, the only occasional need for pesticide treatments, which in turn lead to diminished environmental impact.
Under shelf-life conditions cactus pear fruits deteriorate in a few days as a result of rapid aging and parasitic infections, while low storage temperatures lead to promote physiological disorders known as chilling injury (Cantwell,



1995).The susceptibility of fruit to chilling injury depends on cultivar, environmental growth conditions and fruit age. Mature-green fruit is more prone to decay but less susceptible to chilling injury than ripe fruit.

Fruit should be harvested when the umbilical crown is still slightly green so that it can withstand a certain storage and marketing period. To reduce damage during harvesting and limit postharvest decay caused by wound pathogens, it is advisable to leave a small piece of mother cladode attached to the fruit. The subsequent exposure of fruit to room temperature (curing) favours the drying of the piece of cladode and its detachment during handling and packaging. When suitable storage facilities are lacking, it is advisable to store fruit in the dark in cool rooms. Covering them with straw may be useful. Storage in ventilated cold rooms at 6-8°C and 90-95% relative humidity is generally recommended for a storage life of about 3-4 weeks (Gorini, 1993 Cantwell, 1995). These conditions are found to be the best compromise in limiting rot development, reducing respiration and transpiration rates and chilling injury. When storage continues beyond these limits, losses from rot and chilling injury increase sharply, especially when the fruits are once again subjected to room temperature. Storage under modified or controlled atmosphere has resulted in some benefits to fruit quality (Testoni et al., 1990; Piga et al., 1996), but there are still many problems connected with this technique. Two of these are the lack of suitable storage facilities in most producing countries and high storage costs, which make it unfeasible for fruit of this species. Postharvest heat treatment at 37°C for 36 h, 95% relative humidity and fruit dipping in water at 53-55°C reduced CI and decay during storage and subsequent shelf-life conditions and resulted in better overall fruit appearance (Schirra et al., 1996, 1997a,b). Postharvest dip treatments with TBZ mixtures at 1000 to 1500 mg/l concentrations at room temperature have been recommended to control decay development in cactus pear fruit (Gorini et al., 1993). However, the effectiveness of this fungicide in CI and decay control may be greatly enhanced when TBZ mixtures are used at 50-53 °C (Schirra and Inglese, unpublished data). Moreover, the combination of fungicide and hot water make it possible to use much lower levels (200 mg/l) of TBZ than the conventional treatment (1000 mg/l) at room temperature. This treatment also appeared to be instrumental in removing most glochids, (small barbed prickles associated with the areolas on the fruit surface), without the inevitable skin damage caused by 'brushing', a technique employed prior to marketing.

In conclusion, the potential of TBZ fungicide when applied at 53°C may represent a feasible future approach in extending the postharvest life of cactus pear fruit, with economic advantages deriving from a reduced use of fungicides and great benefit to the environment thanks to the minor risk of pollution when waste water is discharged by packing houses. All this underscores the potential of this species in areas that are both economically and ecologically fragile

REFERENCES

Baldini E., Alberghina O., Bargioni G., Cobianchi D., Jannini B., Tribulato E. and Zocca A. (1982) Analisi energetiche di alcune colture arboree da frutto. *Rivista di Ingegneria Agraria.* 13, 113-118, 191-199.

Barbera G. (1988) Ricerche sull'irrigazione del ficodindia. *Frutticoltura* 8, 49-55.

Barbera, G., Carimi, F. and Inglese, P. (1991) Past and present role on prickly pear *Opuntia ficus-indica* (L) Miller in the agriculture of Sicily. *Econ. Bot.* 46, 10-20.

Cantwell, M. 1995. Postharvest management of fruits and vegetable stems. In: *Agro Ecology, Cultivation and uses of Cactus Pear.* (G. Barbera, Inglese, P. and Pimienta-Barrios E. *eds*). FAO Plant Production and Protection. Paper 132. 120-136.

Gorini, F., Testoni, A., Cazzola, R., Lovati, F., Bianco, M.G., Chessa, I., Schirra, M., Budroni, M. and Barbera, G. (1993) Aspetti tecnologici: Conservazione e qualità di fico d'india e avocado. *Inf. Agrario* XLIX (1), 89-92.

Piga, A., D'Aquino, S., Agabbio, M. and Schirra, M. 1996. Storage life and quality attributes of cactus pears cv 'Gialla' as affected by packaging. *Agricoltura Mediterranea 126: 423-427.*

Pimienta Barrios, E. 1993. El nopal (*Opuntia* spp.): una alternativa Ecológica productiva para las zonas áridas y semiáridas. *Ciencia* 44: 339-350.

Schirra, M., Agabbio, M., D'Aquino, s. and McCollum, T.G. 1997. Postharvest heat conditioning effects on early ripening 'Gialla' cactus pear fruit. *HortScience 32: 702-704.*

Schirra, M., Barbera, G., D'hallewin, G., Inglese, P. and La Mantia, T. 1997. Response of cactus pear fruit to $CaCl_2$ preharvest treatments and prestorage heat conditioning. *Journal Horticultural Science 72: 371 377.*

Schirra, M., Barbera, G., D'Aquino, S., La Mantia, T. and McDonald, R.E. 1996. Hot dips and high temperature conditioning to improve shelf quality of late-crop cactus pear fruit (*Opuntia ficus-indica* L. Mill.). *Tropical Science 36: 159-165.*

Testoni, A. and Echer Zerbini, P. (1990) Conservazione del fico d'india in atmosfera normale e controllata. *Annali I.V.T.P.A.* Milano, Italy XXI, 131-137.

INTERNATIONAL COMMITTEE ON CACTUS PEAR CACTUSNET-FAO

GENERAL COORDINATOR
Istituto di Colture Legnose Agrarie e Forestali, Università di Reggio Calabria, Reggio Calabria, Italy
PAOLO INGLESE

COORDINATOR TECHNICAL SUBGROUP
Center for Semi-Arid Forest Resources, Texas A&M University - Kingsville, Kingsville, Texas
PETER FELKER

COORDINATOR ECONOMIC SUBGROUP
Istituto di Economia e Pianificazione Territoriale, Università di Reggio Calabria, Reggio Calabria, Italy
FILADELFIO BASILE

REGIONAL COORDINATORS

South America
Universidad Nacional de Santiago del Estero, Argentina
JUDITH OCHOA DE CORNELLI

North America
CIESTAAM, Mexico
CLAUDIO FLORES VALDES

Mediterranean Basin
Istituto di Coltivazioni Arboree, Università di Palermo, Italy
GIUSEPPE BARBERA

Central and South Africa
Univeristy of Fort Hare, South Africa
MARC OLIVER BRUTSCH

WORKING GROUPS AND COORDINATORS

Plant Genetic Resources Collection, Conservation and Evaluation: Universidad de Guadalajara, Mexico
EULOGIO PIMIENTA BARRIOS

Postharvest Physiology: Centro de Investigación en Alimentación y Desarrollo, A.C.
Hermosillo, Sonora 83000. Mexico.
ARMIDA RODRIGUEZ-FELIX

Agroindustrial Transformation: Universidad de Chile, Santiago, Chile
CARMEN SAENZ HERNANDEZ

Ecophysiology: University of California Los Angeles, U.S.A.
PARK S. NOBEL

Productivity: Ben Gurion University of the Negev, Israel
AVINOAM NERD

Cochinilla: Universidad San Cristobal Huamanga, Peru
VICTOR FLORES

Forage: INRAT, Tunisia
ALI'NEFZAOUI

Pests and Diseases: Istituto di Patologia Vegetale, Università di Catania, Italy
GIOVANNI GRANATA