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

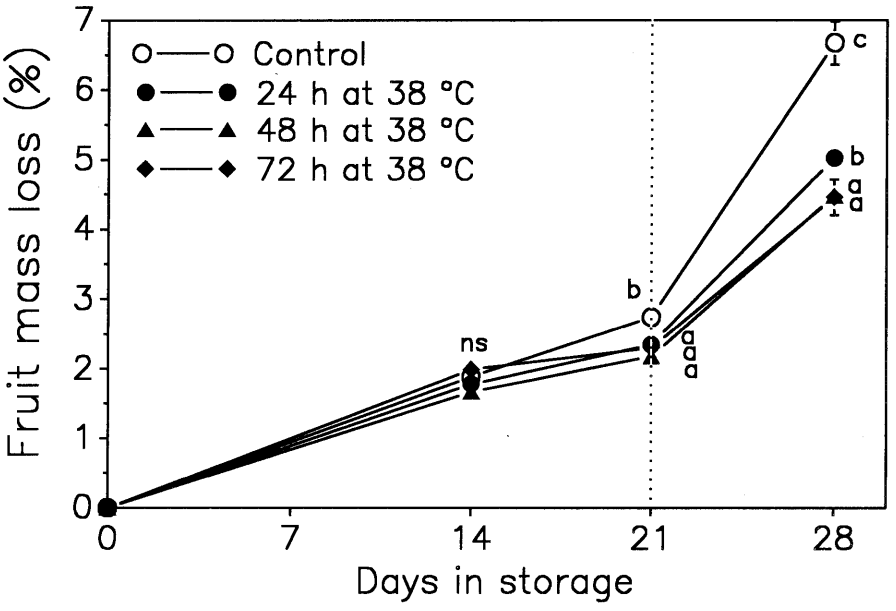

Fig. 1. Effect of temperature conditioning on fruit mass loss of early ripening 'Gialla' cactus pear fruit stored for 21 days at 6 °C plus 7 days at 20 °C.

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[y]	
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).
[x]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.