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Postharvest physiology and quality of bitter melon (*Momordica charantia* L.)

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Abstract

Developing fruits of *Momordica charantia*, known as bitter melon, bitter gourd or balsam pear, were harvested at horticultural maturity and stored up to 14 days in humidified air at different temperatures. Respiration rates of fruits at 20 and 10°C were approximately 40 and 15 $\mu l\ CO_2\ g^{-1}\ h^{-1}$, respectively. Ethylene production rates at these temperatures were 0.1–0.3 $nl\ g^{-1}\ h^{-1}$. Fruits stored for >8 days at 7.5°C showed severe chilling symptoms (decay, pitting and discoloration) and typical chill-induced respiratory and ethylene production increases after transfer to 15°C. Fruit quality was best maintained if bitter melon were stored at 10 and 12.5°C. Fruits at 15°C continued to develop, showing undesirable changes including seed development, loss of green color, and fruit splitting. Immature fruit maintained postharvest quality better than fruit harvested at the fully developed green stage. Bitter melon stored at 15°C in controlled atmospheres (21, 5 or 2.5% O_2 in combination with 0, 2.5, 5 or 10% CO_2) were not different in quality from air-stored fruits at 2 weeks. Fruits stored 3 weeks in 2.5 or 5% CO_2 in combination with 2.5% O_2 showed greater retention of green color and had less decay and splitting than air-stored fruit.

Keywords: Bitter gourd; Harvest maturity; Respiration; Ethylene production; Storage temperature; Controlled atmosphere storage; Chilling injury symptoms

1. Introduction

Momordica charantia is a cucurbit vine native to Asia and now widely cultivated throughout the world for the immature fruits, and sometimes for the tender leafy shoots or the ripe fruits (Yamaguchi, 1983). The immature fruits, called bitter melon, bitter gourd or balsam pear, are harvested at developmental stages up to seed hardening. The bitter principle, for which the fruit is named, is due to the alkaloid momordicine, not to cucurbitacins as in other members of the Cucurbitaceae

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(Walters and Decker-Walters, 1988). The bitter melon is also important for its medicinal properties (Morton, 1967; Walters, 1989).

Unpeeled immature bitter melon are sliced for use as a vegetable in various Asian dishes. Good-quality bitter melon should have a fresh appearance and the peel should be of uniform green color and free from visual defects. The developing fruit should be firm without excessive seed development, and free of defects such as decay and splitting.

Fully developed bitter melon exhibit marked changes during fruit ripening. Increases in respiration and ethylene production rates during storage of mature fruits indicate a climacteric behavior (Kays and Hayes, 1978; Zheng, 1986). Mature bitter melon have high ethylene production rates compared to those of other ripening cucurbit fruits including melons, and ripening can be induced by applying ethylene (Kays and Hayes, 1978; Zheng, 1986) or storing at ambient temperatures (Mohammed and Wickham, 1993). Carotenoids increase greatly during the ripening process, with the fruit changing from green to yellow, and the seed cavity becoming bright red (Rodriguez et al., 1976). Coincident with color changes, the fruit pulp loses bitterness and becomes sweet, and the fruit splits or ruptures at the blossom end (Morton, 1967).

Many immature cucurbit fruits, such as summer squash, chayote, fuzzy melon, and angled luffa, are chilling sensitive (Ryall and Lipton, 1979; Hardenburg et al., 1986; Zong et al., 1992). Zheng (1986) observed that storage of immature bitter melon at temperatures below 15°C resulted in chilling injury, but chilling symptom development was minimized at 2°C. Pantastico et al. (1975) recommended storage at 2–3°C with high humidity and did not mention the chilling-sensitive nature of bitter melon. Recently, Mohammed and Wickham (1993) reported that bitter melon could be stored for 21 days at 5–7°C without chilling symptoms if the fruits were protected with polyethylene film wrap. The time and temperature conditions required to induce chilling injury in bitter melon are unclear, and recommended storage temperatures need to be more clearly defined.

The objectives of this work were to study the effects of storage temperature, maturity at harvest, and controlled atmospheres (CA) on the physiology and quality of bitter melon to provide useful information for growers and distributors of this specialty vegetable.

2. Materials and methods

Bitter melon from selections of a large smooth-fruited type were harvested from two commercial plantings near Stockton and Fresno, Calif., from July to October. Fruits were harvested in the morning at typical commercial maturity (larger size, green-colored, firm fruit), transported 2 h under ambient conditions by car to the Mann Laboratory and immediately prepared for storage. Fruits were selected for uniformity and freedom from defects, and placed in glass containers through which humidified air [85–95% relative humidity (RH)] flowed at rates sufficient to maintain CO_2 concentrations below 0.5%. Fruits were stored at 5, 7.5, 10, 12.5, and 15°C for 2 weeks followed by 3 days at 15°C. In other experiments, fruits were stored at 7.5, 10 and 12.5°C and transferred to 15°C after 4, 8, and 12 days. A CA experiment was conducted at 15°C in which humidified atmospheres of 2.5, 5 or 21% O_2 were combined with 0, 2.5, 5 or 10% CO_2.

Respiration and ethylene production rates were monitored daily by taking 1-ml samples from the outlet streams of the containers, and CO_2 and ethylene were determined by infrared analysis and gas chromatography, respectively. Standards of 0.5% CO_2 and 1 ppm ethylene were used for reference. Concentrations of CO_2 and ethylene in the inlet air streams were monitored periodically and did not exceed 0.05% or 0.05 ppm, respectively.

Quality parameters, including overall visual quality, decay, pitting, sunken areas, and splitting, were evaluated by rating scales of 1 to 9, where 1 = minimum and 9 = maximum. Color was evaluated on a 9-point scale, where 9 = green and 1 = yellow. Evaluations were conducted periodically during storage at different temperatures and after transfer to 15°C for 1, 2 and 3 days. Typically three replications of three fruits each were used per storage treatment. Data were analyzed by ANOVA with mean separation by LSD at the 5% level.

3. Results and discussion

Respiration and ethylene production

The respiration rates by developing bitter melon fruits were similar to rates produced by other immature cucurbit fruits, such as cucumber, but lower than those of summer squash (Hardenburg et al., 1986). Bitter melon fruits stored at different temperatures showed an initial decrease followed by steady or slightly increasing respiration rates (Fig. 1). Respiration rates over the initial 6 days of storage averaged 40, 30, 15, and 8 $\mu l\ CO_2\ g^{-1}\ h^{-1}$ at 20, 15, 10, and 5°C, respectively.

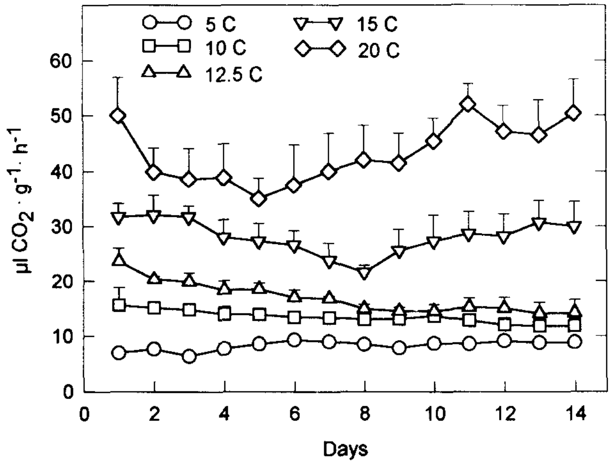

Fig. 1. Respiration rates of bitter melons stored 14 days at different temperatures. Data are means ±SD from three replications of three fruit each.

Ethylene production rates of immature bitter melon were very low (0.1–0.3 nl g^{-1} h^{-1}), and ethylene concentrations were often below the limits of detection at low temperatures. Some fruits stored at higher temperatures (12.5 or 15°C) continued to develop and showed ripening-associated changes undesirable for the bitter melon's use as a vegetable. The ripening fruits showed slight increases in respiration and more than ten-fold increases in ethylene production rates reaching 1–3 nl g^{-1} h^{-1}, rates lower than those previously reported (Kays and Hayes, 1978; Zheng, 1986). Ethylene production by bitter melon fruits is highly cultivar dependent (S. Kays, pers. commun., 1992). The presence of decay during storage was also associated with large increases in ethylene production rates.

Storage temperature and fruit physiology and quality

Commodities that are chilling sensitive often show physiological responses to low-temperature storage before or concurrent with visual chilling symptoms (Saltveit and Morris, 1990). For bitter melon this was exemplified by the differences in respiration and ethylene production rates during storage at 7.5, 10 or 12.5°C and after transfer to 15°C for 2 days (Table 1). With 4 days storage, respiration and ethylene production rates of fruits transferred from all storage temperatures exhibited normal 15°C-rates. By 8 days, the respiration and ethylene production rates after transfer from 7.5 and 10°C were higher than normal 15°C rates. This trend continued with the 12-day transfer, at which time high ethylene production rates were observed by the fruit previously stored at 7.5 and 10°C. Changes in ethylene production and respiration rates coincided with visual chill-induced changes. Mohammed and Wickham (1993) reported that changes in bioelectrical

Table 1
Respiration and ethylene production rates of bitter melons stored at 7.5, 10, and 12.5°C for 4, 8, and 12 days and after transfer to 15°C

Storage period (days)	Storage temperature (°C)	Respiration[a] (μl CO_2 g^{-1} h^{-1})		Ethylene production[b] (nl g^{-1} h^{-1})	
		At storage temperatur	2 days after transfer to 15°C	At storage temperature	2 days after transfer to 15°C
4	7.5	11.1 ± 0.5[c]	32.0 ± 2.8	0.10 ± 0.10	0.40 ± 0.25
	10	16.5 ± 1.5	27.4 ± 2.0	0.26 ± 0.10	0.60 ± 0.05
	12.5	23.6 ± 3.5	28.3 ± 3.0	0.20 ± 0.10	0.20 ± 0.05
8	7.5	11.9 ± 0.9	47.5 ± 6.5	0.42 ± 0.15	1.85 ± 0.25
	10	14.0 ± 1.5	31.5 ± 0.8	0.27 ± 0.20	1.80 ± 0.50
	12.5	22.7 ± 2.7	30.0 ± 4.0	0.59 ± 0.40	0.87 ± 0.40
12	7.5	12.0 ± 0.6	48.0 ± 5.5	0.50 ± 0.30	8.40 ± 1.00
	10	15.5 ± 1.2	36.0 ± 1.0	0.70 ± 0.40	3.34 ± 1.14
	12.5	23.6 ± 2.8	28.3 ± 3.2	0.72 ± 0.30	0.72 ± 0.25

[a] Respiration rates of fruits stored continuously at 15°C were 32.8 ± 2.9, 28.6 ± 2.3, and 26.1 ± 2.5 μl CO_2 g^{-1} h^{-1} at 4, 8, and 12 days, respectively.
[b] Ethylene production rates of fruits stored continuously at 15°C were 0.67 ± 0.25, 0.79 ± 0.26, and 0.99 ± 0.4 nl g^{-1} h^{-1} at 4, 8, and 12 days, respectively.
[c] Data are means ±SD of three replications of three fruit each.

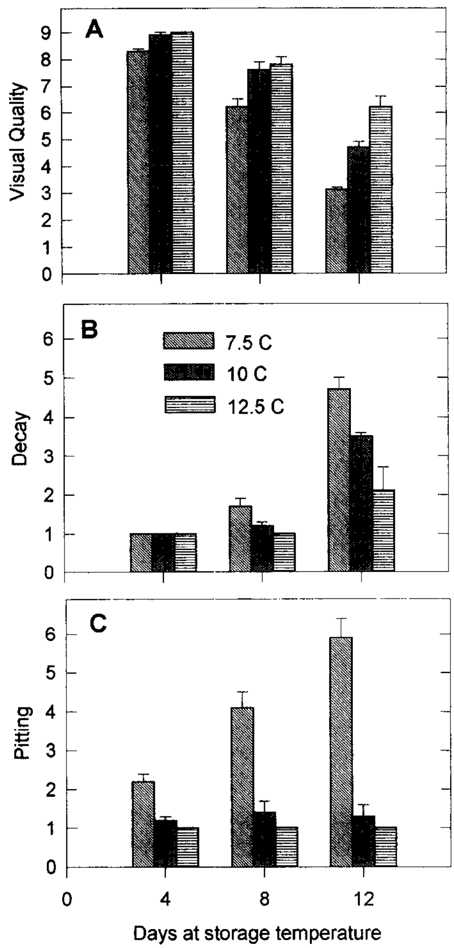

Fig. 2. Visual quality (A), decay (B), and pitting (C) of bitter melons stored at 7.5, 10, and 12.5°C for 4, 8, and 12 days. Product was transferred to 15°C for 3 days before evaluation. Quality parameters were evaluated on a 9-point scale, where 1 = minimum or none and 9 = maximum or very severe. Data are means ±SD from three replications of three fruit each.

resistance and electrolyte leakage preceded the onset of visible chilling injury symptoms in bitter melon.

A greater number of fruits stored at 7.5°C ripened and split when transferred to 15°C as compared to fruits transferred from 10 and 12.5°C. The increased ethylene production rates induced by the 7.5°C-storage may be sufficient to initiate ripening, but in an experiment designed to test this hypothesis, the results were inconclusive.

Visual quality characteristics of the bitter melon fruits stored at 7.5, 10 and 12.5°C were evaluated after 4, 8 and 12 days with an additional 3 days at 15°C to simulate marketing conditions (Fig. 2). After 4 days, the quality of fruits from all temperatures was similar, with slight pitting occurring on the 7.5°C-stored fruits.

Bitter melon stored 8 days at 7.5°C showed marked pitting after transfer. By 12 days these fruits were severely chill damaged, and showed high levels of decay (occurring on sunken translucent areas) and discoloration. Bitter melon stored at 10 and 12.5°C had similar high scores for quality after 8 days, but by 12 days the 10°C-stored fruits showed higher levels of decay and lower overall quality than the fruit stored at 12.5°C. Green color score declined slightly over the 12-days storage period, but was similar for fruit at all storage temperatures (data not shown). Storage at 10–12.5°C resulted in the best-quality bitter melon after a 2-weeks storage period, results similar to those reported for other immature cucurbit vegetables (Ryall and Lipton, 1979; Hardenburg et al., 1986).

Cabrera and Saltveit (1990) showed that chilling damage was reduced in cucumbers if low-temperature storage was periodically interrupted by short periods at nonchilling temperatures. Chilling injury was also reduced in summer squash subjected to intermittent warming (Kramer and Wang, 1989), and this technique has been used successfully for numerous chilling-sensitive plant products (Wang, 1990). The possible benefit of intermittent warming for bitter melon should be investigated since they are often transported and handled in small quantities as part of mixed loads held at temperatures below 10°C.

Effect of maturity at harvest

Precise determination of the stage of maturity of bitter melon is difficult during commercial harvest, and typically some of the product is harvested fully developed (physiologically mature) and begins to ripen during commercial handling. Bitter melon was harvested at two distinct stages: (1) young developing or immature fruits and (2) fully developed but green fruits (fruit were similar in color to immature fruits but were larger in diameter and were less firm or solid), were stored at 7.5, 10, 12.5 and 15°C for 12 days and evaluated after transfer to 15°C for 2 days. There were no quality differences in fruits of the two developmental stages when stored at 7.5, 10 or 12.5°C (data not shown). When stored at 15°C, however, green color loss, softening, and splitting were observed in the bitter melon harvested fully developed. Stage of development at harvest was similarly important in determining postharvest quality of parthenocarpic cucumbers stored at nonchilling temperatures (Kanellis et al., 1986).

Use of controlled atmospheres

Bitter melons are often distributed to local and regional markets under ambient temperatures which favor internal seed development and fruit ripening, as previously described. The possible benefits of CA to delay fruit development and maintain quality were examined at 15°C on bitter melon of typical commercial maturity. Bitter melon stored in air showed an initial decrease in respiration rate at 15°C and then an increase after 6 days and this was associated with color change, softening, and splitting in some fruits. Oxygen levels of 2.5 and 5% resulted in an approximately 40% decrease in respiration rates during the first 12 days of storage, after which rates approached those of air-stored fruit. The increases in respiration rates of low-oxygen stored fruit after 12 days were associated with the onset of decay

Table 2
Quality characteristics of bitter melons stored 2 and 3 weeks at 15°C in air or CA

% O_2	% CO_2	Storage for 2 weeks				Storage for 3 weeks			
		Visual quality [a]	Color [a]	Decay [a]	Splitting [a]	Visual quality [a]	Color [a]	Decay [a]	Splitting [a]
21	0	5.2 ab [b]	6.0 ab	1.1 c	1.0 ns [c]	2.1 e	2.3 f	2.1 e	6.3 a
	2.5	4.0 bc	5.3 b	1.9 b	1.9	2.1 e	4.2 de	4.2 ab	3.7 bcd
	5	4.3 bc	6.1 ab	1.9 b	1.0	2.4 de	3.8 e	3.7 abcd	4.6 bc
	10	4.3 bc	6.6 ab	2.0 b	1.0	2.6 de	4.7 bcde	3.9 abc	5.4 ab
5	0	4.3 bc	6.3 ab	1.8 b	1.0	2.7 cde	3.7 ef	3.2 abcde	5.0 ab
	2.5	5.1 abc	6.2 ab	1.7 b	1.0	3.9 bc	4.6 cde	2.2 e	1.9 de
	5	4.9 bc	6.3 ab	1.9 b	1.0	3.6 bcd	4.4 de	2.3 de	4.6 bc
	10	5.9 a	6.8 a	1.4 bc	1.0	4.9 ab	6.1 ab	2.8 bcde	1.0 e
2.5	0	5.1 abc	6.3 ab	1.9 b	1.0	3.1 cde	4.2 de	2.7 cde	4.6 bc
	2.5	6.2 a	6.7 ab	1.0 c	1.0	5.2 a	6.7 a	2.0 e	1.0 e
	5	6.5 a	7.0 a	1.0 c	1.9	6.0 a	7.3 a	1.0 f	1.6 e
	10	3.7 c	6.6 ab	3.6 a	1.0	3.2 cde	6.0 abc	4.6 a	1.0 e

[a] Scored by rating scales where 1 = minimum or none and 9 = maximum; for color, 9 = maximum green color, 1 = yellow.
[b] Data in a column followed by different letters are signficantly different by LSD at 5% level.
[c] not significant.

and splitting.

Quality differences between air-stored and CA-stored bitter melon were not observed until fruit were stored 2 weeks, and at that time the differences were few (Table 2). At 3 weeks, fruits stored in low O_2 atmospheres in combination with 2.5 and 5% CO_2 showed less green color loss, less decay, less splitting, and better overall visual quality than fruits stored in low O_2 atmospheres or air. The quality ratings of low-O_2 stored fruits were not different from those of air-stored fruits. Fruits appeared to be injured by 10% CO_2 in combination with 2.5% O_2 as reflected by lower visual quality scores at 1 week, and high decay scores at 2 and 3 weeks. The response of bitter melon to CA storage is somewhat different from that shown by other immature cucurbits at nonchilling temperatures. For cucumber, O_2 concentrations of 1–4% retarded senescence, and CO_2-containing atmospheres were not recommended as they provided no benefit or were injurious (Leshuk and Saltveit, 1990). The potential usefulness of CA for bitter melon needs further examination at their ideal storage temperature range of 10–12.5°C.

4. Conclusions

The present study demonstrates the chilling-sensitive nature of bitter melon, with typical injury symptoms of pitting, decay and discoloration occurring when the immature fruits were stored below 10°C. These chill-induced changes were associated with increases in respiration and ethylene production to higher than normal rates after transfer to 15°C. Storage at 10–12.5°C maintained acceptable product quality for 10–14 days. Postharvest quality and shelf-life of bitter melon were greatly affected by the developmental stage of the fruit at harvest. Difficulty in accurately determining harvest maturity may lead to undesirable color, firmness, and flavor changes during marketing at temperatures >12.5°C. Controlled-atmosphere storage can retard undesirable developmental-related postharvest changes, but its potential usefulness requires further investigation.

References

Cabrera, R.M. and Saltveit, M.E. Jr., 1990. Physiological response to chilling temperatures of intermittently warmed cucumber fruits. J. Am. Soc. Hortic. Sci., 115: 256–261.

Hardenburg, R.E., Watada, A.E. and Wang, C.Y., 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA Agric. Handb. No. 66. U.S. Dep. Agric., Washington, D.C., 130 pp.

Kanellis, A.K., Morris, L.L. and Saltveit, M.E. Jr., 1986. Effect of stage of development on postharvest behavior of cucumber fruit. HortScience, 21: 1165–1167.

Kays, S.J. and Hayes, M.J., 1978. Induction of ripening in the fruits of *Momordica charantia* L. by ethylene. Trop. Agric., 55: 167–172.

Kramer, G.F. and Wang, C.Y., 1989. Reduction of chilling injury in zucchini squash by temperature management. HortScience, 24: 995–996.

Leshuk, J.A. and Saltveit, M.E. Jr., 1990. Controlled atmosphere storage requirements and recommendations for vegetables. In: M. Calderon and R. Barkai-Golan (Editors), Food Preservation by Modified Atmospheres. CRC Press, Boca Raton, Fla., pp. 315–352.

Mohammed, M. and Wickham, L.D., 1993. Extension of bitter groud (*Momordica charantia* L.) storage life through the use of reduced temperature and polyethylene wraps. J. Food Qual., 16: 371–382.

Morton, J.F., 1967. The balsam pear — an edible, medicinal and toxic plant. Econ. Bot., 21: 57–68.

Pantastico, Er.B., Chattopadhyay, T.K. and Subramanyam, H., 1975. Storage and commercial storage operations. In: Er.B. Pantastico (Editor), Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI, Westport, Conn., p. 324.

Rodriguez, D.B., Raymundo, L.C., Lee, T.-C., Simpson, K.L. and Chichester, C.O., 1976. Carotenoid pigment changes in ripening *Momordica charantia* fruits. Ann. Bot., 40: 615–624.

Ryall, A.L. and Lipton, W.J., 1979. Handling, Transportation and Storage of Fruits and Vegetables, Vol. 1. Vegetables and Melons. AVI, Westport, Conn., 587 pp.

Saltveit, M.E. Jr. and Morris, L.L., 1990. Overview on chilling injury of horticultural crops. In: C.Y. Wang (Editor), Chilling Injury of Horticultural Crops. CRC Press, Boca Raton, Fla., pp. 3–15.

Walters, T.W., 1989. Historical overview on domesticated plants in China with special emphasis on the Cucurbitaceae. Econ. Bot., 43: 297–313.

Walters, T.W. and Decker-Walters, D.S., 1988. Notes on economic plants. Balsam pear (*Momordica charantia*, Cucurbitaceae). Econ. Bot., 42: 286–288.

Wang, C.Y., 1990. Alleviation of chilling injury of horticultural crops. In: C.Y. Wang (Editor), Chilling Injury of Horticultural Crops. CRC Press, Boca Raton, Fla., pp. 281–302.

Yamaguchi, M., 1983. World Vegetables. AVI (Van Nostrand Reinhold Co.), New York, N.Y.

Zheng, L., 1986. Primary approach on the postharvest physiology of balsam pear. M.S. Thesis, Beijing Vegetable Research Center, Beijing, 43 pp. (in Chinese with English abstract).

Zong, R.J., Morris, L.L., Cantwell, M. and Rubatzky, V., 1992. Postharvest studies on four fruit-type Chinese vegetables. Acta Hortic., 318: 345–354.