The results reported here, in conjunction with previous reports on changes in physical characteristics and chemical composition, strongly suggest that internal bruising modifies tomato quality and flavor, potentially lowering consumer acceptance. From a postharvest quality point-of-view, it is crucial that all the segments in the tomato industry reduce impacts during harvest and handling operations, particularly for mature-green and breaker-stage fruits, to minimize the development of internal bruising.

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COOLING METHOD AND SHIPPING CONTAINER AFFECT LYCHEE FRUIT QUALITY

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Abstract. **A comparison of forced-air cooling (FA), room cooling (RC), hydrocooling (HC), two shipping containers (polystyrene clamshell and corrugated carton) and panicle attachment were conducted on lychees (*Litchi chinensis Sonn.*), Mauritius cultivar. HC lychee packed in cartons retained pericarp color better than the other treatments after 15 days storage at 3 to 5°C. Transferring stored lychees to 20°C for one day significantly increased pericarp browning for all treatments. The results also suggested that lychees stored without panicle had higher pulp quality in terms of total titratable acidity, pH, and total soluble solids content compared to those stored with panicle attached.**

Two major lychee production areas in the United States are Hawaii and Florida. However, fruit availability has been limited by many factors such as the small production area, short storage life, and rapid loss in postharvest quality. Improper handling and shipping methods have a great effect on

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turning of lychee pericarp from bright red to brown. Rapid cooling has been known for reducing metabolic rate after harvest and maximizing the storage life of most horticultural crops (Mitchell 1992; Sargent et al., 1991). Recently postharvest handling of lychees was extensively reviewed (Holcrofft and Mitcham 1996). Ketsa and Leelawatana (1992) reported that hydrocooling 'Hong Huay' lychees from 26-28°C to about 5°C required 18 minutes, while forced-air cooling required 26-28 minutes. They also reported that hydrocooled lychee fruit packed in cartons with polyethylene liners had the best appearance at day six of storage.

This research was conducted to investigate affect of forced-air cooling (FA), room cooling (RC) and hydrocooling (HC) as well as shipping containers (clamshell and carton) on 'Mauritius' lychee quality during storage. Effects of panicle removal were also observed.

Materials and Methods

Lychee fruits (cv. Mauritius) from Homestead, Florida were cooled the same day of harvest (May 18, 1997) by forced-air cooling (FA) with 2.5 cm static pressure difference, 3 to 5°C air and 80 to 90% RH. Room cooling (RC) was accomplished with 3 to 5°C air and 80 to 90% RH, and hydrocooling with 0 to1°C water, pH 6.8 to 7.3, and 100 ppm free chlorine. Fruits cooled by FA and RC were clipped from the panicle prior to cooling and packed loose in commercial shipping cartons [35(L) × 21(w) × 10(H)]. For HC, fruits were hydrocooled with and without panicles attached, prior to draining and packing as above. Pulp temperatures were monitored during cooling by thermister probes inserted near the seed (4 probes per treatment). The following day all treatments were transported in coolers with ice to the Postharvest Horticulture Laboratory at the University of Florida in Gainesville. Upon arrival the fruits were sorted for uniform size and color, then packed in either vented, polystyrene clamshells (1 pint, Ultra-Pac, Minneapolis, MN) or loose in cartons. All containers were stored at 3°C to 5°C and about 85% RH with evaluations made after 15 and 21 days of storage.

After 15 days of storage, twenty fruits from each treatment were measured for marketability by rating incidence of pericarp browning and decay with the scale 5 = bright red/no decay; 4 = 25% pericarp brown/25% decay; 3 = 50% pericarp brown/50% decay; 2 = 75% pericarp brown/75% decay; 1 = 100% pericarp brown/100% decay. Peel color was measured on eight of these fruits at three different points on fruit equator with a Minolta chromameter CR-200b (Minolta., Ramsey, NJ). Lightness (L*), hue angle and chroma were calculated from a*, b* since they have correlation with human color perception (Cheng and Shewfelt 1988).

To simulate commercial handling, fruits stored 15 or 21 days in cartons were repacked in clamshells, and those fruits along with fruits stored in clamshells were transferred to 20°C for 1 day. Twenty fruits per treatment were then measured for pericarp color and marketability as described above. Nine fruits per treatment were peeled and the pulp was frozen at -20°C for later analysis. After thawing pulp from three fruits were homogenized and centrifuged for 20 minutes at 15000 rpm and 4°C (Beckman model J2-21, Palo Alto, CA) then filtered through cheesecloth. This resulted in three replicates per treatment. Total titrable acidity (TTA) was analyzed by diluting 6 g of juice with 50 ml of distilled water and titrating with 0.1N of NaOH using an automatic titrator (No. 9-313-10, Fisher Scientific, Pittsburg, PA). TTA was calculated using the milliequivalent factor for malic acid, 0.067, the major acid (80%) in lychee at maturity (Huang et al., 1986; Paull et al., 1984). Juice pH was determined by a pH meter (model 140, Corning Medical and Scientific Instruments, Medfield, MA). Total soluble solids (TSS) were determined by using a Mark II Abbe refractometer model 10480 (Cambridge Instruments, Inc., Buffalo, NY). Peel moisture content (wet weight basis) was determined by drying the peels of 5 fruits/treatment at 70°C for 2 days.

Total soluble phenolic compounds in lychee pericarp were determined using the method of Folin and Ciocalteu (1927). The pericarp of one fruit/treatment was mixed with 10 ml of deionized water, homogenized and filtered with Whatman #4 paper. Absorption of the extracts was read using a spectrophotometer (Beckman DU 20, Beckman Instrument, Inc., Irvine, CA) at 760 nm. Total phenolic concentration was determined using a standard curve prepared with gallic acid. Data were calculated from five replications per treatment and duplicate absorption readings per sample.

The data were analyzed with the SAS program (1982) using analysis of variance (ANOVA), and means were separated using Duncan's Multiple Range Test, 5% level.

Results and Discussion

HC required 12 to 15 min, while FA and RC took about 60 min and 13 hr respectively, in order to cool the lychees from 25 to 27°C to 3°C (Fig. 1). After 15 days storage and one day at 20°C, neither cooling method (FA, RC, HC) nor package container (clamshell and carton) had a significant effect on the incidence of lychee decay (Table 1). However, after 21 days storage at 3 to 5°C fruits were no longer marketable due to excessive decay in all treatments.

Pericarp browning significantly increased after 15 days of storage. HC lychees without panicles and packed in the cartons had significantly less browning than other treatments, with a rating of 2.78 (Table 1). After one day at 20°C, pericarp browning was 100% in all treatments except HC lychees without panicles which had a slightly better color (1.25). It was reported by Huang and Scott (1985) that the initial bright-red peel became brown within 24 hours at ambient temperature supposedly due to dehydration.

The results from the visual observations of the lychees were comparable to those from the objective color measure-

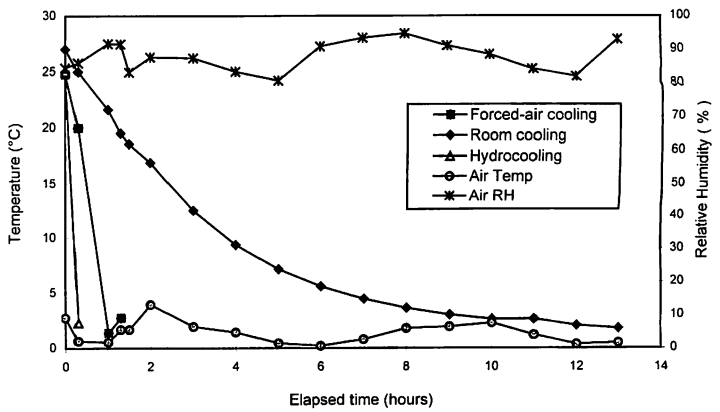

Figure 1. Reduction of initial temperatures of 'Mauritius' lychee fruits by forced-air cooling, room cooling, and hydrocooling.

Table 1. Decay, peel browning and peel color of 'Mauritius' lychee fruits after 15 days @ 3-5°C plus 1 day at 20°C.

Treatments	Decay[z]	Browning[y]	L*	a*	b*	Hue Angle	Chroma
Initial	—	—	38.48 a[x]	17.52 a	22.08 a	51.73 b	28.47 a
After 15 days of storage at 3-5°C							
Without panicle							
FA/clamshell	5.00 a	2.00 b	33.75 c	12.46 bc	21.15 ab	59.21 a	24.63 bc
RC/clamshell	4.90 a	2.00 b	32.99 c	12.76 bc	20.45 abc	57.82 a	24.15 bcd
HC/clamshell	4.85 a	2.05 b	32.13 c	12.14 bcd	19.30 bc	58.08 a	23.06 cde
FA/carton	4.90 a	2.00 b	33.97 c	10.75 d	18.80 c	60.29 a	21.74 e
RC/carton	5.00 a	2.08 b	33.94 c	11.62 bcd	18.95 c	58.20 a	22.33 de
HC/carton	4.95 a	2.78 a	36.31 b	13.13 b	21.77 a	58.54 a	25.71 b
With panicle							
HC/carton	4.90 a	2.05 b	33.57 c	11.08 cd	19.64 bc	60.65 a	22.59 de
After transfer to 20°C for 1 day							
Without panicle							
FA/clamshell	4.95 a	1.00 b	36.54 b	11.19 b	21.09 ab	61.85 a	23.94 b
RC/clamshell	4.90 a	1.00 b	35.45 bc	10.84 bc	19.97 bc	61.18 a	22.77 bc
HC/clamshell	4.85 a	1.00 b	35.00 bc	10.70 bc	19.56 bcd	61.40 a	22.34 bc
FA/carton	4.90 a	1.00 b	35.79 bc	9.82 bc	17.59 de	61.07 a	20.26 d
RC/carton	5.00 a	1.00 b	35.24 bc	9.36 c	17.18 e	61.39 a	19.62 d
HC/carton	4.95 a	1.25 a	35.90 bc	11.47 b	19.18 bcde	58.93 a	22.53 bc
With panicle							
HC/carton	4.90 a	1.00 b	34.40 c	11.12 bc	18.45 cde	61.29 a	21.10 cd

[z]Decay scored on a scale of 1-5; 1 = 100% decay and 5 = 0% decay.
[y]Browning scored on a scale of 1-5; 1 = 100% brown and 5 = 0% brown.
[x]Means within column in the same storage time sharing common letters are not significantly different by Duncan's Multiple Range Test, 5% level.

ment (Table 1). L*, a*, and chroma values for all treatments were significantly lower after 15 days of storage, which corresponds to darker and less intense red color. HC lychees without panicles and stored in cartons maintained slightly higher L*, a*, and chroma values (more intense red color). For hue angle, the values of all treatments increased (less red) compared to initial values but not significantly among treatments. These results indicate that HC fruits without panicles and stored loose in cartons retained slightly better color than those from the other treatments, consistent with observations reported by Vilasachandran and Sargent (1997).

After transfer to 20°C for one day, the peel color of all treatments became significantly darker and less red, as indicated by increased hue angle and decreased a* values (Table 1). There was no significant difference in L* value for most treatments, except HC lychees packed in carton with panicles were significantly darker than FA lychees packed in clamshells. FA and RC fruits stored in cartons had the least intense color. There was no significant difference among treatments for hue angle.

Shipping containers and cooling methods affected TSS, TTA and pH of the lychee pulp without panicles. When these quality factors are compared with initial values, HC lychees without panicles attached had significantly lower pH and higher TSS and TTA. All values were calculated on a fresh weight basis (Fig. 2). HC fruits packed in cartons without panicles had the highest peel moisture content (45%) after 15 days storage at 3 to 5°C plus one day at 20°C while those lychees with panicles attached had the lowest (19%) (Fig. 3). Fruits may have absorbed water during the HC process and the carton box with few vents may have helped maintain low pH and high TTA and TSS (Fig. 2).

The phenolic concentration has been associated with browning in many fruits (Richardson and Hyslop 1985). HC lychees without panicles packed in cartons maintained the highest peel moisture content (Fig. 3), reddest color and had slightly lower total phenolic compounds than other treatments. It is possible that the high moisture content of the peel resulted in a lower phenolic concentration. Total phenolic compounds determined on a dry weight basis were not significantly different among treatments. HC lychees without panicles stored in cartons and FA lychees stored in cartons had less total phenolic compounds than those from RC in clamshell; the former (HC and FA) retained high relative humidity during transport and storage. We determined that the clamshells had excessive ventilation which led to higher weight loss during storage. The results indicate that color retention of the fruit peel had a high correlation with peel moisture content. Underhill and Critchley (1983) stated that

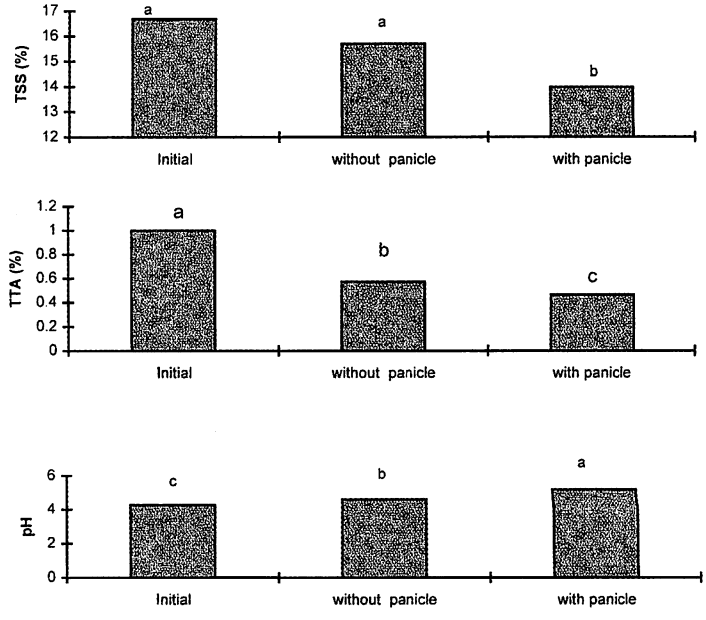

Figure 2. Comparing effect of hydrocooled lychees with and without panicle packed in carton on TSS, TTA, and pH (Mean values with different letters are not significantly different by Duncan's Multiple Range Test, 5% level).

Table 2. Total soluble solids content, total acidity, pH, and total peel phenolic compounds of 'Mauritius' lychee after 15 days @ 3-5°C plus 1 day @ 20°C.

Treatments	Total Soluble Solid[z] (%)	Total acidity[z] (%) Malic acid	pH[z]	Total Phenolic Compounds: Fresh weight basis[y] (mg phenolic/g FW)	Total Phenolic Compounds: Dry weight basis[y] (mg phenolic/g DW)
Initial	16.50 ab[x]	0.82 a	4.41 c	no data	no data
Final					
Without panicle					
FA/clamshell	17.50 a	0.38 e	4.47 c	78.05 ab	106.04 a
RC/clamshell	16.70 a	0.70 ab	4.61 bc	100.33 a	129.76 a
HC/clamshell	15.83 ab	0.72 ab	4.61 bc	85.77 ab	112.95 a
FA/carton	16.27 ab	0.54 cd	4.95 ab	66.92 b	91.32 a
RC/carton	15.97 ab	0.75 ab	4.65 bc	76.97 ab	112.20 a
HC/carton	16.30 ab	0.65 bc	4.79 abc	62.10 b	112.47 a
With panicle					
HC/carton	13.97 b	0.46 de	5.19 a	84.11 ab	103.95 a

[z]Value are means of three determinations.
[y]Value are means of five determinations.
[x]Mean within column sharing common letters are not significantly different by Duncan's Multiple Range Test, 5% level.

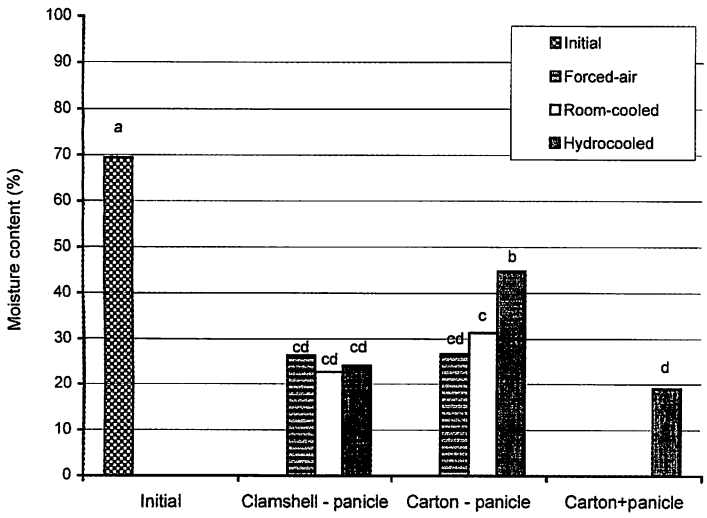

Figure 3. Peel moisture content of lychees after 15 days storage @ 3-5°C + 1 day @ 20°C (fresh weight basis).

browning can be reduced by minimizing desiccation. Since color of the pericarp changed rapidly upon transfer to a warmer and drier environment, it is suggested that the fruits should be immediately hydrocooled to 3°C with 85 to 90% RH and held under these conditions during storage and merchandising. Removal of the panicle is suggested to maintain fruit quality and reduce weight loss during this period.

In conclusion, HC with chlorinated water required the least time to cool the fruits and did not increase decay compared with RC and FA following storage at 3 to 5°C for 15 days. HC lychees packed loose in cartons retained higher peel moisture content and better peel color than those from the other treatments. Pericarp browning significantly increased following transfer to 20°C for 24 hours. HC lychees without panicles resulted in better pulp quality and pericarp color than lychees HC with panicle attached. Most of the fruits in all treatments had decay after 21 days storage at 3 to 5°C, therefore effective decay control should be studied to extend lychee postharvest life beyond 15 days.

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