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Storage Characteristics of Small Watermelon Cultivars

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Abstract. **Two newly released cultivars of small watermelons [Citrullus lunatus (Thumb.) Matsum and Naki], 'Mickylee' and 'Minilee', plus two other cultivars, Baby Fun and Sugar Baby, were stored at various temperatures from 1 to 21C for up to 4 weeks plus 1 week at 21C over two seasons. All cultivars were susceptible to chilling injury (CI) when stored below 7C; however, 'Minilee' was less susceptible than the other cultivars tested. Chilling injury increased with storage length. Conditioning at 26C for 3 days before storage at 1C reduced CI and increased the percentage of marketable watermelons after storage. Decay percentage increased with storage time and was highest on fruit held at 1C where CI led to decay. The flesh of 'Mickylee' and 'Minilee' was firmer than that of the other cultivars tested and 'Mickylee' and Minilee' retained their firmness better during storage. Total soluble solids concentration decreased with increased storage temperature. 'Minilee' watermelons were superior to the other three cultivars in postharvest storage potential and exhibited the least CI and decay.**

Watermelon production in the United States has traditionally centered around production of large-fruited types. United States per-capita consumption has dropped 30%, from 8.2 kg during the 1950s to 5.9 kg during the 1980s. The drop in watermelon consumption has been attributed to smaller families, inconvenience in handling large watermelons, and, if sliced at retail, higher per-unit prices. Small watermelon cultivars, sometimes called icebox watermelons; have been available for many years. Their yield and quality have not been as good as that of the large melons. Two recently released cultivars, Minilee and Mickylee, developed by Crall (1986), have acceptable yields and excellent eating quality. These two cultivars also are resistant to anthracnose and fusarium wilt. The flesh of these fruit is very crisp and total soluble solids (TSS) range from 10% to 12% at maturity. In recent years, imports of watermelons of 'Mickylee' and 'Minilee' from Central and South America and the Caribbean Islands have been increasing.

Watermelons generally are not refrigerated when shipped domestically. However, refrigerated storage and transit may be used to extend the shelf life during export shipment. The recommended range is 10 to 15C (Hardenburg et al., 1986). At lower temperatures, fruit are susceptible to CI and decay (Dow et al., 1979) and loss of color (Showalter, 1960). At higher temperatures, fruit are subject to decay (Leupeschen, 1961) and sugar loss (Chisholm and Picha, 1986). Prestorage conditioning at 26C for 4 days reduces development of CI and increases the percentage of marketable fruit following storage (Picha, 1986).

The objective of this study was to determine the storage quality potential of small watermelon cultivars in the range of 1 to 21c.

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Materials and Methods

Three independent storage tests were conducted; two at Orlando and one at Gainesville, Fla. The fruit for the Orlando tests were harvested from plantings at the Univ. of Florida's Agricultural Research Centers at Bradenton or Leesburg during 1987 and 1988. Three harvests were made for each test in 1987 and 1988 with 'Baby Fun', 'Mickylee', and 'Minilee'. One harvest at Gainesville was made from plantings at Univ. of Florida's Horticultural Unit plots with 'Baby Fun', 'Mickylee', 'Minilee', and 'Sugar Baby'. Harvested fruit for the Gainesville test were rinsed with tap water to remove field debris and dipped for 1 min in a 0.5% solution of sodium-o-phenyl-phenate (SOPP) (FMC Freshguard, Lakeland, Fla.). Fruit for the Orlando tests were not treated.

Five fruit of each cultivar were stored at 1, 7, 13, or 21C for 1, 2, 3, or 4 weeks plus 1 additional week at 21C for the tests in 1987 at Orlando. For the 1988 Orlando test, five fruit of each cultivar were stored at 1, 7, 13, or 21C for 3 weeks plus 1 additional week at 21C. Two additional treatments were added to this test: conditioning at 26C for 3 days at high (90% ± 5%) or low (60% ± 5%) RH before storage at 1C. Five fruit of each cultivar for the Gainesville test were stored at 5, 10, 15, or 20C for 2 or 4 weeks plus 4 additional days at 20C. Storage rooms in the Orlando tests were maintained at the desired temperature ± 0.5C and RH of 85% ± 5%; those in the Gainesville test were maintained at the desired temperature + 0.5C. Relative humidity was 90% ± 5% in the 5, 10, and 15C rooms and 70% ± 5% in the 20C room. All melons were in storage within 4 to 8 hr after harvest.

At Orlando, the fruit were scored at each evaluation for CI (1 = none, 2 = <10% of surface area, 3 = 11% to 25%, 4 = 26% to 50%, and 5 = > 50%), stem condition (sound or not), and decay. CI of watermelon surface is indicated by brownish, water-soaked areas. Marketable fruit were considered to be without decay and not overripe. The fruit were then cut

Table 1. Chilling injury rating and percentage of marketable watermelons stored for 1, 2, 3, or 4 weeks at 1, 7, 13, or 21C[z] plus 1 additional week at 21C (three tests, 1987, Orlando).

Storage		Chilling injury (rating)[x]				Marketable[y] (%)			
Temperature (°C)	Time (wk)	Minilee	Mickylee	Baby Fun	x̄	Minilee	Mickylee	Baby Fun	x̄
1	1	1.0	1.5	1.3	---	100	100	100	---
	2	1.4	2.3	1.8	---	75	67	50	---
	3	2.3	3.8	4.0	---	58	58	60	---
	4	2.5	3.7	4.0	2.4	17	25	38	61
7	1	1.0	1.0	1.0	---	100	100	100	---
	2	1.2	1.3	1.1	---	92	83	100	---
	3	1.5	1.8	1.8	---	50	83	50	---
	4	2.0	2.0	2.3	1.5	25	25	30	71
13	1	1.0	1.0	1.0	---	92	100	100	---
	2	1.0	1.0	1.0	---	83	92	40	---
	3	1.0	1.0	1.0	---	92	75	60	---
	4	1.0	1.0	1.0	1.0	67	58	0	71
21	1	1.0	1.0	1.0	---	100	100	100	---
	2	1.0	1.0	1.0	---	100	100	100	---
	3	1.0	1.0	1.0	---	92	92	90	---
	4	1.0	1.0	1.0	1.0	83	92	60	93
x̄[w]	---	1.3 b	1.6 a	1.6 a	---	76 a	78 a	67 b	---

[z]All storage rooms maintained at ± 0.5C and 85% ± 5% RH.
[y]Melons ripe and not decayed.
[x]Chilling injury ratings: 1 = none, 2 = <10% of surface area, 3 = 11% to 25%, 4 = 26% to 50%, and 5 = >50%.
[w]Means separation in row by Duncan's multiple range test, $P = 0.05$.

Table 2. Quality characteristics of three small watermelon cultivars stored at 1, 7, 13, or 21C[z] for 4 weeks plus 1 additional week at 21C (three tests, 1987, Orlando).

Treatment	Firmness	Total soluble solids (%)	Marketable fruit[y] (%)
Cultivar averaged over temperatures[x]			
Mickylee	16.7 a	10.2 b	58 a
Baby Fun	11.1 b	11.1 a	30 c
Minilee	15.5 a	11.0 a	48 b
Temperature (°C) averaged over cultivars			
1	14.1	12.3	24
7	14.4	10.7	27
13	16.2	10.0	53
21	13.7	9.8	78

[z]Storage rooms maintained at ± 0.5C and 85% ± 5% RH.
[y]Melons ripe and not decayed.
[x]Means separation in columns by Duncan's multiple range test, $P = 0.05$.

in half before being evaluated for ripeness stage at Gainesville (1 = unripe, 2 = ripe, 3 = overripe). Rind thickness was measured at three equally spaced locations around the circumference of the fruit. Color of a section of flesh at the center or heart area was measured with a color difference meter (Model D25-9, Hunterlab, Reston, Va.) signal processor with an optical sensor (model D25-L).

A section of flesh (3 × 8 cm and ≈ 2 cm deep) in the Orlando tests was cut from the central area of the fruit and a food-testing system (Model 1132, Instron, Canton, Mass.) was used to measure firmness. Firmness was measured by applying a load cell calibrated to a range of 0-10 kg at a constant speed of 5 cm·min^{-1} equipped with a round-ended probe (1.1 cm in diameter). The amount of force required to enter the fruit surface to a depth of 5 mm was recorded. Three readings were taken on each melon. Two tissue sections (3 × 3 × 10 cm) from opposite fruit halves were used to measure flesh firmness in the Gainesville test. The firmness was measured with a firmness testing device (Chatillon Model HTCM, John Chatillon and Sons, New York) with a crosshead speed of 20 cm·min^{-1} and equipped with a round-ended probe (1.1 cm in diameter).

The TSS content of the juice was determined by homogenizing in a blender the two tissue sections used for flesh firmness, centrifuging an aliquot of the resultant slurry at 12,000 × *g*, and measuring the supernatant with an Abbé refractometer in the Gainesville test. TSS was determined by squeezing juice from the heart section, previously used for color and firmness measurements, directly onto a hand-held refractometer in the Orlando tests.

All data were statistically analyzed using an analysis of variance, and Duncan's multiple range test was used to separate means.

Results

All three cultivars in the 1987 tests at Orlando were susceptible to CI at 1 at 7C. 'Minilee' was the least-susceptible cultivar (Table 1). CI was more severe at 1 than 7C and the severity of CI increased with increased storage time. The percentage of marketable watermelons was highest at 21C and lowest at 1C (Table 1). At 1 and 7C, most of the decay originated on the sites of CI, and at 13 and 21C, most decay originated from the stem end. Decay increased with storage time. 'Mickylee' and 'Minilee' fruit were less susceptible to decay than 'Baby Fun'. 'Mickylee' and 'Minilee' fruit were firmer than 'Baby Fun' fruit during storage (Table 2). TSS values were higher for 'Baby Fun' and 'Minilee' than for 'Mickylee' fruit. TSS decreased with increased storage temperature. The percentage of marketable watermelons was highest for 'Mickylee' fruit, followed by 'Minilee' and 'Baby Fun' fruit, during this extended storage period. Storage at 21C resulted in the highest percentage of

Table 3. Quality characteristics of three small watermelon cultivars stored at 1C (with and without conditioning), 7, 13, or 21C for 3 weeks plus 1 additional week at 21C (three tests, 1988, Orlando)[z].

Treatment	Chilling injury (rating)	Firmness	Total soluble solids (%)	Overripe (%)	Sound stems (%)	Decay (%)	Marketable[y] (%)
Cultivar averaged over temperature and conditioning[x]							
Mickylee	2.2 b	15.7 a	11.1 a	3 b	49 b	10 b	87 a
Baby Fun	2.4 a	7.8 b	10.8 b	19 a	51 b	26 a	55 b
Minilee	1.8 c	14.7 a	10.6 b	8 b	58 a	2 b	90 a
Temperature averaged over cultivar							
1C	3.9	14.7	11.1	0	23	52	48
Cond HRH + 1C	2.5	12.7	11.2	2	67	16	82
Cond LRH + 1C	2.6	11.8	11.3	5	72	9	86
7C	1.6	12.7	11.3	9	42	19	72
13C	1.0	12.7	10.9	16	23	9	75
21C	1.0	11.8	10.6	23	88	2	75

[z]Conditioning 3 days at 26C at either high (90% ± 5%; HRH) or low RH(60% ± 5%; LRH). All other storage rooms maintained at ± 0.5C and 85% ± 5% RH.
[y]Melons ripe and not decayed.
[x]Means separation in columns by Duncan's multiple range test, $P = 0.05$.

Table 4. Quality characteristics of four small watermelon cultivars stored at 5, 10, 15, or 20C for 4 weeks (one test, 1987, Gainesville)[z,y].

Cultivar	Ripeness[x] (rating)	Color ('a')	Firmness	Rind thickness (mm)	Total soluble solids (%)	Decay[w] (%)
			At harvest			
Sugar Baby	1.2 a	18.2 b	18.2 b	12.8 b	7.6 c	---
Baby Fun	1.6 a	28.9 a	17.3 b	13.3 b	10.2 ab	---
Minilee	2.0 a	34.3 a	25.8 a	11.7 b	10.6 a	---
Mickylee	1.6 a	28.7 a	16.5 b	15.2 a	9.3 b	---
Avg.	1.6	27.5	19.5	13.3	9.4	---
			Stored at 5C			
Sugar Baby	1.2 b	27.7 a	11.1 b	13.1 a	9.7 a	14a[x]
Baby Fun	1.2 b	26.8 a	8.9 b	13.4 a	10.2 a	17a
Minilee	2.2 a	29.8 a	12.9 b	13.7 a	10.1 a	14a
Mickylee	2.2 a	28.1 a	16.0 a	13.6 a	9.1 a	25a
Avg.	1.7	28.1	12.2	13.5	9.8	17.5
			Stored at 10C			
Sugar Baby	3.0 a	28.7 b	8.9 c	15.0 a	10.7 a	44 b
Baby Fun	2.0 a	27.8 b	16.5 b	12.9 a	10.8 a	39 b
Minilee	2.2 a	28.7 b	11.1 c	10.6 a	10.5 a	15 c
Mickylee	2.3 a	34.9 a	20.5 a	13.4 a	9.3 a	70 a
Avg.	2.4	30.0	14.3	13.0	10.3	42
			Stored at 15C			
Sugar Baby	2.3 a	25.7 c	12.5 b	9.5 b	10.0 ab	55 a
Baby Fun	2.8 a	30.0 a	12.0 b	9.6 b	10.5 a	46 a
Minilee	2.6 a	29.0 b	10.2 b	11.4 a	9.1 c	5 b
Mickylee	3.0 a	32.3 a	17.8 a	11.7 a	9.6 bc	44 a
Avg.	2.7	29.3	13.1	10.6	9.8	38
			Stored at 20C			
Sugar Baby	3.0 a	27.0 b	8.0 c	10.2 a	9.5 a	26 a
Baby Fun	2.6 a	28.3 b	8.9 c	8.4 a	10.0 a	19 a
Minilee	2.8 a	30.9 a	15.1 b	8.0 a	9.4 a	9 b
Mickylee	2.6 a	31.4 a	22.2 a	9.1 a	8.8 a	17 ab
Avg.	2.8	29.4	13.6	8.9	9.4	18

[z]All storage rooms maintained at ± 0.5C and 90% to 95% RH in 5, 10, and 15C rooms and 70% RH in 20C room.
[y]Mean separation in columns (within a given storage temperature) by Duncan's multiple range test, $P = 0.05$.
[x]Ripeness: 1 = unripe, 2 = ripe, 3 = overripe.
[w]After storage for 4 weeks plus 4 days at 20C.

marketable fruit and 1C in the lowest. At 1 and 7C storage, CI was severe and decay originated at the sites of Cl during the additional week of storage at 21C.

In the 1988 tests at Orlando, 'Baby Fun' fruit were more susceptible to Cl than either 'Mickylee' or 'Minilee' fruit during storage for 3 weeks at 1C (with or without conditioning at 26C for 3 days), plus 1 week at 21C (Table 3). Prestorage conditioning reduced the incidence and severity of CI. 'Mickylee' and 'Minilee' fruit were firmer than 'Baby Fun' fruit during storage, and firmness was not affected by increased storage temperature. TSS values were higher for 'Mickylee' than for 'Baby Fun' or 'Minilee.' The stems of 'Minilee' fruit had better appearance (absence of mold or decay) than those of either 'Baby Fun' or 'Mickylee' fruit. Fruit stored at 21C and at 1C with conditioning had more sound stems than fruit stored at 1, 7, or 13C. 'Baby Fun' fruit were overripe and had more decay than 'Mickylee' or 'Minilee fruit during storage. The incidence of overripe fruit was the lowest for storage at 1C, with or without conditioning, and highest for storage at 21C. The incidence of decay was highest in fruit stored at 1C. Storage at 1C with conditioning resulted in the highest amount of marketable fruit, and storage at 1C without conditioning in the lowest (Table 3). The humidity level during conditioning (90% or 60% RH) did not affect any of the quality factors studied. Prestorage conditioning reduced the severity of CI with reduced incidence of decay and maintained a desirable stem condition.

The ripeness rating in the test at Gainesville for all cultivars tended to increase with increased storage temperatures during 4 weeks of storage at 5, 10, 15, or 20C (Table 4). There were no differences among cultivars except for storage at 5C. The initial ripeness ratings indicated that the fruit generally were harvested somewhat before being fully ripe. 'Mickylee' generally had the deepest red flesh, as indicated by the higher Hunter 'a' values, while 'Sugar Baby' had the lowest after storage. Firmness of the flesh was quite variable after storage, but 'Mickylee' fruit tended to be firmer than the other three cultivars. Rind thickness tended to decrease with increasing storage temperatures. Decay tended to be lower at 20C than at 10 or 15C storage and equal to that at 5C. 'Minilee' fruit had the lowest amount of decay compared to other cultivars at 10C and above. Most decay was limited to the stem end of the fruit, indicating that decay was from infection through the stem.

Discussion

Small watermelon cultivars respond similarly to large-fruited types during storage. 'Mickylee' and 'Minilee' responded very well to long-term storage. They maintained crispness, firmness, and TSS content. 'Minilee' fruit were less susceptible to CI and had less decay than the other cultivars tested. Subjecting small watermelons to storage at ≤ 7C for more than 1 week induced CI and led to decay after subsequent holding at room temperature. Conditioning (3 days at 26C) of small watermelons reduced the incidence and severity of CI and increased the percentage of marketable fruit for storage at 1C, which is similar to the findings of Picha (1986). Conditioning not only reduced CI, but increased the percentage of sound stems. The high temperature of conditioning before cold storage tended to dry out the stems, which, presumably, reduced infection from the stem end of the fruit. Film-wrapping of melons caused excessive decay originating at the stem end, presumably because of the high relative humidity inside the wrapping (unpublished data). Data from a related test in Gainesville showed that artificially drying stems resulted in less decay than dipping fruit in SOPP-treated water.

Some shippers of small watermelons from Central America are using shipping temperatures <7C without CI; however, transit times are <1 week. Perhaps some inadvertent conditioning of fruit also occurs after harvest and before shipment, when time between harvest and shipment is 2 to 4 days (M. Harris, personal communication).

In our studies, long-term storage at 20C produced the highest percentage of marketable fruit and, generally, the lowest percentage of decayed fruit. However, fruit from long-term storage at 20C also had the lowest amount of TSS. The fruit flesh was also not as crisp as at lower storage temperatures. Therefore, 10 to 15C was in the best range for long-term storage for non-conditioned small watermelons. For 'Mickylee' and 'Minilee,' storage at 1C with conditioning at 26C for 3 days would be acceptable for long-term storage. These data agree with the recommendations of Hardenburg et al. (1986) and Dow et al. (1977) for large-type watermelons. Prestorage conditioning at ambient temperatures before storage at 1C should enhance longevity of watermelon during storage.

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