Biochemical and Microbial Changes during the Storage of Minimally Processed Cantaloupe

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The effect of storage time on pH, titratable acidity, °Brix, organic acids, sugars, amino acids, and color of minimally processed cantaloupe melon (*Cucumis melo* L. var. *reticulatus* Naud. cv. Mission) was determined at 4 °C and 20 °C. Changes in most of the biochemical parameters with storage time were relatively slow at the lower temperature. At 20 °C, a 17% loss in soluble solids and a 2-fold increase in acidity occurred after 2 days. Organic acid content also increased considerably with time at this temperature as a result of the production of lactic acid. Oxalic, citric, malic, and succinic acids were the organic acids, and glucose, fructose, and sucrose were the sugars present in the freshly cut cantaloupe. Malic acid concentration decreased concurrently with lactic acid production indicating the possible involvement of anaerobic malo-lactic fermentation along with sugar utilization by lactic acid bacteria. The effect of storage on microbial growth was determined at 4, 10, and 20 °C. Gram-negative stained rods grew at a slower rate at 4 °C and 10 °C than the Gram-positive mesophilic bacteria that dominated microorganism growth at 20 °C. Eighteen amino acids were identified in fresh cantaloupe: aspartic acid, glutamic acid, asparagine, serine, glutamine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, isoleucine, leucine, phenyl alanine, and lysine. The dominant amino acids were aspartic acid, glutamic acid, arginine, and alanine. Total amino acid content decreased rapidly at 20 °C, but only a slight decrease occurred at 4 °C after prolonged storage. Changes in lightness (L^*), chroma, and hue at both temperatures indicate the absence of browning reactions. The results indicate the potential use of lactic acid and lactic acid bacteria as quality control markers in minimally processed fruits.

Keywords: *Melons; fresh-cut; fruits; Cucumis melo L.; carbohydrates; sugars; organic acids; amino acids; microorganisms; lactic acid bacteria; shelf life; quality*

INTRODUCTION

Consumer demand for the convenience offered by fresh-cut produce has increased interest in understanding the physiological and biochemical changes that result from their processing and storage (Cantwell, 1992; Huxsoll et al., 1989; Wiley, 1994a; Varoquaux and Wiley, 1994). Keeping pre-cut fruits and vegetables looking and tasting like unprocessed raw fruits and vegetables is a considerable challenge. In addition to the increased respiration rate caused by fresh-cut processing, water, microbial, and enzyme activities are accelerated (Rolle and Chism, 1987; King and Bolin, 1989; Brackett, 1994; Wiley, 1994a). These increased reaction rates reduce shelf life.

Minimally processed fruits and vegetables with high pH (>4.6) and water activity (a_w > 0.85) are considered to be highly perishable when they are not subjected to preservative processes that delay undesirable biological and biochemical changes (Wiley, 1994b). This group includes commonly fresh-cut processed fruits such as melons. Low temperature has been used to preserve quality and extend shelf life of fresh-cut produce. Although cold storage retards many biochemical processes in foods, reactions related to psychrotrophic enzymes and microorganism growth continue at low temperatures. Psychrotrophs such as pseudomonads that cause spoilage of refrigerated foods, for example, can accumulate rapidly at low temperatures (Kraft and Rey, 1979; Brackett, 1987; Nguyen-the and Carlin, 1994). These adversely affect fruit flavor, texture, nutrients, and overall quality (Matthews and McCarthy, 1994; Varoquaux and Wiley, 1994; Wiley, 1994b; Klein, 1987; Shewfelt, 1987; King and Bolin, 1989; Watada and Qui, 1999). Information on the biochemical changes that occur in minimally processed fruits and vegetables is limited, and there is a critical need for research in this area (Brody, 1998). Although fresh-cut cantaloupe is commonly displayed on ice, a survey of local supermarkets showed that temperatures of some fruits sold in this manner, particularly cut fruits at the top of large trays and those that have been on display for long periods of time, are close to ambient. Consumers may also hold fresh-cut fruits for a number of days after purchase before consuming them. This results in further product deterioration. Thus, this study was based on biochemical and microbial changes that occur during storage of fresh-cut cantaloupe at 4 °C and 20 °C.

Sugars, organic acids, and amino acids significantly contribute to sweetness and aroma of fruits. Sweetness and aroma are the two most important quality indica-

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tors in melons (Wyllie et al., 1995; Wang et al., 1996). In addition, organic acids are important flavor precursors and respiratory energy sources in plant cells (Ulrich, 1970). Free amino acids impart flavor and are major precursors of melon aroma volatiles (Wyllie et al., 1995; Bauchot et al., 1998). Although there are limited reports on the content of some of these compounds in melon cultivars (Pratt, 1971; Hubbard et al., 1989; Wyllie and Leach, 1992; Wyllie et al., 1995) there is no indication as to the nature of changes that occur to these compounds during fresh-cut fruit processing and storage.

The objective of this study was to determine changes in some biochemical parameters that are important to the quality of cantaloupe after fresh-cut processing. The nature and extent of growth of naturally occurring microorganisms in fresh-cut cantaloupe were also determined under conditions that may be encountered in retail packaging and storage.

MATERIALS AND METHODS

Fruit Preparation. Cantaloupes (*Cucumis melo* L. var. *reticulatus* Naud.) were purchased from a local supermarket. The cultivar used was identified from the box numbers and picking date as Mission′. The unprocessed fruits were surface disinfected with 80% ethanol and placed in a laminar flow hood that was also sanitized with ethanol. All materials used for cutting and handling the fruits were continually disinfected and metallic surfaces were flamed at regular intervals. Fruits were sliced horizontally into halves with a sharp knife. Seeds were removed and the fruit cavity was cleaned. Each half was cut at the exposed end into four equal pieces. The skins were then removed and each piece was cut into slices approximately 3 mm thick. The cantaloupe slices were transferred into plastic containers with airtight lids. Slices from a whole melon wereused as one of three replicates for each temperature. Fruit pieces that were stored at 20 °C were kept inside the laminar flow hood. The other containers were kept in an incubator at 4 °C.

For the analysis of organic acids, sugars, and free amino acids, cantaloupe slices were dipped in liquid nitrogen and lyophilized. Liquid nitrogen was poured over dried fruits in a mortar before crushing them into powder.

Determination of pH, °Brix, and Titratable Acidity. Cantaloupe slices were initially crushed in a mortar and pestle. They were then blended into a slurry with a PowerGen 700 homogenizer for 30 s. The homogenized fruits were centrifuged at 5000×*g* for 15 min. The supernatant was used for determination of pH, °Brix, and titratable acidity. Titratable acidity of 5.0-mL aliquots was determined as malic acid by titration with 0.1 M NaOH. Soluble solids were determined with a hand-held temperature-compensated refractometer.

Determination of Tristimulus Lightness (*L), Chroma (*C*), and Hue (*H*).** Fruit pieces were homogenized for 30 s using a PowerGen 700 homogenizer and transferred into a beaker. Homogenization was done to measure changes in color at the cut fruit surface and within the fruit slices. Tristimulus *L**, *a**, and *b** values were immediately recorded with a HunterLab DP-9000 colorimeter. Changes in *L** (ΔL), chroma (ΔC), and hue (ΔH) from freshly processed cantaloupe with storage time were determined. Chroma values were calculated as $(a^{*2} + b^{*2})^{1/2}$. ΔH was determined as $(\Delta e^2 - \Delta L^{*2} - \Delta C^2)^{1/2}$, where *e* is the total color difference. Δe was calculated as $(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$ (CIE, 1978).

Organic Acid Analysis. Dried fruits (0.1 g) were suspended in acetic acid solution (pH 2.5; 1.5 mL) and vortexed for 30 s. (Wicks and Kliewer, 1983; Lamikanra et al., 1995). These were kept at 4 °C for 12 h. After a second agitation, they were centrifuged at 4 °C and 12 000*g* for 20 min. The supernatant was filtered through a membrane filter (0.45-μ). The resulting solution was lyophilized and redissolved in H_2SO_4 (0.1 M). Organic acid contents of the solution were analyzed on an ISCO HPLC system interfaced with an HP 3394 integrator. The system was equipped with an Interaction Ion 300; 250-nm × 4-mm i.d. column and an LDC Spectromonitor II UV monitor. The acids were monitored at 213 nm. Isocratic elution was performed using 0.1M H_2SO_4 solution at a flow rate of 0.4 mL/min. Identification and quantitation were done by comparison of sample peaks with those of external standards.

Determination of Sugars. Samples were treated as described for the organic acid analysis. Instead of redissolving the lyophilized supernatant in H_2SO_4, it was dissolved in the same volume of NaOH (100 mM). HPLC determination of sugars present in the supernatant was performed on an Applied Biosystems Inc. Spectroflow 400 pumping system. A diode-pulsed amperometric detector (PAD-2) with a gold working electrode utilizing cyclic voltametry was employed. Isocratic elution was carried out with NaOH (100 mM) at a flow rate of 0.5 mL/min on a Dionex Ion Pac column. Injections were made with a Rheodyne 7125 manual injector and 20-μL fixed loop. A repeated sequence of three applied potentials (E1 (0.07v), E2 (0.60v), and E3 (−0.80v)) for specific durations (t1(2 ms), t2(2 ms), and t3 (5 ms)) provided measurable current from carbohydrate oxidation simulations to gold oxide reduction to maintain a clean gold electrode. Identification and determination of sugar concentrations were carried out by comparing their retention times and concentrations with standards.

Free Amino Acid Analysis. Dried fruit samples (0.1 g) were dissolved in a mixture (1.5 mL) of methanol, chloroform, and water (60:25:12) and stirred for 1h (Lamikanra and Kassa, 1999). The resulting mixture was centrifuged at 15 000*g* for 20 min. The residue was allowed to dry overnight in a hood and then dissolved in citrate borate buffer (10 mL; pH 2.2) and centrifuged at 8000*g* for 10 min. Sulfosalicylic acid (50% w/v; 1 mL) was added to the supernatant (4 mL). The mixture was then centrifuged for 20 min. at 50 000*g*. Polyvinylpyrrolidone (2%; 4 mL) was added to the supernatant and recentrifuged at 20 000*g* for 20 min. The resulting supernatant (7 mL) was lyophilized and resuspended in Milli-Q purified water (3.5 mL; Millipore Corp. Milford, MA). The mixture (100 μL) was passed through a 5000-mw Millipore filter). To this was added a mixture (100 μL) of ethanol, trimethylamine, and water (2:2:1), and the resulting mixture was dried. Phenylisothiocyanate (PITC) derivatization of amino acids was done by the addition of ethanol/triethylamine/water/phenylisothiocyanate (7:1:1:1; 40 μL) to the residue and allowing the mixture to sit at room temperature for 20 min. The derivative was then added to buffer A (sodium acetate (pH 6.4; 140 mM) with triethlyamine (0.5 mL) added) and used for HPLC analysis.

Samples were analyzed on a Waters HPLC system with gradient controller model 680, pump model M6000, and the MAXIMA software. The solvent system consisted of sodium acetate buffer (buffer A) and a mixture of acetonitrile and water (3:2; solvent B). Samples (20 μL) were injected on to the Waters physiological fluids column (3.9 × 300 mm). The initial solvent mixture used for elution was 89% buffer A and 11% solvent B. A 20 min. gradient to 52%B was followed by a 29 min. gradient to 85%B using gradient curve 6 in both cases. Peak detection and quantitation by UV at 254 nm were confirmed by the use of external standards (Amino Acid H; Pierce, Rockford, IL).

Determination of Microbial Activities. Total microbial counts were carried out aerobically. Although the presence of molds was also recorded, emphasis was on the occurrence of bacterial populations. Nutrient agar (Difco, Detroit, MI) was prepared and used for microbial enumeration. At different day intervals, three melon cubes were sampled from each pre-cut melon stored at 4, 10, and 20 °C. Using sterile technique, a melon cube ranging from 10 to 20 g was finely ground by mortar and pestle with 10 mL of sterile water. The homogenate was evenly suspended into 190 mL of sterile water by swirling. After a series dilution, 0.1 mL of melon suspension was overlaid on the surface of a Nutrient agar plate. Duplication was made for each dilution. Bacterial colonies were counted after 48 h of incubation at 30 °C. Colony forming units (CFUs) per gram of melon werecalculated. To further characterize the

Table 1. Changes in pH, Total Acidity (g/100 mL), and Soluble Solids in Minimally Processed Cantaloupe with Storage at 20 °C and 4 °C[a]

day	pH	acidity	°Brix
	20 °C		
0	6.58A	0.21E	9.03A
1	6.61A	0.25E	9.07A
2	5.99B	0.44D	6.60B
3	5.25	0.83C	5.80B
5	4.60D	1.61B	4.74C
	4 °C		
0	6.47A	0.21A	8.53A
1	6.42A	0.20A	8.60A
2	6.51A	0.18A	8.00A
3	6.51A	0.26A	7.87A
5	6.55A	0.22A	7.73A
14	6.30A	0.19A	7.37A

[a] Values in the same column without the same letters are significantly different ($P<0.1$; $n = 3$).

Table 2. Changes in Sugars in Minimally Processed Cantaloupe (μmol/100 g of fruit) with Storage at 20 °C and 4 °C[a]

day	glucose	fructose	sucrose	total
		20 °C		
0	38.6A	23.2B	15.8B	77.7B
1	37.6A	33.8A	21.4A	93.0A
2	28.4B	20.1B	12.6CB	61.2C
3	18.2C	13.4C	9.61C	41.3D
5	1.80D	3.75D	1.28D	6.84E
		4 °C		
0	39.0A	32.7A	16.2A	88.0A
1	42.4A	32.9A	19.0A	94.4A
2	36.6A	30.0A	18.7A	85.4A
3	36.6A	27.4A	18.6A	82.7A
5	36.2A	25.6A	18.7A	80.6A
14	35.3A	29.3A	16.6A	81.3A

[a] Values in the same column without the same letters are significantly different ($P<0.1$; $n = 3$).

isolated bacteria, Gram stain was performed on selected colonies from different sources.

RESULTS AND DISCUSSION

The average pH, total acidity, and °Brix for the fresh-cut fruit were 6.5, 0.225 g/100 mL, and 8.8 respectively (Table 1). At 4 °C, these values did not change significantly over a period of two weeks. Portela and Cantwell (1999) also demonstrated the stable levels in pH and soluble solids with low-temperature storage of fresh-cut cantaloupe. A 17% reduction in soluble solid content and a 2-fold increase in total acidity occurred after 2 days of storage at 20 °C. Glucose, fructose, and sucrose were the sugars identified in the cantaloupe samples (Table 2). Sugar contents of the fruits decreased with storage time at 20 °C, but significant changes did not occur at the lower temperature.

Citric acid appears to be present in all melons of the species *Cucumis melo* L. (Prat, 1971, Wang et al., 1996). The presence and amounts of other acids, such as malic, succinic, malonic, formic, glycolic, and oxalic acids, vary. Organic acids identified in this study for the freshly cut cantaloupe are oxalic, citric, malic, and succinic acids (Table 3). Citric and malic acids were the dominant acids, occurring at concentrations of 3.8 and 6.3 μm/100 g of fresh fruit, whereas oxalic and succinic acids were found at concentrations of 0.06 and 0.56 μm/100 g of fruit, respectively. Consistent with the trend observed for pH and total acidity of fruits stored at 4 °C, their organic acid contents did not change much during storage. Malic acid content of fruits stored at 20 °C decreased with time with a concurrent formation of lactic acid. Lactic acid was increased from being absent in the fresh fruit to a concentration of about 1.7 μm/100 g after the first day of storage at this temperature. Small quantities of malonic acid and traces of tartaric acid were detected after 3 and 5 days of storage, respectively. Lactic acid was by far the dominant acid present after 2 days of storage at this temperature. The observed decrease in pH and increase in acidity with storage obviously results from the production of lactic acid. The concurrent loss of malic acid during the production of lactic acid is indicative of a synthetic pathway similar to that of the malo-lactic fermentation by lactic acid bacteria (Vine et al., 1997). An ecological study by Salama et al., (1995) indicates that cantaloupes may be contaminated by *Lactococcus lactis* ssp. *lactis* from the field prior to harvest. *Lactococcus lactis* ssp. *lactis* was also identified as the dominant microflora present in minimally processed fruits and vegetables during the period they are intended to be eaten (Kelly et al., 1998; Heard, 1999). All strains ferment glucose and fructose, and most strains ferment sucrose. The loss in soluble solids with storage time at 20 °C is indicative of the utilization of sugar as nutrient during sugar fermentation, bacterial growth, and the production of lactic acid.

Morphological flora of microbial growth on plates indicated the prevalence of bacteria with minimal fungal growth at both temperatures. An increase in microbial population from 1.05 to 132.3 CFU/g occurred within 24 h of storage at 20 °C (Figure 1). At 4 °C, there was an induction period of about 5 days before a more rapid bacterial growth occurred. Bacterial growth at this temperature did not result in as much loss of the sugars as the growth at the higher temperature. Microscopic examination indicated Gram-negative stained rods for cantaloupe stored at 4 °C, but the flora were Gram-positive in fruits stored at 20 °C. At 10 °C, the induction period for Gram-negative bacterial growth was reduced to 1 day. This observation is consistent with the transition from Gram-negative to Gram-positive bacteria that occurs in vegetable salads with increase in storage temperature (Manvell and Ackland, 1986; King and Bolin, 1989). The ability of lactic acid bacteria to multiply on minimally processed fruits and vegetables is dependent on temperature and the medium of growth (Nguyen-the and Carlin, 1994). The potential use of the presence and amount of this mesophilic microflora for determining temperature abuse in vegetable salads and for predicting shelf life was demonstrated by Manvell and Ackland (1986), and Garcia-Gimeno and Zurera-Cosano (1997). O'Connor-Shaw et al., (1994) reported a decrease in *Lactobacilli* population in fresh-cut pineapple from 9×10^4 to 6.3×10^3 CFU/g after storage at 4 °C for 11 days and an increase to 6.8×10^5 CFU/g after storage at 20 °C for 4 days. Fresh-cut cantaloupe *Lactobacilli* population was also reported to increase from 3.3×10^4 to 3.6×10^6 CFU/g after storage at 4 °C. Portella et al., (1997) indicated the presence of 4.0×10^7 *Lactobaccilli*/g in fresh-cut cantaloupe stored at 5 °C for 12 days. When stored under controlled atmosphere at varying concentrations of O_2 and CO_2 (1.5−3% O_2 and 7.7−15% CO_2) the *Lactobacilli* concentration decreased. *Lactobacilli* were identified in both studies based on plate counts on *Lactobacilli* agar. Our results

Table 3. Changes in Organic Acid Contents of Cantaloupe (μmol/100 g of Fruit) with Storage at 20 °C and 4 °C[a]

20 °C					4 °C				
day	oxalic	citric	tartaric	malic	day	oxalic	citric	tartaric	malic
0	0.05C	3.22A	0C	6.22A	0	0.06A	4.45A	0	6.05A
1	0.03C	3.37A	0C	3.46B	1	0.08A	3.75A	0	7.11A
2	0.07BC	2.53BA	0C	2.20CB	2	0.06A	4.84A	0	5.86A
3	0.09BC	3.11A	0C	1.38CD	3	0.07A	3.02A	0	5.57A
5	0.13BA	2.70BA	0.04B	0.47D	5	0.07A	4.93A	0	5.35A
					14	0.07A	3.79A	0	5.07A
day	malonic	succinic	lactic	total	day	malonic	succinic	lactic	total
0	0B	0.37BA	0E	9.87E	0	0	0.83A	0	11.4A
1	0B	0.22B	1.65ED	8.75E	1	0	0.80A	0	11.7A
2	0B	0.30BA	7.65D	12.8ED	2	0	0.77A	0	11.6A
3	0.07B	0.26B	19.4C	24.4C	3	0	0.77A	0	9.21A
5	0.68A	0.31BA	34.3B	38.7B	5	0	0.54A	0	11.2A
					14	0	0.50A	0	9.45A

[a] Values in the same column without the same letters are significantly different ($P<0.1$; $n = 3$)

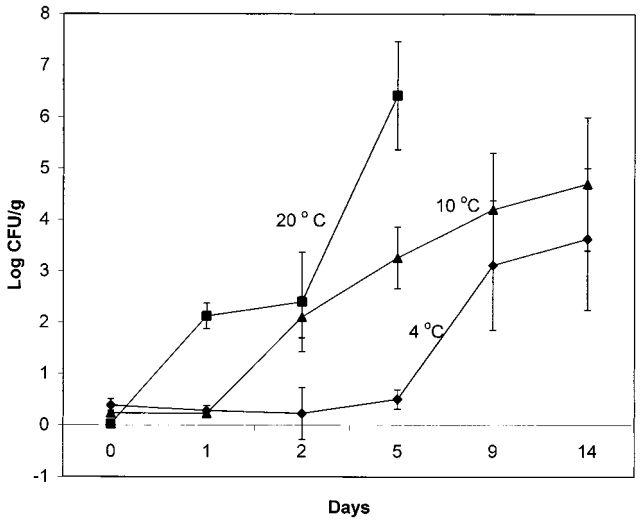

Figure 1. Microbial growth during storage of minimally processed cantaloupe melon at 4 °C and 20 °C.

indicate the absence of *Lactobacilli* at 4 °C as evidenced by the absence of Gram positive bacteria and lactic acid, even after prolonged storage at this temperature. The sanitation procedure and the use of a laminar flow hood for all our processing and sampling might have been more effective in preventing contamination by this bacteria during processing and storage. In commercial fresh-cut processing and storage, however, contamination during processing, and the higher temperatures to which fresh-cut fruits may be subjected, would increase the likelihood of lactic acid bacteria multiplication. The ability of this microorganism to alter food flavor is well-known (Olson, 1990; Hansen and Hansen, 1994; Scott and Swaffield, 1998). A possible pathway of fruit flavor deterioration by lactic acid bacteria is by way of an increased lipase production (Chandler and Ranganathon, 1975; Meyers et al., 1996). The delicate balance of flavors in fruits could be more severely affected by the growth of *Lactobacilli* than vegetables, and this might contribute to the relatively rapid flavor loss in minimally processed fruits. Proper sanitation during fresh-cut processing and effective temperature control should be effective in minimizing the growth of these bacteria. A reduction of mesophilic flora in fresh-cut cantaloupe would result in the dominance of the relatively slow growing Gram-negative pseudomonad flora after prolonged storage. These are more sensitive to CO_2, and the use of controlled atmosphere to extend shelf life of fresh-cut fruits (O'Connor-Shaw et al., 1996; Ayhan and Chism, 1998; Portela et al., 1997) would be more effective at low temperatures. Sapers and Simons (1998) demonstrated the effectiveness of Cl_2 wash and H_2O_2 in reducing the fluorescent pseudomonads in fresh-cut cantaloupe.

Eighteen amino acids were present in the fruits: aspartic acid, glutamic acid, asparagine, serine, glutamine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, isoleucine, leucine, phenylalanine, and lysine (Table 4). Small quantities of cysteine appeared in cantaloupe that was stored at 20 °C after 5 days. The dominant amino acids at the time the fruits were processed were aspartic acid, glutamic acid, arginine, and alanine. The observed trends in amino acid content during storage at both temperatures were similar to those of other parameters that were determined. With the exception of the slight decreases in a few amino acids such as glutamic acid and arginine in fruits stored at 4 °C, amino acid content essentially remained the same over a period of about two weeks. A number of amino acids decreased significantly in fruits stored at 20 °C. Total amino acid content of the fruit was reduced by about 40% after 2 days of storage at this temperature. The most significant losses during the first 2 days were aspartic acid, glutamic acid, asparagine, and glutamine. Many of the other amino acids, including arginine, histidine, proline, and phenylalanine also decreased with storage time at this temperature.

Amino acids are normally involved in physiological and biochemical processes that could take place as a result of fresh-cut produce processing and storage. Some of these are their utilization as nutrients in bacterial growth, formation of other compounds, and catabolic degradation (Loubiere et al., 1997; Singh and Chohan, 1979). Any, or a combination, of these could be responsible for the trend observed. These changes will, however, have significant impacts on flavor. Amino acids contribute to fruit flavor quality directly by their taste, taste enhancing capability, and buffering effects (Kato et al., 1989; Wyllie et al., 1995; Wang et al., 1996). A very large portion of compounds that constitute the total melon aroma profile also contain structural elements which could be derived from valine, isoleucine, methionine, and alanine (Wyllie, 1995).

The most notable changes in color are the rapid increase in lightness (ΔL^*) for fruits stored at 20 °C and the slight drop in chroma (ΔC) for fruits stored at the

Table 4. Changes in Amino Acid Contents of Cantaloupe (pmol/100 g of Fruit) with Storage at 20 °C and 4 °C[a]

20 °C					4 °C				
day	asp. acid	glut. acid	asparagine	serine	day	asp. acid	glut. acid	asparagine	serine
0	22.0A	24.3A	0.96A	5.39A	0	22.1A	8.60A	0.82A	3.65A
1	18.7BA	8.65B	0.55B	3.26BA	1	24.0A	5.97BA	0.79A	3.44A
2	16B	6.37B	0.54B	4.05BA	2	23.1A	4.34B	0.74A	3.40A
3	14.2B	6.28B	0.54B	4.4BA	3	24.8A	4.33B	0.68A	2.59A
5	6.52C	5.37B	0.39B	3.47BA	5	24.5A	3.56B	0.72A	3.34A
					14	21.6A	3.26B	0.58A	3.09A
day	glutamine	glycine	histidine	arginine	day	glutamine	glycine	histidine	arginine
0	4.51A	4.98A	3.02A	19.5A	0	2.56BA	3.51A	2.41A	20.0A
1	4.04A	3.59B	2.12B	17.2BA	1	2.61BA	3.23A	2.52A	18.2BA
2	0.77B	2.74CB	1.68B	16.0BA	2	3.79A	3.76A	1.94BA	15.9BA
3	0.78B	2.89CB	1.97B	13.9BAC	3	2.93BA	2.94A	2.04BA	13.3B
5	0.50B	1.97CD	1.36B	9.17BC	5	2.33B	3.00A	2.17BA	17.7BA
					14	0.80C	2.09B	1.04B	13.1B
day	threonine	alanine	proline	tyrosine	day	threonine	alanine	proline	tyrosine
0	2.40A	29.8BA	4.22A	3.50A	0	2.09A	16.5A	5.17A	2.88A
1	1.95A	39.4A	2.99B	2.46B	1	2.14A	21.2A	4.86A	2.72BA
2	2.18A	21.6BC	2.73B	2.46B	2	1.72A	23.9A	4.64A	2.29BA
3	3.44A	23.3BC	2.41CB	1.61CB	3	1.93A	22.3A	3.88A	2.34BA
5	3.82A	21.2BC	2.40CB	2.13CB	5	1.70A	26.9A	4.30A	2.54BA
					14	1.77A	18.2A	3.79A	1.87B
day	valine	methionine	cystien	isoleucine	day	valine	methionine	cystien	isoleucine
0	5.47A	1.46A	0C	1.48A	0	3.12A	0.85A	0.08A	1.10A
1	4.43BA	1.26A	0.18BC	0.92A	1	3.21A	1.01A	0A	1.05A
2	3.12BC	1.37A	0C	0.88A	2	3.50A	0.89A	0A	1.08A
3	3.25BC	1.16A	0.26BA	1.01A	3	3.28A	0.86A	0A	0.94BA
5	3.18BC	1.46A	0.47A	1.58A	5	2.97BA	1.04A	0.05A	1.12A
					14	1.53B	0.95A	0A	0.71B
day	leucine	phenyl. al	lysine	total	day	leucine	phenyl. al	lysine	total
0	1.56BA	3.12A	0.21B	138.A	0	1.37A	2.09A	0.13A	99.1A
1	1.00B	2.29BA	0.10B	115.A	1	1.29A	1.82BA	0.12A	100.A
2	1.24BA	1.22B	0.25B	85.3B	2	1.25A	1.2C	0.16A	97.7A
3	1.67BA	1.94BA	0.62A	85.8B	3	1.06A	1.95BA	0.13A	92.5A
5	2.52A	1.37B	0.83A	69.8CB	5	1.34A	2.09A	0.11A	101.A
					14	0.95A	1.38BC	0.11A	77.0A

[a] Values in each column without the same letters are significantly different ($P<0.1$; $n = 3$).

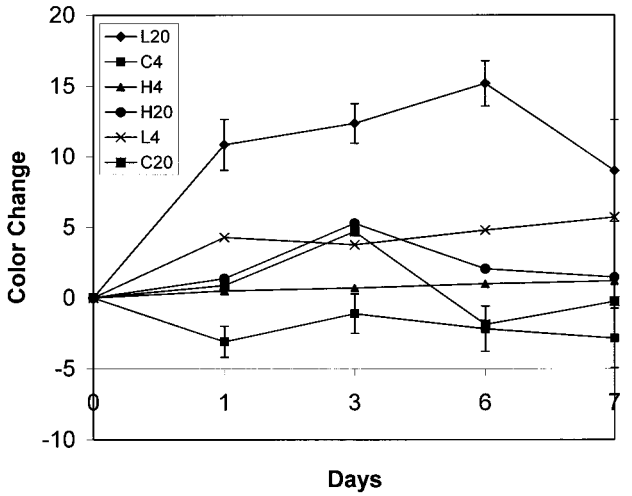

Figure 2. Color changes relative to freshly processed cantaloupe melons with storage at 4 °C and 20 °C. L20, C20, and H20 are changes in lightness (ΔL^*), **c**hroma (ΔC), and hue (ΔH) with storage at 20 °C, and L4, C4, and H4 are corresponding changes with storage at 4 °C.

lower temperature (Figure 2). The increase in L^* values with storage time suggests that browning reactions did not take place during storage of the fruit pieces. This is further indicated by the minor changes that occurred in the reflectance values (ΔC and ΔH) at both temperatures. Visually observed discoloration in the fruit pieces is consistent with absence of browning, and appears to be the result of disruption of tissue and cell wall structure. Similar changes in color were observed in fresh-cut cantaloupe on display at some supermarkets. The absence of polyphenol oxidase (PPO) induced darkening could result from the absence of these enzymes and/or oxidizable phenols in the fruit. Little work has been done on the enzymology of cantaloupe, but there is indication that they might have some amounts of PPO enzymes (Pratt, 1971). In a recent study (Lamikanra and Watson, 2000), storage of fresh-cut cantaloupe at 4 °C for 25 days resulted in considerable changes in hue, chroma, and L^* values. The bleaching of cantaloupe observed was attributed to the oxidation of β-carotene. There appears to be no report on the nature of phenolic compounds in cantaloupe melons.

CONCLUSION

Storage temperature has a considerable effect on biochemical changes occurring during processing and storage of minimally processed cantaloupe. At low temperatures (and with proper sanitation), biochemical compounds such as sugars, amino acids, and organic acids that are important to the quality of minimally processed fresh fruits are more stable. Storage temper-

ature also appears to influence the biochemical pathway of product deterioration. The nature and rate of microorganism growth are also temperature dependent. Microbial and color changes that occur at lower temperatures are indicative of physiological andbiochemical activity. Some of these reactions might be related to enzymes and other organic compounds that become more reactive because of the reduction in cellular compartmentalization that occurs in fresh-cut processing. The production of lactic acid in fresh-cut cantaloupe appears to be related to temperature abuse during handling and storage. Research on the effect of minimal fruit processing on enzymes that affect fruit quality and on the possible use of the production of lactic acid or lactic acid bacteria as fresh-cut fruit product quality markers is needed.

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