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Note

Quality Changes in Carrot Slices, Sticks and Shreds Stored at Various Temperatures

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Quality changes in carrot slices, sticks, and shreds were not similar during storage at 0°, 5° and 10°C. The surface area per gram of tissue, respiration rate, and weight loss were greater with shreds than with slices or sticks. The total microbial count increased on all cuts during storage and the greatest increase was on shreds. Shear force of the sticks was greater than that of slices and shreds throughout storage. Chroma values for all types of cuts generally decreased during storage. These results indicate that carrot shreds quality cannot be maintained as well as that of slices and sticks during low temperature storage.

Keywords: carrots, fresh-cut, respiration rate, weight loss, microbial count, shear force, color

Quality of fresh-cut carrots has been reported to be poorer than that of intact roots. Carrot slices have been shown to have higher respiration rates and microbial counts and poorer appearance and flavor quality than that of intact roots after 10 days storage at 4.4°C (Priepke *et al.*, 1976). Carlin *et al.* (1989) reported that carrot shreds stored at 10°C produced off-flavors associated with lactic acid bacteria. Carrot sticks stored for 25 days at 2°C scored lower in quality by a taste panel when compared with freshly cut sticks that were prepared from roots stored for the same period at the temperature (Bruemmer, 1988). Abe *et al.* (1993) indicated that carrots cut lengthwise had a higher respiration rate and greater decay than those cut crosswise. Although the fresh-cut carrots are more perishable than the whole roots, it is not well-known if the different cuts of carrots behave similarly during storage.

We report here the behavior of carrot slices, sticks, and shreds during storage at 0°, 5°, and 10°C. These temperatures were selected because although 0°C is the recommended storage temperature, fresh cut carrots are held at higher temperatures. Attributes measured included respiration, microbial population, weight loss, shear force, and color.

Materials and Methods

Carrots (*Daucus carota*) were washed, peeled, trimmed of root tip and stem plate, and cut as slices (20–40 mm dia., 5 mm thick, and 3.0±0.1 g), sticks (ca. 5 mm wide, 50 mm long, 4 mm thick, and 1.0±0.02 g) and shreds (ca. 4 mm wide, 50 mm long, 2 mm thick, and 0.3±0.01 g) using a food processor (Model DLC-10, Cuisinart, East Windsor, NJ). The surface area per gram of tissue, determined with a caliper, was the greatest ($p \leq 0.01$) in shreds (17.4 cm^2), followed by sticks (9.4 cm^2) and then slices (5.9 cm^2). Each cut was rinsed for 2 min with distilled water and the slices, sticks, and shreds were then centrifuged at 580 rpm for 2, 1.5, and 0.5 min, respectively. A 100-g sample of each cut was placed in a 2-*l* closed glass jar for respiration measurement and in a 1-*l* plastic tray for physical and microbial measurements. Three plastic trays were inserted in a closed polyethylene bag. Distilled water was placed in the jar and polyethylene bag to keep the relative humidity greater than 90%. Humidified air was metered through the jar and polyethylene bag at a sufficient rate to keep the CO_2 concentration below 0.5%.

Carbon dioxide contents of the inlet and outlet streams of each jar were measured every 8 h with a carbon dioxide analyzer (Model CA-3A. Ametek, Paoli, PA).

Subsamples from each plastic tray were removed at scheduled days, based on regular intervals during storage, for analysis of total microbial population, weight, shear force, and color. The total microbial count on the surface of 10 g of tissues was determined and expressed as $\log_{10}$ count per g sample as previously described (Izumi & Watada, 1994). Shear force was based on the force in newtons (N) required to shear a 40-g sample. The surface color of 10 carrot samples, in which each sample consisted of a slice, 4 sticks, or 5 g of shreds, was measured with a chromameter (Model CR-300, Minolta, Ramsey, NJ). The L^*, a^*, and b^* readings were recorded and the results were expressed as the L^* value and Chroma $C^*=(a^{*2}+b^{*2})^{0.5}$.

Duncan's multiple range test was used to separate the means of the surface area ($p \leq 0.01$) and respiration ($p \leq 0.05$) data. Statistically significant differences ($p \leq 0.05$) among the types of cut carrots were determined for total microbial count, weight loss, shear force, and color data on each sampling day using an analysis of variance.

Results and Discussion

A typical wound-induced respiration occurred only for 12 to 24 h after cutting as already reported (Karl & Laties, 1989;

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Table 1. Average respiration rate of carrot slices, sticks, and shreds on day 1 and during storage for 20, 17, and 11 days at 0°, 5°, and 10°C, respectively.

Storage temp. (°C)	Type of cut	CO_2 production (mg/kg·h)	
		Day 1	During storage
0	Slices	9.1 b[a)]	5.1 b
	Sticks	7.8 b	13.1 a
	Shreds	12.7 a	11.7 a
5	Slices	21.7 b	13.2 c
	Sticks	19.3 b	20.2 b
	Shreds	30.3 a	24.6 a
10	Slices	55.0 b	25.6 b
	Sticks	48.2 b	50.8 a
	Shreds	82.9 a	48.3 a

[a)] Means separation within each temperature in the same column by Duncan's multiple range test, $p \leq 0.05$.

Abe *et al.*, 1993). The induced rate was greater with shreds than with slices or sticks (Table 1), probably because the shreds had more surface cells per gram of tissue exposed to injury than the other two cuts. The average sustained rate was higher with shreds or sticks than with slices (Table 1), which may be due to differences in the anatomy of the cuts. Abe *et al.* (1993) reported that the respiration of xylem tissue was greater than that of phloem-cortex tissue. The shreds and sticks used in our study were cut longitudinally to the vascular bundle and the slices were cut transversely. This would result in more xylem tissue in the shreds or sticks than in the slices, and consequently, can account for the higher respiration rate.

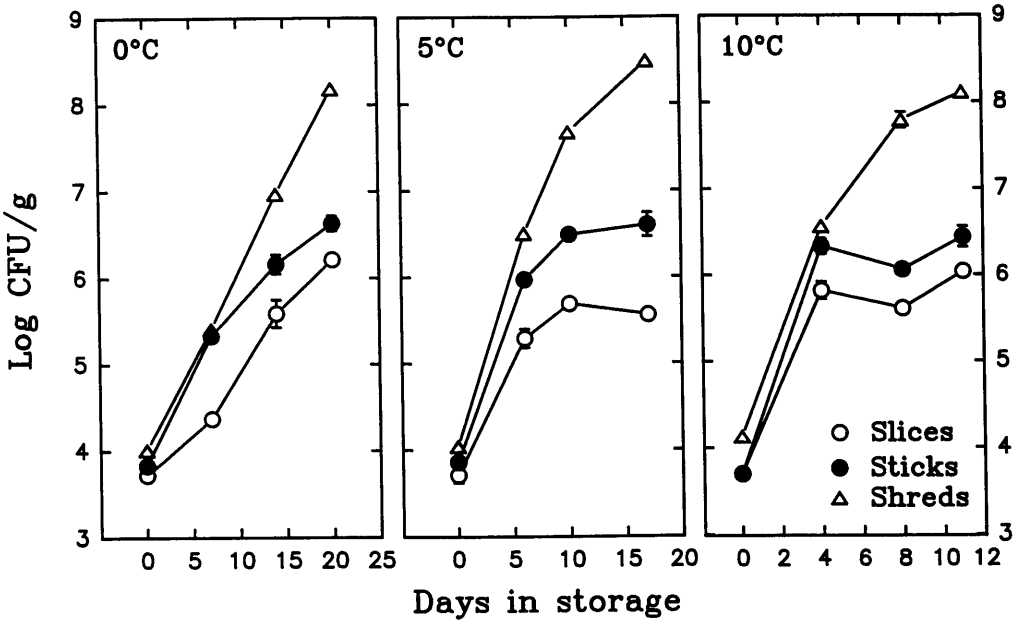

Fig. 1. Total microbial count on surface tissue of carrot slices, sticks, and shreds stored at 0, 5, and 10°C. Points are means of three replicates±SE. Error bars not shown when smaller than the symbol.

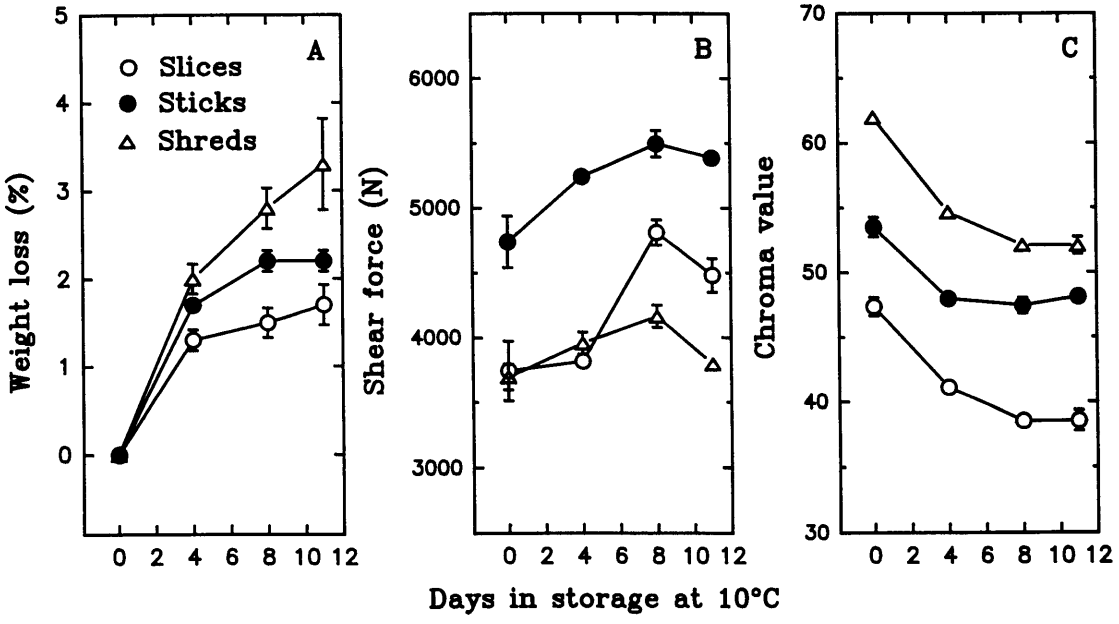

Fig. 2. Percentage weight loss (A), shear force (B), and chroma value (C) of carrot slices, sticks, and shreds stored at 10°C. Points are means of three replicates± SE. Error bars not shown when smaller than the symbol.

The microbial population of all cuts increased during storage and the increase was greater on shreds than on slices or sticks and greater at higher temperature (Fig. 1). The population on sticks and slices did not continue to increase after day 4 at 10°C and day 10 at 5°C. The total microbial count of shreds reached 10,000 times the initial count by the end of the storage period, while the count on sticks and slices reached 1,000 and 100 to 1,000 times the initial count, respectively. The increased microbial count on shreds can contribute to hastened deterioration of the tissue. Although Zhou *et al.* (1992) did not make a microbial count, they reported that fine shredded bell peppers deteriorated more rapidly than the larger cuts, the deterioration being relative to surface area and direction of cutting. Bolin *et al.* (1977) reported that the initial microbial load influenced the storage stability of shredded lettuce. The higher initial count on shreds than on slices or sticks in this study probably contributed to the continual and higher total microbial count on shreds than on the other two cuts.

All samples lost weight during storage and the rate of loss was greater at higher temperature (data not shown). The loss was continuous with shreds and was minimal, if any, after the second analysis with slices and sticks as shown for those at 10°C (Fig. 2A). This resulted in the greatest weight loss by the shreds and the least by the slices at 10° and 5°C, but not at 0°C, where the differences were not significant (data not shown).

Shear force of the cuts did not consistently change during storage and it increased with some samples rather than decreasing as shown for the samples at 10°C (Fig. 2B). The increase was thought to be due to the dehydration of the tissue, but it was not correlated with the amount of weight loss. The shear force of sticks was greater than that of slices or shreds.

The L^* values of all samples generally remained unchanged during storage (data not shown). The chroma value of all samples decreased from the beginning to the end of the storage period as shown for samples at 10°C (Fig. 2C). The decrease in chroma values were associated with fading of the orange color as visually noted (data not shown). The average chroma values were the highest with shreds and the lowest with slices, which may have been due to the differences in the area of the tissue that was measured.

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