Scanning Electron Microscopy of Carrot Stick Surface to Determine Cause of White Translucent Appearance

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ABSTRACT

Carrot sticks that were prepared with a sharp culinary knife exhibited a whitish translucent appearance on the surface. This condition was not readily apparent with carrot sticks sliced with a razor sharp blade. Scanning electron microscopic examination of the translucent tissue revealed that the knife tended to shear, separate and compress the cells and tissues of the root. Dehydration of the large mass of exposed cells probably was responsible for the appearance of the whitish translucent tissue. Development of this condition is undesirable because consumers associate this with aged or nonfresh carrot sticks.

INTRODUCTION

DEMAND for partially processed fruits and vegetables by institution dining rooms, restaurants and fast food franchise outlets has increased substantially. This has resulted in part from consumers' growing appetites for fresh fruits and vegetables, as evidenced by the popularity and growth in numbers of salad bars. To meet these demands without increasing cost of products, the food industry has mechanized many labor intensive operations such as peeling, slicing, coring etc. However, the success of such mechanizations in food preparation is dependent on maintaining fresh appearance and high quality.

Recently, the quality of partially processed carrot sticks has been questioned both by processors and venders. Carrot sticks, which are sold in grocery stores and are available on most salad bars, may be unsatisfactory or unacceptable because they sometimes exhibit a whitish translucent appearance on the surface. Consumers tend to associate this condition with aged or nonfresh carrot sticks. This has been observed in nonvacuum packaged carrots that were stored at 10° or 15°C for 2 to 4 days, but not in carrots that were stored 5 days at 4°C (Buick and Damoglou, 1987). The cause of the discoloration and the possible ways to alleviate the condition have not been reported.

Our objective was to determine whether there might be a physical cause for the effect. We examined the cut surface of carrot sticks visually, and the cells and tissues with scanning electron microscopy (SEM). The elemental content of the cut surface was also examined using an energy dispersive X-ray microanalysis (EDX) in an attempt to explain the appearance of the whitish tissue.

MATERIALS & METHODS

WHOLE CARROTS (cultivar unknown) packaged in ventilated polyethylene bags were purchased at a local produce market and stored in a waxed fiberboard container at 0°C until use. To prepare the sticks, carrots were washed, cut to 6 cm lengths, and quartered with a sharp culinary knife or a razor blade. Each quarter was placed in a separate lot with each lot containing 20 sticks. One lot of each prepared with a knife or blade was analyzed immediately. The remaining lots of 20 sticks each were placed in unsealed polyethylene bags (0.025 mm thickness) and stored at 5°C, 95% RH for subsequent daily analysis. The amount of whitish translucent tissue on the surface of each stick was scored using the following index: 1 = None: 2 = Slight; 3 = Moderate; 4 = Severe and; 5 = Extreme. A severity index for each lot was calculated by multiplying the index score by the percentage of sticks in each category.

For SEM observation, 1 × 1 × 0.5 cm sections of tissue were sampled from either the freshly prepared sticks, (referred to as "fresh"), or the 3-day stored sticks, (designated "aged"). Tissues were prepared as described for cucumbers (Tatsumi et al., 1987), with modifications. The tissue pieces were fixed in 3% glutaraldehyde in distilled water for 24 hr at room temperature (18–20°C) and dehydrated in a standard ethanol solution series (20, 40, 60, 80, 90, and 100%). The samples were critical-point dried from liquid carbon dioxide. The cut surface was sputter-coated with gold/palladium 60/40 and examined with a Hitachi S530 scanning electron microscope operated at 15 kV.

For EDX, samples were fixed, dehydrated, critical-point dried, mounted, carbon coated and examined at 20 kV in the SEM equipped with a Kevex 8000 EDX system. Samples were tilted 30° toward the X-ray detector. Analysis provided a qualitative and semi-quantitative elemental composition of an 8–10 mμ layer of surface tissue.

RESULTS & DISCUSSION

CARROT STICK that were cut with the culinary knife or the razor blade did not exhibit any visible translucent whitish tissue or discoloration on the day of slicing. Surfaces of sticks prepared with the blade, however, were visibly smoother than those cut with the knife. The whitish tissue, similar to that noted on grocery store products, developed on the surface during storage of the sticks that were cut with the knife. This discoloration was associated with a noticeable amount of loose or sloughing tissue. By day 1, (≈24hr after slicing) 65% of the sticks exhibited discoloration, resulting in a total severity index of 455 (Table 1). Those sticks also contained slight cracks along the cambium layer between the cortex and the vascular cylinder. By day 2, 90% of sticks scored a severity index of 490, near the maximum severity index. No increase in severity index was noted on day 3; however, the separation between the cortex and the vascular cylinder had widened and the sticks

Table 1—Relation between severity of white translucent tissue on surface of carrot sticks and method of slicing or storage

Slicing tool	Severity score[z]	Days at 5°C: 1 %[y]	1 S.I.	2 %	2 S.I.	3 %	3 S.I.
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
Knife	3	10	30	0	0	0	0
	4	25	100	10	40	10	40
	5	65	325	90	450	90	450
Total		100	455	100	490	100	490
	1	55	55	50	50	35	35
	2	45	90	50	100	50	100
Razor blade	3	0	0	0	0	15	45
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
Total		100	145	100	150	100	175

[z] 1-None, 2-Slight, 3-Moderate, 4-Severe, 5-Extreme.
[y] Percentage of 20 carrot stick sample.
[x] Severity Index (S.I.) = Score of severity × %.

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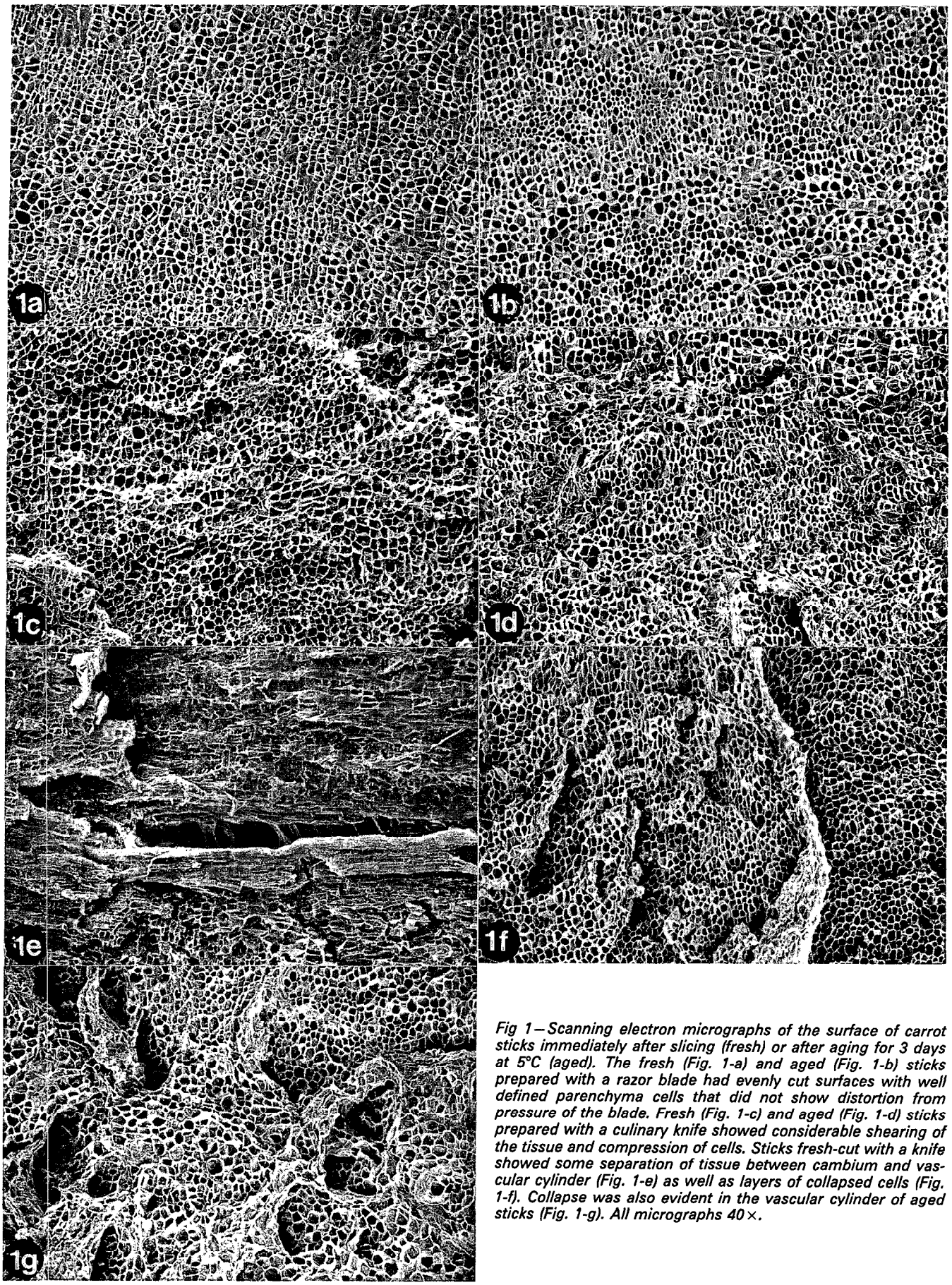

Fig 1—Scanning electron micrographs of the surface of carrot sticks immediately after slicing (fresh) or after aging for 3 days at 5°C (aged). The fresh (Fig. 1-a) and aged (Fig. 1-b) sticks prepared with a razor blade had evenly cut surfaces with well defined parenchyma cells that did not show distortion from pressure of the blade. Fresh (Fig. 1-c) and aged (Fig. 1-d) sticks prepared with a culinary knife showed considerable shearing of the tissue and compression of cells. Sticks fresh-cut with a knife showed some separation of tissue between cambium and vascular cylinder (Fig. 1-e) as well as layers of collapsed cells (Fig. 1-f). Collapse was also evident in the vascular cylinder of aged sticks (Fig. 1-g). All micrographs 40×.

became curved along the longitudinal axes, a condition similar to that noted with carrot sticks from the grocery store.

About 55% of the sticks that had been cut with the razor blade exhibited some loose tissue on day 1. This resulted in a

severity index of 145, only one-third that scored for knife-prepared sticks. The amount of loose tissue increased slightly each day resulting in 15% of the sticks having a severity index of 175 by day 3. However, the sticks did not exhibit any tissue separation along the cambial layer or longitudinal curving.

SEM examination of the surface of the fresh tissue prepared with a razor blade revealed that the cortical region appeared evenly cut, was not compressed and consisted of well organized parenchyma cells which did not show mechanical damage (Fig. 1a). The appearance of the cortical region and the organization of the cells remained unchanged during subsequent aging (Fig. 1). However, the vascular cylinder, especially the xylem and pith, appeared to sustain some mechanical damage from the blade, which was not apparent to the naked eye (Micrograph not shown).

Fresh tissue prepared with the knife appeared visually similar to that prepared with the blade, but SEM examination revealed in the knife-cut samples a serrated surface characterized by tearing, shearing, and compression of cells and tissues (Fig. 1-c and d). Furthermore, cracks were present along the cambium that separated the outer cortical layer from the inner vascular cylinder (Fig. 1-e). These cracks were frequently associated with loose layers of sloughing cells. Such cracks and sloughing cells became more conspicuous as the knife-cut sticks aged (Fig. 1-d, f, and g).

Probably the loose layers of cells on the surface of the sticks resulted from mechanical damage of the knife and because those cells were severely damaged and separated from underlying tissue, they were highly susceptible to dehydration. Similarly, the cracks between the vascular cylinder and the cortex further exposed the inner surface tissues to water loss, which caused the cracks to increase in size and eventually become visible after 1 or 2 days in storage. As water loss from those tissues continued, the coloration of the surface changed from rich orange generally associated with healthy succulent tissue to white, which probably resulted from dehydration of cell walls and cytoplasm of damaged tissues.

The knife, although sharp, tended to shear and tear the tissue whereas the sharper razor blade cut cells cleanly as it passed through the root and did not cause significant damage to underlying tissues. As a result, only the single layer of cells that had been cleanly cut by the blade were susceptible to dehydration. Drying of a single layer of cells apparently was not sufficient to cause the carrot stick surface to have the whitish translucent appearance.

Ten elements were identified on the cut surface of carrot tissues by the energy dispersive X-ray microanalysis, and as reported by others, (Hopkins, 1959; Haytowitz and Matthews, 1984), K and Ca accounted for 70% of the total content (data not shown). The content of none of these elements differed between carrots sliced with a knife or razor blade (data not shown). This implied that these elements had no influence on the tissue surface changes.

We concluded that the abrasive action of the culinary knife caused considerable tearing and shearing of tissues. The resulting cells, which were compressed and sloughed, were highly susceptible to dehydration which in turn caused the white discoloration that was characteristic of the aged cells cut with the knife. No consistent relationship was apparent between changes in elemental composition on the surface of the slices and the preparation method or aging process. Results tend to support the hypothesis that the white discoloration resulted from dehydration rather than from chemical changes or elemental redistribution from underlying tissues.

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