Sodium Chloride Treatment or Waterjet Slicing Effects on White Tissue Development of Carrot Sticks

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ABSTRACT

Treatment of carrots with NaCl solution or slicing with a high pressure water jet stream was evaluated for reducing the amount of white tissue development on carrot stick surfaces. A 0.5 or 1.0M solution treatment resulted in less white tissue than treatment with lower concentrations of NaCl. However, the NaCl treatment caused a weight loss of 4–10% (not commercially acceptable). Water jet slicing resulted in striation of surface tissue and left loose layers of cells, as observed with the scanning electron microscope. These cells dehydrated rapidly and formed as much white tissue as on carrots sliced with a culinary knife.

Key Words: carrots, waterjet, salt wash, white tissue

INTRODUCTION

ACCEPTABILITY of carrot sticks in the grocery stores and salad bars is lessened when the sticks have a white translucent tissue on the surface. Such condition may cause consumers to perceive that the carrot sticks are aged and of low quality. We reported previously (Tatsumi et al., 1991) that this condition was caused by the slicing knife, which tears and shears layers of cells away from the tissue. These loose cells dehydrate rapidly, as noted with the scanning electron microscope (SEM). Bolin and Huxsoll (1991) reported that the surface discoloration of carrots peeled by abrasion was due to formation of a white lignin type material on the cut surface during storage. The development of the white or discolored tissues probably is due to a combination of physical and chemical reactions, and may be minimized by inhibiting either.

Based on our earlier findings with the SEM (Tatsumi et al., 1991), we had hypothesized that the less turgid or deflated cells would not have as much resistance to the force of a slicing knife as the turgid cells. With less resistance, the cells would be less likely to rupture or separate away from the tissue when subjected to the force of a knife and hence, less white tissue would develop. Turgidity of cells can be regulated or reduced by osmotic removal of water by salt treatment.

We showed that the amount of white tissue development was less with carrots sliced with a razor blade than with a knife (Tatsumi et al., 1991). In seeking an alternative means of slicing, the use of a high pressure water jet stream was considered since it had been patented for cutting vegetables (Orr and Spingler, 1988). The basic principle is that water is pumped at a very high pressure through a small orifice to produce a needle-like jet stream. In slicing potatoes with water jets (Becker and Gray, 1992), most of the cellular contents was washed from the cut surface as noted with SEM photomicrographs. Repeated washing of the surface continued to yield protein, which indicated damage to subsurface cells. Water jet slicing was utilized for removing stem ends from carrots (Posselius and Conklin, 1988), and with appropriate pressure and nozzle orifice, reportedly up to 20 tons of carrots could be cut in an hour.

Our objective was to determine any benefit and consequence of reducing turgidity with NaCl solutions and the shearing effect of a high pressure water jet stream in slicing carrots of different temperatures to minimize formation of white surface tissue.

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MATERIALS & METHODS

CARROTS were purchased from a local distribution center and stored in a ventilated polyethylene bag at 0°C until used. To reduce turgidity, 15 carrots were placed in NaCl solutions of 0, 0.3, 0.4, 0.5, or 1.0M concentration, for 20 hr at 5°C or 3 hr at 20°C. After the salt solution treatment, carrots were rinsed with water prior to slicing. The unpeeled carrots were sliced longitudinally into quarters with a razor blade and two sticks, 6 cm length, from each set of quarters were placed in unsealed polyethylene bags (0.025 mm thickness) and stored at 5°C, 95% RH for subsequent daily analysis.

An Ingersoll Rand Water Jet Cutting System was used. The system pumped water under 378,950 kPa pressure through a nozzle with orifice diameter 0.178 mm. Fifteen carrots, held at 0° or 20°C 24 hr prior to slicing, were fed longitudinally by hand through the jet stream and cut into quarters. A comparable set of carrots were also sliced with a culinary knife and razor blade.

The amount of white tissue on the surface of each stick was visually 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. Fresh weight loss was monitored with the NaCl treated sticks. The color was based on L^*, a^* and b^* readings of each sliced stick using a Gardner XL-800 Colorimeter. Surface tissues were prepared and observed with SEM as described previously (Tatsumi et al., 1991).

RESULTS

THE AMOUNT or severity of white tissue development on the carrot stick surface was less on sticks from carrots that had been treated with higher concentrations of NaCl solution (Fig. 1). Those treated in water (0.0M) had a severity index of almost 500 units after one day, and 500 units, the maximum severity, after two days storage. Roots treated with 0.3 and 0.4M solution had severity indexes of about 425 and 356 units, respectively, after two days, and increased slightly between days 2 and 5. Severity index of roots treated with 0.5M solution increased continually to about 250 units after five days. The severity index of roots treated with 1.0M solution was low even after five days storage. The surface of these carrots however, darkened during storage.

The NaCl solution treatment caused weight loss and the loss was greater at higher concentrations (Fig. 2). The weight loss ranged from 2.5 to 9% for samples treated with 0.5M solution and 5.5–10.5% for those treated with 1.0M solution. The regression equation for the loss was $Y = 0.69 + 8.37X$ with $r^2 = 0.82$. The relationship between severity index and weight loss was linear for samples that lost up to about 5% weight (Fig. 3). With weight loss above 5%, severity index was lower and similar among samples. The regression equation of the

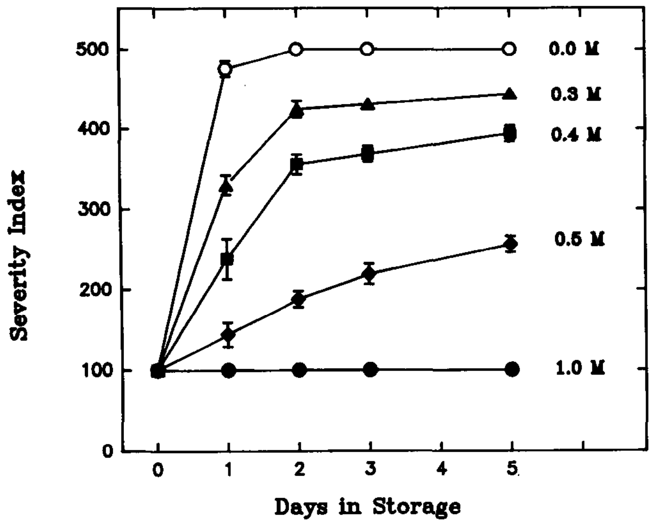

Fig. 1—Severity of white tissue development on carrot sticks pretreated with NaCl for 20 hr at 5°C. Severity index = severity score × percentage of roots with that score. Bars represent SE of the mean.

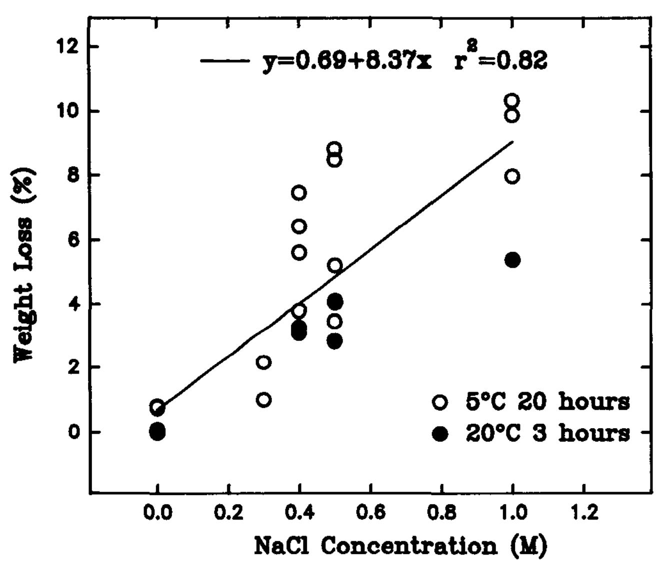

Fig. 2—Relationship of weight loss of carrots treated with NaCl to time and temperature.

relationship between weight loss and severity index was Y = 511 − 42.9X, with r^2 = 0.93.

Surfaces of carrot sticks cut with the water jet had visible striations or furrows. The surface white tissue was visible one day after slicing and was comparable to those sliced with a culinary knife, but not to those sliced with a razor blade. White tissue developed fairly rapidly on sticks sliced with the water jet or knife (Fig. 4). By day 3, the white tissue was quite severe, as noted by the severity index of 400–500. The rate and amount of white tissue development was similar with 0° or 20°C carrots. Those sliced with a razor blade developed minimal white tissue.

The Gardner L* values of carrot sticks gave the best indication of color changes, and changes in L* values with time were compared. The L* values changed more with carrots sliced with a water jet than those sliced with a knife or a blade, and the change was minimal with those sliced with the blade (Fig. 5). Most changes occurred within the first day or two as noted visually, but differences among treatments were not the same as noted visually as indicated by severity index scores.

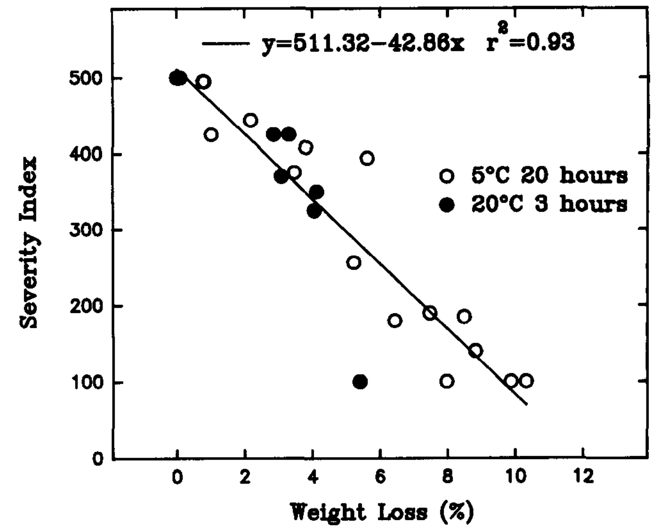

Fig. 3—Relationship between severity of white tissue development and weight loss due to pretreatment with NaCl.

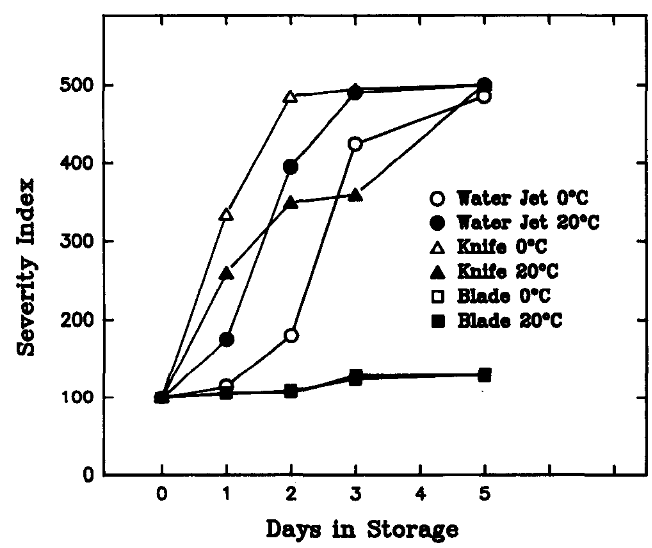

Fig. 4—Severity of white tissue on 0° or 20°C carrots sliced by different methods. Each point is the average of 10 carrot sticks.

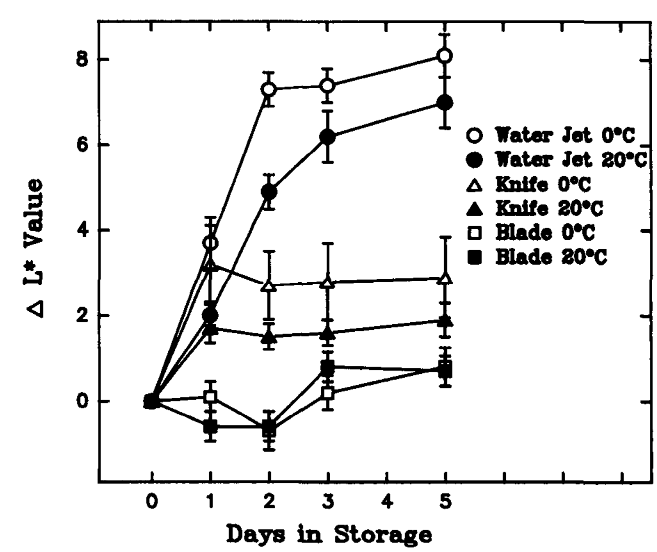

Fig. 5—Changes in the Gardner L values during storage of 5° or 20°C carrots sliced by different methods.*

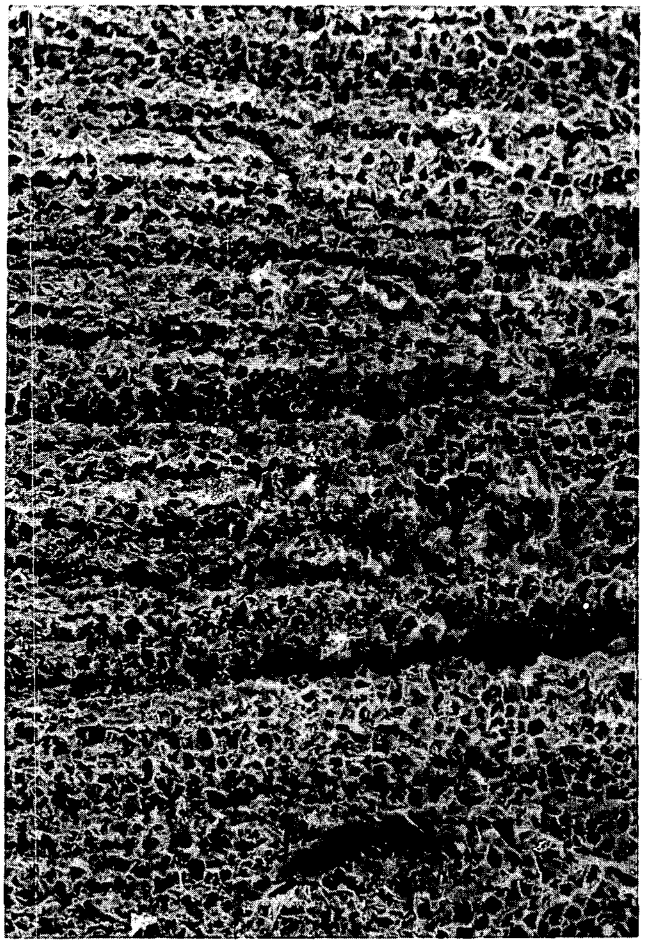

Fig. 6—Scanning electron micrograph of carrot surface sliced with high pressure water jet.

Changes in L* values were greater with 0°C roots than the 20°C roots, which was in contrast to effects noted with the severity index scores. The reason for differences between L* values and severity index scores is not known.

An SEM photomicrograph of striated tissue showed that, in addition to the striation, the water jet left layers of cells separated from the tissue and exposed to the air (Fig. 6). The combination of exposed layers of cells and increased surface area caused by striation enabled large masses of cells to dehydrate rapidly and form the white tissues on the surface.

DISCUSSION

TREATMENT of carrot roots with NaCl solution reduced the amount of white tissue formed on the surface of carrot sticks. The salt solution caused an osmotic movement of water out of the cells and concomitantly lowered cell turgidity. With reduced turgidity, the cells were not as susceptible to being cut or removed from adjacent cells by the knife as a turgid cell. Development of white tissue has been shown also to be due to lignin formation (Bolin and Huxsoll, 1991), and possibly the salt solution treatment had an inhibitory effect on enzymes involved in lignin synthesis.

However, the salt solution treatments caused a significant weight loss, which would not be acceptable in marketing of carrots. The carrots lost more than 7% weight before notable reduction of white tissue occurred and this weight loss would be excessive for a marketable product (Robinson et al., 1975). The 3–6% weight loss caused by the 0.4M solution resulted in unacceptable carrots. The benefit derived by NaCl treatment in reducing white tissue development was also not of value due to darkening of the surface caused by 1.0M NaCl solution.

The use of water jet technology for slicing carrots was tested based on a patent for slicing fruits and vegetables (Orr and Springler, 1988) and prolonged shelf life of pre-cut celery (Orr and Springler, 1987). Since the water washed the cellular contents from the surface of potatoes (Becker and Gray, 1992), we hypothesized that all loose layers of cells on the carrot surface would also be washed away. The SEM photomicrograph of carrot surface showed that the water jet caused striation similar to that reported with potatoes (Becker and Gray, 1992), but did not remove loose layers of cells. Consequently, with the increased surface area of exposed cells and retention of loose layers of cells, a large amount of white tissue developed as these cells dehydrated or lignified.

Becker and Gray (1992) indicated that damages incurred on potato tissue by the water jet could be regulated by adjusting the speed of cutting, pressure of water, and the size of nozzle orifice. In using orifice sizes from 0.076 to 0.584 mm, they found that orifice size was the most influential factor. The most effective cuts were obtained with the smallest orifice size, which was about 40% of the size (0.178 mm) we used. Speed of cutting can be controlled uniformly only when using a robotic system similar to that used for processing of poultry (Swientec, 1991). The loose layers of cells might have been avoided or eliminated by using a smaller orifice or adjusting cutting speed.

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