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Influence of pH treatment on pectic substances and firmness of blanched carrots

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The influence of blanching and the gradual reduction of pH within carrot tissue from 6·2 to 3·9 by acetic acid infiltration was studied. Maximum firmness of about 86 N was observed at pH 4·4, while at higher or lower pH firmness was about 58 N. Galacturonic acid content, and neutral sugars of the water-soluble pectic, EDTA and alkaline-soluble pectin fractions were assessed after the pH treatments. EDTA-soluble pectin increased after blanching at all pH values, but less so at pH 4·4. Total pectin decreased to a lesser extent at pH 4·4 than at either higher (6·2) or lower (3·9) pH values. Lower amounts of soluble pectin were found at pH 4·4 than in the control. A significant positive correlation was found between firmness and the alkali-soluble pectin content.

INTRODUCTION

The firmness of blanched vegetables is ultimately a function of the strength of the plant cell wall. When plant tissue is heat-treated during industrial blanching, changes in the structural constituents of the cell wall and intercellular tissue are observed. After blanching, the residual mechanical properties that survive after the loss of turgor depend on the structure, arrangement and chemical composition of the cell walls (Van Buren, 1979). Most investigators agree that the polysaccharides classified as pectic substances contribute significantly to the texture of fruits and vegetables (Jarvis, 1984). Pectins are among the main water-binding components of the plant cell wall, and the cohesion of the pectin gel is probably the critical factor in determining fruit texture (Williams & Knee, 1980). The degradation of the pectic substances (Doesberg, 1965; Plat *et al.*, 1988, 1991) could thus cause structural (textural) breakdown, resulting in variations in firmness and the liberation of bound water after blanching treatments. Sterling (1968) demonstrated that it was possible to strengthen the tissues of vegetables and fruits by bonding calcium ions to the free carboxyl groups of the galacturonic acid polymers to form a more rigid matrix in the middle lamella and primary cell wall.

The kinetics of thermal softening of sliced carrots after blanching was studied by Bourne (1987). Direct acidification followed by blanching was found to cause an increase in firmness of sliced carrots (Juliot *et al.*, 1989).

In our previous papers (Plat *et al.*, 1988, 1991), we showed that blanching carrot tissue caused massive changes in the water-soluble pectin and the EDTA-soluble pectin fractions, in the galacturonic acid content, in the degree of pectin esterification, and in the pectin neutral sugars composition. Consequently, we are now looking at the possibility of decreasing the degradation of pectin during the blanching of carrot tissue. *The objective* of the present study was to assess the effect of acidification following blanching on the major pectic substances and their relation to the firmness of the carrot tissue.

MATERIALS AND METHODS

Carrots, var. 'Chantenay Red Core', were obtained from the Deco dehydration plant in Israel. The carrots were hand-peeled and cut into cubes (8 × 8 × 8 mm^3). Batches of 0·5 kg were put in a glass tank under vacuum in 0·1 M acetic acid, at a 3:1 (v/w) ratio of solution to carrot cubes. The vacuum was applied for 1 min to obtain pH 4·4 in the carrots, and for 2 min to obtain pH 3·9, after which the carrot cubes were washed with distilled water for 5 s to remove excess acetic acid. The samples were steam-heated (blanched) for 4 min, the time found necessary to inactivate the pectin esterase (PE), and cooled by a fine spray of distilled water.

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The effects of blanching and pH on carrot quality characteristics were evaluated with the following experimental treatments:

(1) an untreated control;
(2) blanched but not acidified, pH equilibrated to 4·4 and blanched;
(3) and pH equilibrated to 3·9 and blanched.

Firmness of the tissue was measured before and after blanching. Five cubes (1 × 1 × 1 cm³ each) were compressed at the same time with an Instron TM 1026 to 50% of their height, at 5 cm/min velocity. The instrument was calibrated with a full-scale load of 50 kg. The force (in newtons) applied to compress the cubes was calculated at the peak of the compression curve. Data are expressed as the average of three separate compressions for each experimental treatment. The linear correlation between the firmness, blanching and pectin content (r = correlation coefficient; p = significance of correlation) was assessed with a Texas Instrument TI-55-II calculator (built in program).

Alcohol-insoluble solids (AIS) were prepared from the untreated and blanched tissue by repeated extractions with 70% and 96% alcohol. Soluble pectin was obtained by four-times extraction of the AIS with water at ambient temperature until no galacturonic acid appeared in the extract. EDTA-soluble pectin was extracted from the washed pellet of the AIS with 0·2% EDTA and Tris–HCl (0·02 M, pH 6·2), dialyzed against water, and freeze-dried. Alkaline-soluble pectin was obtained by repeating extractions with 0·05 N NaOH.

The amount of galacturonic acid was assessed colorimetrically by the m-hydroxyphenol method of Blumenkrantz and Asboe-Hansen (1973), and total pectin was measured according to Rayah and Labavitch (1977). Dry matter (DM) was determined as described by Levi *et al.* (1980), and the ratio between AIS and DM was calculated as described by Levi *et al.* (1988).

The type and amounts of individual neutral sugars present in the pectic fractions were analysed by gas chromatography, as described by Albersheim *et al.* (1967). The soluble pectin was treated with 40 ppm α-amylase (Sigma) for 2 h at 37°C to remove the starch from this fraction before gas chromatography. The significance of the difference (p) between the means for each pectic fraction after the pH treatment and blanching was calculated by analysis of variance (Kramer & Twigg, 1962).

RESULTS AND DISCUSSION

Blanching carrot tissue at three different pH values, 6·2, 4·4 and 3·9, caused massive changes in the firmness of the tissue. It was therefore interesting to follow the changes in the pectic fractions of the cell wall.

The content of the water-soluble pectin (WSP) and its neutral sugars (NS) in the carrot tissue after pH treatments and blanching is illustrated in Fig 1. Blanching the tissue caused a minor decrease in its pH from (6·3 to 6·2). The content of galacturonic acid (GA) decreased about 30% (treatment 2), but almost no change

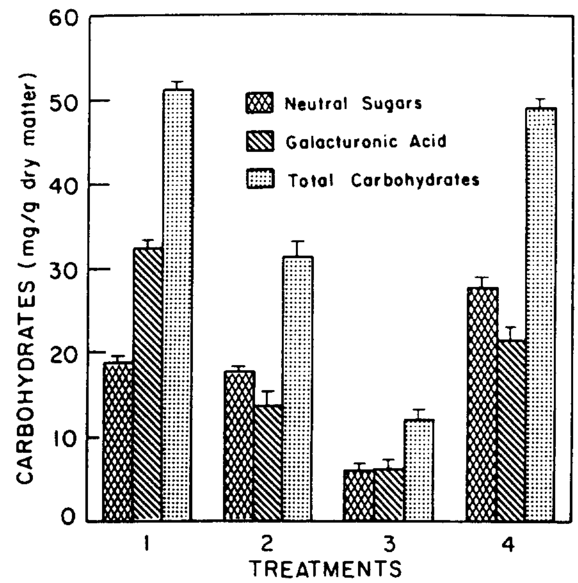

Fig. 1. Effect of acidification and blanching of carrot tissue on the content of total galacturonic acid and neutral sugars in the soluble pectic fraction. 1, Untreated control; 2, blanched but not acidified; acidified to pH 4·4 and blanched; 4, acidified to pH 3·9 and blanched.

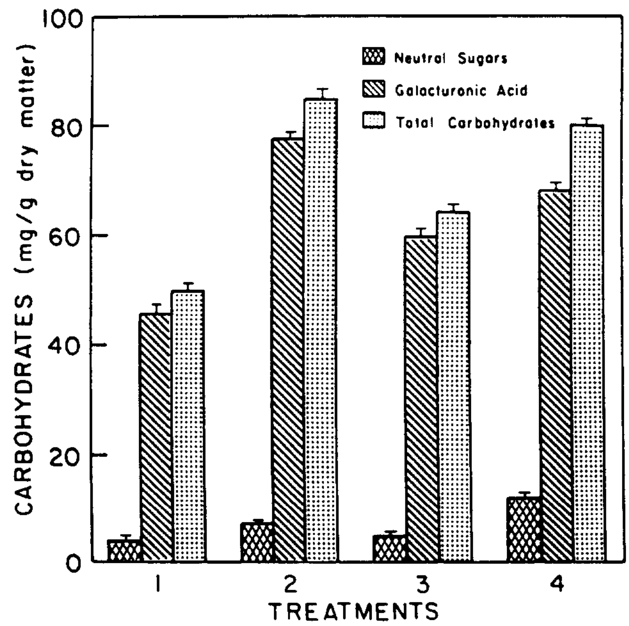

Fig. 2. Effect of acidification and blanching of carrot tissue on the content of total galacturonic acid and neutral sugars in the calcium pectate fraction. 1, Untreated control; 2, blanched but not acidified; 3, acidified to pH 4·4 and blanched; 4, acidified to pH 3·9 and blanched.

was observed in the NS content. At pH 4·4 (treatment 3), WSP (GA + NS) was found to be much lower than with other treatments. At pH 3·9 (treatment 4), the WSP content was almost the same as that of the untreated tissue but GA decreased, with a parallel increase in NS. It seems that the ratio between the GA and the NS completely changed in the various pH treatments. The EDTA-soluble pectin (EDTA-SP) content increased about 60% upon blanching at pH 6·2 (Fig. 2, treatment 2), as previously shown (Levi *et al.*, 1988; Plat *et al.*, 1988, 1991). An increase of 25% in the EDTA-SP was observed at pH 4·4 (Fig. 2, treatment 3), as compared with untreated tissue, but its content was still higher than that of the untreated tissue. The EDTA-SP content was higher at pH 3·9 than that of the other treatments. It is concluded that the EDTA-SP content increased on blanching over the range of pH tested but to a lesser extent at pH 4·4 than at either higher or lower pH values. Analysis of the content of the alkaline-soluble pectin (ASP) after blanching (Fig. 3, treatment 2) showed a decrease of more than 50% of the GA content and a decrease of about 15% in the NS. The GA content was 90% higher at pH 4·4 than tissue blanched at pH 6·2, and total ASP was decreased by 10% as compared to the untreated carrot. Blanching the tissue at pH 3·9 (Fig. 3, treatment 4) caused strong degradation in the ASP fraction. The main change was in the content of the GA, with a smaller change in the NS content. It was concluded that at pH 4·4, the pectic fractions degraded much less than at pH 6·2 or pH 3·9.

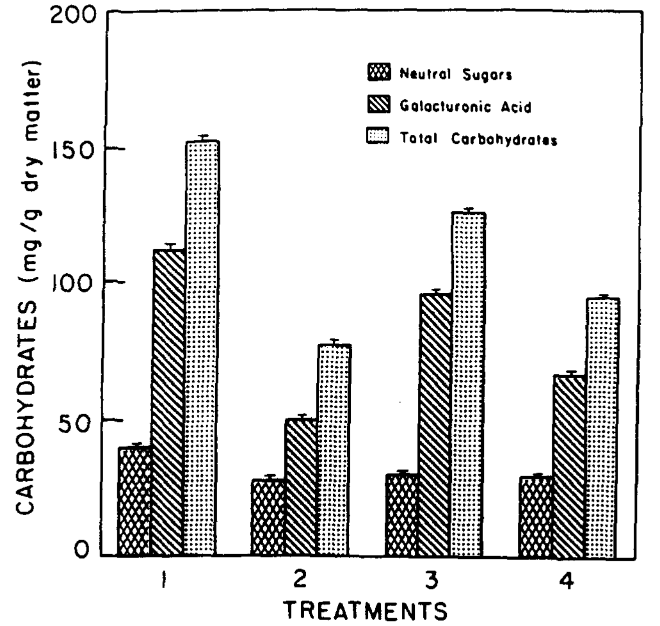

Fig. 3. Effect of acidification and blanching of carrot tissue on the contents of total galacturonic acid and neutral sugars in the alkaline-soluble pectin. 1, Untreated control; 2, blanched but not acidified; 3, acidified to pH 4·4 and blanched; 4, acidified to pH 3·9 and blanched.

Blanching the carrot tissue at pH 6·2 caused a significant reduction (about 70%) in the firmness of the carrot tissue (Fig. 4). Acidifying and blanching the tissue at pH 4·4 improved the firmness almost 50%, as compared with blanching the tissue at pH 6·2. But acidifying the tissue to pH 3·9 and blanching it decreased its firmness to the same value as at pH 6·2. It appeared that the degradation of firmness in carrot tissue during heat treatment occurred by two different mechanisms — one at neutral pH and another at pH 3·9 since at an intermediate pH the degradation was much less. The strong decrease in firmness after blanching was previously shown to be accompanied by massive changes in the soluble and EDTA-soluble pectin (Plat *et al.*, 1988, 1991). In trying to correlate the changes in firmness after blanching, and the change in the pectic fraction (Fig. 4), we found that the EDTA-SP content increased during blanching at the three pH values more than in the non-treated tissue (Fig. 2). This fraction, which seems to contribute to the texture of the tissue (Sterling, 1968), showed negative correlation with heat treatment. Although no correlation with firmness was found in the WSP fractions, the ASP content showed positive correlation ($p < 0.01$) with firmness. The loss of ASP from tissue blanched at pH 4·4 was not as great as that from tissue blanched at either 6·2 or 3·9, and the pH 4·4-blanched tissue had a greater degree of firmness.

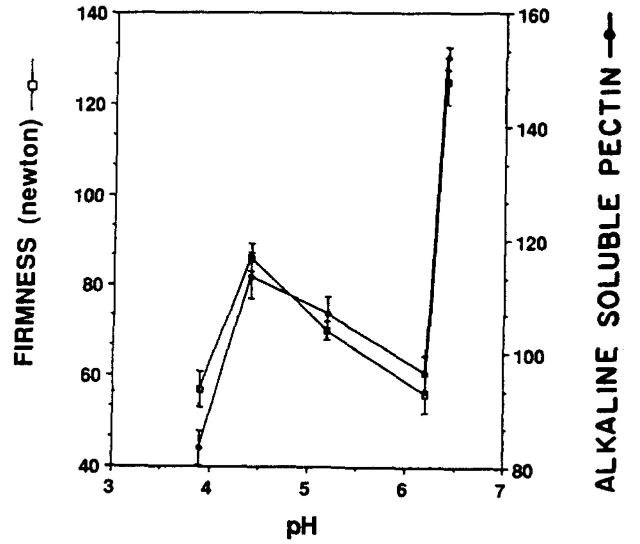

Fig. 4. Firmness and content of total carbohydrates (galacturonic acid and neutral sugars) in the alkaline-soluble pectin of carrot tissue after blanching and acidification.

These results indicate that pectin plays a major role in the structural and textural characteristics of carrot, while ASP is an important fraction affecting the texture. A similar correlation between the texture and galacturonic acid in the protopectin was shown in peaches and apricots by Proni *et al.* (1986), and between texture and galacturonic acid in the ASP in peaches by Levi *et al.* (1988). It was previously shown by Doesberg (1965) that an increase in WSP in various plant tissues, due to heat treatment, was accompanied by a decrease in firmness, but a correlation between the two parameters was not shown.

In the heat-treatment process we are dealing with a dynamic system in which breakdown products from the ASP and the residual cell wall accumulate in the WSP and change its amount and composition (as shown earlier; Plat *et al.*, 1991). But, at the same time, part of the WSP can be degraded to small oligomers that are extracted in the alcohol phase (data not shown) during AIS preparation, or another part of the WSP can interact with calcium ions and increase the EDTA-SP fraction, as shown in Fig. 2. During heat treatment, less changes occurred in the ASP than in the other pectic fractions. This may be the reason why good correlation with texture was only found in this fraction.

CONCLUSIONS

Blanching is a commonly practised method for stabilisation of vegetables and is typically done at near-neutral pH. By reducing the pH of the carrot tissue before blanching, the loss of tissue firmness was reduced. Therefore, in order to keep the changes in tissue firmness after blanching to a minimum, an induced decrease in the pH of carrots, and possibly other vegetables, should be considered.

The significant correlation between the changes in the firmness and the ASP fraction will allow us to understand physical changes by chemical means.

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