Low-Temperature Blanching of Sweetpotatoes to Improve Firmness Retention: Effect on Compositional and Textural Properties

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ABSTRACT: Low-temperature blanching of sweetpotatoes (SP) prior to cooking has been shown to significantly increase firmness retention. This research investigated the effect of blanching on firmness, pectin methylesterase activity (PME), pectin methylation, and galacturonic acid and cell wall material concentrations in SP tissue subjected to blanching and cooking treatments. PME activity decreased 82% after 20 min of blanching in water at 62 °C, while sample firmness continued to increase with blanching time (3.5 N for unblanched and 19.0 N for 90 min blanched, and cooked tissue), indicating that firming due to pectin demethylation explains part of the observed increased firmness retention caused by low-temperature blanching, but unknown factors also play a role.

Keywords: cell wall, degree of esterification, preheating, texture

Introduction

INABILITY TO CONTROL THE TEXTURAL PROPerties of processed sweetpotatoes (SP) has been a major obstacle to the development of commercially available products. Canned SP can be produced for only a few months each year because roots processed after being stored for a short time tend to disintegrate and/or slough surface tissue. To ameliorate this problem, researchers have added calcium chloride to the syrup (Bouwkamp 1985) and vacuum-infiltrated base, followed by tissue neutralization with acid prior to canning (Walter and others 1993). The mechanism by which calcium increases firmness retention is believed to be cross-linking with pectic substances according to the 'egg box' model proposed by Van Buren (1979). Treatment of tissue with base, followed by neutralization with acid, was postulated to be efficacious because it mediated demethylation of cell wall pectins by endogenous pectin methylesterase enzymes. Once either cross-linking of the pectins by calcium or pectin demethylation has occurred, the rate of cleavage of pectic substances by β-elimination during heat processing is decreased, resulting in increased firmness retention.

Another promising approach to increasing firmness retention in canned SP is the low-temperature blanching (LTB) process reported by Truong and others (1998). These workers found that sweetpotato tissue cylinders heated at 62 °C prior to canning were 2 to 3 times more intact and 2 to 7 times firmer, depending upon the blanching time, than were control samples which were canned without pretreatment. Firming mediated by LTB has been observed for sweetpotatoes (Binner and others 2000) as well as other commodities such as potatoes (Bartolome and Hoff 1972; Anderson and others 1994; Van Dijk and others 2002), carrots (Fuchigami and others 1995), and peppers (Howard and others 1997). Mechanistic models for this phenomenon have generally centered on interaction of pectin molecules with divalent metal ions to form cell wall stabilization via cross-linking (Bartolome and others 1972; Van Buren 1979). Binner and others (2000) suggested that the firming effect of cooking sweetpotatoes in water hold at a constant temperature of 70 °C is not caused by pectin methylesterase enzymes but by the breakdown of starch into sugars that can escape from the cell without causing cell separation. The report by Truong and others (1998) demonstrated that LTB was able to effectively increase firmness retention of canned SP. However, the mechanism for this increase was not elucidated. The objective of the present research was to investigate the effect on SP of LTB prior to cooking by relating firmness retention to selected compositional components and enzymatic activities as compared to conventionally cooked tissue.

Materials and Methods

Samples and replication

Data presented in this report were obtained using Jewel cultivar SP. The entire study was replicated twice using SP roots from the 1997 and 1998 crop years, with each crop year serving as one replicate.

Low-temperature blanching procedure

Cylinders (13.5 × 30 mm) were cut with a cork borer from large, firm, peeled Jewel SP (70 pieces for each analysis). Blanching was done by immersing the cylinders in water (5 parts water:1 part SP) at 62 °C. Samples were removed after 45 and 90 min. After blanching, SP were cooled in ice water for 10 min and divided into 2 portions. One portion was analyzed and the other portion was cooked in boiling water for an additional 20 min and then analyzed. In addition, one set of samples was blanched at 100 °C for 2 min, and then cooled in ice water and divided into 2 portions as described for the 62 °C blanched temperature samples. In a separate experiment, we removed samples from the blanching solution every 10 min, cooled the tissue in ice water and measured the pectin methylesterase activity.

Tissue firmness

Cylinders of SP were cut into 13.5-mm-long pieces, and the force of compression measured with a TA-XT2 texture analyzer (Texture Technology Corp., Scarsdale, N.Y., U.S.A.; Stable Micro Systems, Surrey, U.K.). Peak forces at fracture were obtained as measures of tissue firmness of cylinders of SP. Instrumental parameters were as follows: aluminum cylinder probe, 50 mm dia; pre-test speed, 2 mm/s; test speed, 1.6 mm/s; post-test speed, 10.0 mm/s; distance, 12.1 mm; acquisition rate, 200 point/s; force

units in Newtons. Twenty-five cylinders of SP were used for each determination.

Dry matter and alcohol-insoluble solids

The contents of dry matter and alcohol-insoluble solids (AIS) were determined as described by Walter and others (1997). Approximate 300 g of sample was grated in a Cuisimart Model DLC 10 food processor. Duplicate 10 g samples were weighed and the dry matter content determined after 6 h of drying at 68 °C followed by 18 h at 100 °C. For AIS, duplicate 100 g samples of the grated material were extracted 3 times with 300 mL of boiling 80%/20% ethanol/water. The residue was dried overnight at room temperature and then 24 h in a convection oven at 100 °C, and the weight of AIS was measured after drying.

Isolation of cell wall material

The phenol-acetic acid-water (PAW) method described by Selvendran (1975) and modified for SP was used. Grated SP (25 g) was mixed with 50 mL PAW (2:1:1, w/v/v) and homogenized for 2 min. The slurry was refrigerated for 2 h and filtered through a Miracloth filter. The entire extraction was repeated once more using 25 mL PAW. The extracted residue was washed with acetone (3 × 50 mL), air-dried, oven-dried at 105 °C, cooled, and held in a desiccator until analysis.

Determination of galacturonic acid concentration

Galacturonic acid concentration was measured colorimetrically using 3,5-dimethylphenol on hydrolyzed cell wall material (CWM) as described by McFeeters and Lovdal (1987). For the analysis, 10 mg dry cell wall material was weighed into a 1.5-mL screw-cap septum vial, and 125 μL 72% sulfuric acid (v/v) was added and mixed in. The vial was left at room temperature (25 °C) for 45 min, 1.35 mL of water was added, and the vial placed in the boiling water for 2 h. After cooling, 320 μL concentrated ammonium hydroxide was added and the contents diluted to 25 mL. An aliquot of that solution was centrifuged, 0.125 mL of the supernatant was removed and put into a test tube and mixed with 0.125 mL of 2% NaCl. The tube was then partially submerged in ice. Two mL of cold, concentrated sulfuric acid was added and the tube returned to the ice bath. Sample tubes were heated at 70 °C for 10 min and cooled in water. One-tenth mL of 0.1% aqueous solution of 3,5-dimethylphenol was added and vortexed. The tubes were held at room temperature for 15 min and the absorbance measured at 450 nm and subtracted from the absorbance measured at 400 nm. Sample galacturonic acid concentrations were determined from a standard curve developed from known anhydrogalacturonic acid concentrations and utilizing the same colorimetric procedure as was used for samples.

Determination of methanol concentration

Methanol liberated from CVM was measured by the method described by Wood and Siddiqui (1971). CWM (0.025 g) was weighed in a screw-cap vial, and 2 mL of 4 M NaOH solution was added and mixed in. Then 2 mL of distilled deionized water was added, followed by sonication, and refrigeration. Concentrated H_2SO_4 (5.5 mL) was added and transferred to a 25-mL volumetric flask. Color was developed as described in the above-mentioned method using acetylacetone as the chromogen.

Percent methyl esterification

Percent methyl esterification of the CWM was calculated by dividing the molar concentration of methanol per g of CWM by the molar concentration of galacturonic acid per g of CWM and multiplying the quotient by 100.

Pectinmethylesterase activity

Grated tissue of SP (15 g) and 30 mL of 0.35 M NaCl containing 1% polyvinyl pyrrolidone (PVP 40; Sigma Chemical Co., St. Louis, Mo., U.S.A.) were mixed. The mixture was macerated into a slurry and held in the refrigerator for 1 h. The slurry (5 g) was weighed in a beaker and 15 mL of 0.5% apple pectin solution containing 0.25 M NaCl was added. The pH was adjusted to 7.5 using 0.4 N NaOH. The mixture was stirred for 5 min at room temperature. A timer was started, and the solution was titrated with 0.02 N NaOH at room temperature, keeping pH at 7.5. The volume of base consumed at 4 timed intervals in 12 min was recorded. The amount of NaOH consumed was plotted against reaction time. The activity of pectinmethylesterase (PME) was the slope of the line.

Protein concentration

Where enzyme activities were expressed on a per unit protein basis, the Lowry and others (1951) assay was used to measure protein concentration.

Statistical analysis

Data were analyzed by analysis of variance using the General Linear Models Procedure. Differences ($P \leq 0.05$) between treatment means were determined by the Least Square Means Procedure. All statistical analyses were performed using the Statistical Analysis System (SAS 1994).

Results and Discussion

We chose to use 62 °C as our LTB temperature because Truong and others (1998), using response surface methodology, found that this was the optimum temperature for increased firmness retention. Blanching of cylinders of SP resulted in decreased dry matter content due to leaching of low-molecular- weight carbohydrates and amino compounds. Untreated samples had a dry matter content (DM) of about 19%, while the DM of blanched samples declined to about 13.5 to 16.0%, depending on the blanching treatment (Table 1). Alcohol-insoluble solids concentrations (AIS) responded somewhat differently. In this case, samples blanched at 100 °C for 2 min had the lowest AIS, probably due to the solubilization of starch hydrolysates occurring after starch gelatinization at temperatures above 73 °C (Walter and others 2000).

Cooking the samples caused greater decreases in DM (Table 2). In the cooked samples, both unblanched and 100 °C blanched samples lost DM, but still had significantly more than did the 62 °C blanched samples. For all cooked samples decreases in DM were likely due to leaching of starch hydrolysates mediated by enzymatic breakdown of heat-gelatinized starch and low-molecular-weight components, as described in the preceding paragraph.

Previously, Truong and others (1998) reported that the peak force for tissue of SP blanched at 60 °C increased for 90 min of blanching. This increase in firmness as a function of blanching time was also observed for LTB tissue cooked after blanching. Our results confirmed their observations (Table 3). It has been postulated (Van Buren 1979) that firmness retention caused by LTB is due to a decreased rate of cleavage of pectic substances by β-elimination during heat treatment. The β-elimination rate is decreased because the number of free carboxylic acid groups of pectic substances has been increased by the de-esterification of methyl esters by the pectinmethylesterase enzyme (PME) system. The PME is postulated to be activated by the LTB temperatures (Wu and Chang 1990; Fuchigami and others 1995).

As part of this study, we measured the PME activity of sweetpotato tissue blanched at 62 °C for varying periods of time. PME activity declined to about 20% of its original activity after 20 min at 62 °C, and by 40 min had declined to less than 10% of its original activity (Figure 1). At the same

time, firmness, as measured by compression force, increased in a linear fashion up to 90 min of blanching. This behavior is inconsistent with the hypothesis that de-esterification of pectin methyl esters is primarily responsible for firmness retention. However, support for the fact that demethylation was occurring was provided by measurement of the degree of esterification (DE) for uncooked blanched LTB tissue (Table 1). It can be seen that the DE does decrease when compared to either no treatment or samples heated for 2 min in 100 °C water. There was no statistically significant difference between samples blanched for 45 and 90 min, indicating that PME activity was lost by 45 min of blanching and most of the pectin de-esterification occurred during the 1st 20 min of preheating. For potatoes, PME activity remains constant during preheating at 60 °C for 1 h and, thus, the pectin de-esterification plays an important role in the firming effect (Van Dijk and others 2002).

When blanched tissue was cooked, although firmness declined relative to that of the blanched-uncooked tissue (Figure 1 and Table 3), the order remained the same, with firmness declining in the order: 90 min blanch at 62 °C > 45 min blanch at 62 °C > unblanched-blanched at 100 °C for 2 min. As was true for the blanched tissue, the LTB tissue was firmer than the other samples. However, although the DE for blanched tissue was lower than for unblanched and 100 °C blanched material (Table 1), when cooked this difference disappeared with no statistically significant differences observed in the DE for any treatment (Table 2). It is possible that during cooking the de-esterified pectic substances were selectively cleaved and/or extracted by the hot water during cooking. The site of cleavage on pectin molecules and the type of dissolved pectins may affect the galacturonic acid and methanol concentrations (Tables 1 and 2), and consequently on DE. Moreover, the differences in the amounts of starch degraded and solubilized among the blanching and cooking treatments that were not measured in the present study, may have an effect on the results on pectic substances. Several recent publications cite findings which may be germane to our research. Hou and Chang (1996) reported that the PME enzyme complex from pea sprouts not only exhibited methyl ester hydrolysis activity but also transacylation activity. Consequently, this enzyme complex was able to catalyze the formation of new ester linkages between pectin molecules, thereby increasing tissue firmness. The increased transesterification could have occurred more slowly than did PME inactivation and, thus, was a contributing factor to firmness retention. However, the transesterification reaction was not evident in potatoes wherein PME was activated by blanching at 55 °C or 70 °C (MacKinnon and others 2002). Recently, Van Dijk and others (2002) showed that pectin de-esterification in blanched potatoes resulting in a decrease in pectin degradation by β-elimination upon cooking, and, consequently, a larger yield of cell wall materials

Table 1—Composition of sweetpotato samples subjected to different blanching treatments without further cooking[a]

Treatment	Dry matter	Alcohol-insoluble solids	Galacturonic acid (μM/g CWM)	Methanol (μM/g CWM)	Tissue degree of esterification (%)[b]
None	19.23a	11.43a	759.04b	453.93b	59.80a
Blanched 2 min at 100 °C	15.97b	6.84c	960.14a	586.41a	61.08a
Blanched 45 min at 62 °C	14.81bc	9.01b	882.28ab	419.03b	47.49b
Blanched 90 min at 62 °C	13.58c	8.88b	835.02ab	397.42b	47.59b

[a]Values within columns having the same letter are not significantly different (P < 0.05).
[b]{mM MeOH/mM GA (only cylinders of SP)} x 100

Table 2—Composition of blanched sweetpotato samples cooked for 20 min[a]

Treatment	Dry matter	Alcohol-insoluble solids	Galacturonic acid (μM/g CWM)	Methanol (μM/g CWM)	Tissue degree of esterification (%)[b]
None	13.49a	6.98a	352.02b	158.43b	45.00a
Blanched 2 min at 100°C	13.05a	6.86a	355.32b	166.31b	46.80a
Blanched 45 min at 62°C	11.57b	6.14b	580.47a	310.94a	53.56a
Blanched 90 min at 62°C	11.44b	6.34ab	692.70a	341.01a	49.23a

[a]Values within columns having the same letter are not significantly different (P < 0.05).
[b]{M MeOH/mM GA(only cylinders of SP)} x 100

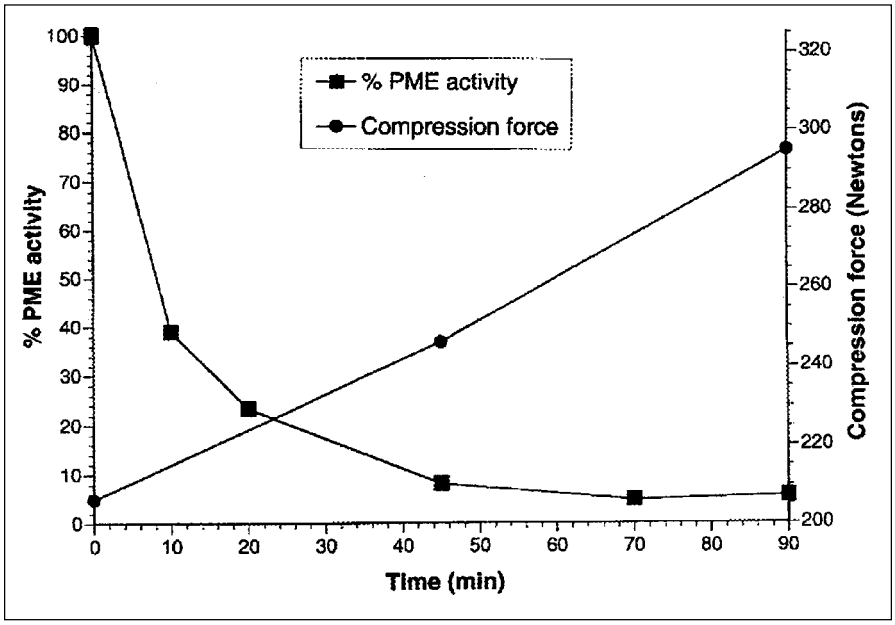

Figure 1—Percent pectinmethylesterase activity and compression force plotted against blanch time in minutes for Jewel cultivar SP. Blanch temperature was 62 °C. Standard deviation error bars for % pectinmethylesterase activity are covered by the symbols.

Table 3—Force of compression for cooked[a] sweetpotato pieces

Precook treatment	Compression force (Newtons)[b]
None	3.51c
Blanched 2 min at 100 °C	3.63c
Blanched 45 min at 62 °C	11.04b
Blanched 90 min at 62 °C	19.03a

[a]Samples cooked in boiling water for 20 min
[b]Values followed by the same letter are not significantly different ($P < 0.05$).

(CWM). This increase in the amount of CWM resulted in a firmer texture. They also observed substantial amounts of glucose in the CWM indicating that starch breakdown products catalyzed by β-amylase might contribute to the texture of cooked potatoes preheated at 60 °C, as previously reported by Binner and others (2000).

Finally, Howard and others (1997) reported that preheating of jalapeno pepper rings at 60 °C prior to brining and storage resulted in only a slight decrease in the degree of pectin esterification. However, significant firming was observed only in peppers which had been preheated in brine containing both NaCl and $CaCl_2$. We did not use calcium in our blanch water, so it is difficult to visualize how this might have affected our results. On the other hand, the quantity of endogenous calcium may have been sufficient to contribute to firmness retention once the methyl esters had been hydrolyzed. The delayed effect could have been caused by the time required for endogenous calcium to diffuse to the middle lamella.

Conclusion

IN SUMMARY, THIS RESEARCH HAS DEMONstrated that mediation of firming due to pectin demethylation appears to explain part of the observed increased firmness retention caused by low-temperature blanching; however, unknown factors also play a role. Since firmness retention increases with blanching time and a too firm product is not desirable to consumers, processors wishing to adapt this technology will have to reconcile blanching time, product quality, and processing efficiency.

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