ALKALI-NEUTRALIZATION PROCESS MAINTAINS THE FIRMNESS AND SENSORY QUALITY OF CANNED SWEETPOTATO PIECES[1]

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ABSTRACT

Jewel cultivar SP stored 1, 5, and 10 months after harvest were peeled, cut into pieces, treated, and canned in 15 and 30 deg Brix syrups. Samples were evaluated for degree of disintegration (wholeness), firmness (shear force), chemical composition, and sensory acceptance. Untreated samples (controls) disintegrated as storage time prior to processing increased, while treated samples remained intact; firmness and sensory texture scores declined with increasing storage time. Treated samples were significantly firmer than controls throughout the study, and, although shear force declined over time, sensory panelists did not detect any texture change. Overall sensory acceptance at 10 months was greatest for phosphate-treated samples in 30 deg Brix syrup. Thus, the alkali-neutralization process retains firmness, wholeness, and sensory quality of SP canned after long-term storage. This process will permit commercial processing of SP roots stored for up to 10 months.

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INTRODUCTION

Textural properties of processed sweetpotatoes (SP) depend on the length of time the roots are stored before processing. Generally, SP processed shortly after harvest are firmer and maintain their integrity better than those which have been harvested and stored for more than 2 months before processing (Kattan and Littrell 1963; Woodroof *et al.* 1955; Culpepper and Magoon 1925). As a result, processing facilities operate at full capacity around harvest time and then must either close or process other commodities. If processing conditions could be found to minimize softening and disintegration of roots processed after long-term storage, then the length of the canning season could be extended. Moreover, a process to retain firmness would be an encouragement for the development of other SP products.

Vacuum infusion or infiltration (VI) of compounds such as acetic acid, sodium phosphate, sodium hydroxide, calcium chloride, and pectin methylesterase have been used to increase the firmness and/or firmness retention of fruits and vegetables (Javeri *et al.* 1991; Van Buren and Pitifer 1992; Walter *et al.* 1992, 1993; Moreira *et al.* 1994). Walter *et al.* (1993) showed that infiltratlon of SP tissue with bases, followed by blanching and neutralization, caused a significant increase in firmness retention of sliced SP strips when compared with blanched, untreated strips. Later research (Sylvia and Walter 1997) demonstrated that infiltration of a dilute Na_3PO_4 solution, followed by blanching and neutralization, gave the most acceptable French frytype product from SP stored for up to 1 year before processing. In this report we discuss the use of the alkali infusion-neutralization process to minimize softening and disintegration of SP stored for 1, 5 and 10 months before canning.

MATERIALS AND METHODS

Processing

Jewel cultivar SP cured and stored at 85% relative humidity and 13C for 1, 5, and 10 months after harvest were hand-peeled and cut into 1 × 2 × 2 cm pieces. Weighed batches of pieces were subjected to one of three treatments. These treatments were as follows: (1) blanching in boiling water for 3 min (control); (2) VI of a solution of 0.03 M Na_3PO_4, blanching in boiling water for 3 min drained, VI 0.1 M sodium acetate (pH 5.2) at 22C to lower tissue pH to ca. 5.8-6.0; (3) same as treatment (2) except the sodium acetate solution contained 2% calcium chloride. VI and blanching were as described earlier (Walter *et al.* 1993; Sylvia *et al.* 1997).

After treatment, the pieces (230-270 g) were put into #303 cans ("C" enamel), which were filled with 15 or 30 deg Brix sucrose syrup at 90C, and exhausted in steam for 5 min. The cans were sealed, retorted for 35 min at 121C, and stored at 20-22C until the SP were analyzed.

For each sampling date, the above experiment in its entirety was replicated three times.

Analyses

Cans were held for a minimum of 2 months after processing to allow equilibrium between syrup and tissue to occur. All analyses were performed on samples from two cans from each replicate. Upon opening the can, the syrup was decanted, the pieces drained for 10 min, and the weight of the pieces was measured.

Shear Force. Forty-two grams of pieces were weighed into a Kramer Shear cell and the shear force measured in an Instron Universal Testing Machine (UTM, model 1122, Instron Inc., Canton, MA) fitted with a 50-kg load cell. All analyses were conducted at ca. 25C and with a crosshead speed of 10 cm/min. Data collection and calculation were electronically done with the aid of the TestWorks computer program (MTS Sintech Inc., Cary, NC).

Sensory Evaluation. Panels consisted of 30 to 36 members and were recruited from faculty, staff, and students of the Food Science Department at North Carolina State University. Although the panelists were untrained, only those persons who liked SP were selected. In addition, all panelists were generally familiar with taste panel procedures. Panelists were asked to rate samples for texture on a 9-point intensity scale, where 1 = too soft and 9 = too firm. At a separate sitting, panelists were asked to rate samples for overall acceptability on a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. The questionnaire also contained a section for panelists' comments for each of the attributes evaluated.

Panelists were situated in individual booths illuminated with red light (to mask any sample color differences) in a darkened room. At each sitting, five samples (three pieces per sample) were served, each in a plastic cup positioned on a partitioned plate with each partition coded with a randomly selected three-digit number. Panelists were asked to rinse their mouths with water between samples. Replicate samples were evaluated within a 1-week period. Cans used for overall acceptability and sensory texture were not shaken as was done for determination of the degree of disintegration, thus panelists were served only intact diced pieces.

For determination of sample disintegration, only samples from control and phosphate treatments were evaluated. Cans were punctured and about 5 mL of syrup was removed from each to permit adequate movement of the pieces. Cans were shaken vigorously seven times to simulate movement occurring during distribution and display of canned products. The cans were then opened and the liquid drained. At each sitting, five diced samples, each coded with a randomly selected three-digit number, were served to each panelist one sample at a time. Panelists were selected as described above and the evaluations were conducted in individual booths illuminated with fluorescent light. The ballot asked panelists to select the description which best fit sample appearance. The ballot used a 7-point scale ranging from "no disintegration" to "very severe disintegration". In addition, the following definition of disintegration was included on each ballot: "Disintegration on the scale below refers to how well the diced SP maintain their wholeness. For example, a sample with "No Disintegration" would be intact wiht no broken of fractured dice visible. A sample with "Very Severe Disintegration" would consist entirely of broken dice with no whole pieces visible." Panelists did not taste the samples. The entire evaluation was run in duplicate. The number of panelists ranged from 26 to 28 at each sitting.

Tissue Composition

Alcohol Insoluble Substances (AIS). Twenty-five grams of pieces were blended with 100 mL 95% ethanol for 1 min. The mixture was allowed to stand 1 week and then filtered. The residue was blended for 1 min with boiling 80 ethanol, allowed to cool, and filtered. This was repeated once more. The supernatants were combined, mixed, and the volume measured. Sugar concentrations were measured as described below. The residue was air-dried overnight and then dried at 100C for 16 h in a convection oven. After drying, the residue was weighed and the percent AIS calculated based on starting weight.

Sugar Analysis. Appropriate aqueous dilutions of the combined 80:20 (v/v) ethanol: water supernatants from the AIS determination were made and separation and quantitation of the sugars was performed on a 4 mm x 250 mm Dionex Carbopack PA1 column eluted with 0.15 N sodium hydroxide at 1 mL/min, using a Dionex HPLC System (Dionex Corp., Sunnyvale, CA) operating with a pulsed amperometric detector. Output was processed with the Lab Calc chromatography program (Galactic Enterprises, Salem, NH).

Percent Esterification of Galacturonic Acid. This procedure was performed as previously described (Walter *et al.* 1993). Briefly, the galacturonic acid content was measured after dispersion of weighed AIS samples with

concentrated sulfuric acid using 3,5-dimethylphenol as the chromogen. Methyl ester content was determined by hydrolysis of the methyl esters in the AIS followed by quantitation of the methanol released using pentane-2,4-dione as the chromogen. To calculate the percent methyl ester, the molar concentration of galacturonic acid per gram of AIS was divided into the molar concentration of methanol per gram of AIS and the result multiplied by 100.

RESULTS AND DISCUSSION

When data collection for the 1 month samples had been completed, we noted that treated samples were significantly less sweet than the control samples. To remedy this we added a 30 deg Brix syrup treatment to the study. This syrup concentration is commonly used by SP processors. Thus, no data are reported for this syrup concentration for the 1 month period. We did not include the phosphate plus calcium samples in the 30 deg Brix syrup study.

Treatment with Na_3PO_4 solution, followed by blanching and treatment with sodium acetate solution, significantly increased the shear force (firmness) of the SP dice (Table 1). However, firmness declined with increased storage time before processing for both control and treated samples. Treated samples were approximately twice as firm as the controls throughout the study. The shear force for the control samples declined from 84.4N at 1 month to 52N at 10 months, while shear force for the treated samples decreased from 174N and 220N (for phosphate and phosphate + calcium, respectively) at 1 month to 119N and 181N, respectively, at 10 months. As expected, the phosphate + calcium samples were somewhat firmer than those treated with phosphate only.

TABLE 1.
SHEAR FORCE (NEWTONS) FOR CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	84.4e	68.4ef	52.0f
Phosphate	15	173.7bc	140.0cd	118.7d
Phosphate + $CaCl_2$	15	220.0a	173.0bc	181.3b
Control	30	-	75.6ef	58.9ef
Phosphate	30	-	151.8c	133.5cd

[a]Values with the same letter are not significantly different ($P < 0.05$).

Sensory panelists scored the texture of the control samples as softer than preferred, and these scores decreased progressively as storage time before processing increased (Table 2). For phosphate treated samples, scores were a little above the mid-point throughout the study. However, for the phosphate plus calcium samples, the texture scores varied between 6.1 and 6.7, indicating that they were slightly too firm for panelists' preference. Thus, the most acceptable texture was not found in samples with the highest shear force value, but in those samples with a moderate level of firmness. This indicates that there may be an optimal level of shear force that gives the "right" amount of resistance to chewing, resulting in a more acceptable product. Interestingly, the panelists did not detect any time-dependent texture change in either of the treated samples, while panel scores for the control declined with storage time. It should be noted that the treated samples' firmness, as measured by shear force, decreased by as much as 30% over time (Table 1). Apparently, this firmness decrease was not large enough to cause these samples to be scored by the sensory panel below the "just right" point.

TABLE 2.
SENSORY TEXTURE SCORES[a,b] FOR CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	3.3c	3.0cd	2.5d
Phosphate	15	5.9b	5.6b	5.8b
Phosphate + $CaCl_2$	15	6.5a	6.1ab	6.7a
Control	30	-	3.3c	2.9cd
Phosphate	30	-	5.6b	5.5b

[a]Scale: 1 = too soft; 9 = too firm.

[b]Values with the same letter are not significantly different ($P < 0.05$).

For all samples canned with 15 deg Brix syrup, panelists showed no overall preference for treated or control samples, although scores for the control tended to decrease more rapidly than did scores for both sets of treated samples (Table 3). On the other hand, in 30 deg Brix syrup for the 10 month samples, overall sensory acceptance was greater for the treated samples. These changes probably were influenced by the panelists perceptions of time-related firmness decreases. Because the samples were not perceived as being of lower overall acceptability

than the controls for all time periods treated, the treatments did not cause any off-flavor. This conclusion is reinforced by the fact that panelists did not report off-flavor in the comments section of the ballots. Samples served to sensory panelists were not shaken before being served and so only whole pieces were presented. Thus, for the overall acceptability evaluation, scores were not influenced by appearance of disintegrated samples. Shaking of the samples resulted in a very unattractive appearance for the control samples and yet had minimal effect on the appearance of the treated samples (Table 4). Even the one month controls had an unappealing appearance, and the 5- and 10-month control samples were even more disintegrated and unattractive.

TABLE 3.
SENSORY OVERALL SCORES[a,b] FOR CANNED JEWEL CULTIAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	6.0ab	5.4ab	4.9bc
Phosphate	15	5.6b	5.2bc	5.3bc
Phosphate + $CaCl_2$	15	5.2bc	5.1bc	4.9c
Control	30	-	6.2a	5.3bc
Phosphate	30	-	6.6a	6.4a

[a]Scale: 1 = dislike extremely; 5 = neither like nor dislike; 6 = like slightly; 9 = like extremely.

[b]Values with the same letter are not significantly different ($P < 0.05$).

As stated above, control samples disintegrated as storage time increased, while treated samples exhibited little disintegration over 10 months (Table 4). The data also indicated that, for the controls, 30 deg Brix syrup resulted in slightly less disintegration than for samples canned in 15 deg Brix syrup. The control samples' degree of disintegration increased with time until they were a very unattractive pack. Conversely, although slight disintegration was observed for the treated samples, they remained of high quality throughout the study. When the contents of the cans were poured into a household strainer, the liquid and from 5 to 10 g of residue for the control samples passed through the strainer, while only 1 to 2 g of residue for the treated samples accompanied the liquid. These residues resulted from disintegration of dice and sloughing of the surface tissue.

TABLE 4.
DISINTEGRATION SCORES[a,b] FOR CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	3.9d	5.8a	5.5a
Phosphate	15	1.7ef	2.0e	1.7ef
Control	30	-	4.3c	4.9b
Phosphate	30	-	2.0e	1.6f

[a]Scale: 7 = very severe disintegration; 4 = moderate disintegration; 2 = very slight disintegration; 1 = no disintegration.

[b]Values with the same letter are not significantly different (P <0.05).

Since the canning syrups were composed of sucrose and water, it was not surprising that the major sugar component in all samples was sucrose. Generally, sucrose made up about 90% of the total sugars in the SP tissue, maltose about 7% of the total, and glucose and fructose comprised the remainder (data not shown). Drained samples canned in 30 deg Brix syrup contained about 50% to 90% more sugar than those canned in the 15 deg Brix syrup (Table 5). The 30 deg Brix syrup removed water from the tissue, as evidenced by a 38% increase in dry matter for drained samples canned in the high deg Brix syrup (Table 6).

TABLE 5.
TOTAL SUGAR[a] CONCENTRATIONSSS (PERCENT OF DRAINED WEIGHT) FOR CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	10.26 bcd	12.82 b	11.09 bc
Phosphate	15	8.69 cd	9.86 bcd	8.96 cd
Phosphate + $CaCl_2$	15	9.06 cd	10.38 bcd	7.62 de
Control	30	-	18.32 a	17.63 a
Phosphate	30	-	17.52 a	16.50 a

[a]Values with the same letter are not significantly different (P <0.05).

TABLE 6.
PERCENT DRY MATTER[a] (DRAINED WEIGHT) FOR CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTHS BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	21.0de	21.16d	20.02e
Phosphate	15	20.12e	19.36ef	18.76f
Phosphate + $CaCl_2$	15	20.07e	19.31ef	19.43ef
Control	30		28.34ab	29.04a
Phosphate	30		26.32c	27.44bc

[a]Values with the same letter are not significantly different ($P < 0.05$).

TABLE 7.
PERCENT ESTERIFICATION[a] OF GALACTURONIC ACID OF CANNED JEWEL CULTIVAR SWEETPOTATOES STORED FOR 1, 5, AND 10 MONTH BEFORE PROCESSING

Treatment	Syrup (deg Brix)	1 Month Storage	5 Month Storage	10 Month Storage
Control	15	46.3ab	48.2a	38.5bc
Phosphate	15	30.9c	32.3c	24.2c
Phosphate + $CaCl_2$	15	33.0c	34.6c	31.5c
Control	30	-	46.3ab	43.2ab
Phosphate	30	-	35.8c	31.5c

[a]Values with the same letter are not significantly different ($P < 0.05$).

With regard to the mechanism by which base causes increased firmness retention of processed SP products, it has been shown that, in base-treated tissue, pectic substances are de-esterified and that de-esterification is primarily the result of the action of endogenous pectin methylesterase (Walter *et al.* 1993). Others have reported that the lower the methyl ester content, the lower the rate of pectin chain degradation during heating (Sajjaanantakul *et al.* 1989). These workers postulated that the negative charge associated with the de-esterified carboxylic acid would inhibit beta elimination by destabilizing any developing negative charge on the carbon attached to the cleavage site, thus decreasing the rate of

pectin chain cleavage. Increased firmness retention results because of the decreased rate of the beta elimination reaction. Analysis of samples from the present research, as expected, indicated that the degree of esterification of pectins was greater in the control than in the treated samples (Table 7), and that the addition of calcium chloride to the acetate buffer caused increased firmness retention greater than that found in treated samples which did not contain the calcium ion (Table 2). This latter finding is consistent with research published previously (Van Buren 1979; Walter *et al.* 1993). Since more carboxylic acid groups are available in the treated samples, more calcium ions are bound and this, in turn, leads to increased bridge formation, decreased beta elimination, and increased firmness.

CONCLUSIONS

Infiltration of diced SP (made from roots stored from 1 to 10 months before processing) with Na_3PO_4 solution, followed by blanching, adjustment of tissue pH to ca. 6, and canning in sucrose syrup, caused increased firmness retention and decreased disintegration over dice canned without phosphate treatment. When canned in 30 deg Brix sucrose syrup, SP dice made from roots stored for 10 months prior to treatment were more acceptable to a sensory panel and showed very little disintegration than untreated canned dice. This infiltration process can be used to give an acceptable pack from SP stored up to 10 months before processing, and could significantly extend the processing season.

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