

ALKALI-PROCESSED SWEETPOTATO FRENCH FRIES¹K.E. SYLVIA², W.M. WALTER, JR.^{2,3,5} and F.G. GIESBRECHT⁴²*Department of Food Science*³*United States Department of Agriculture, Agricultural Research Service*⁴*Department of Statistics**North Carolina State University**Raleigh, North Carolina 27695-7624*

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ABSTRACT

A combination of alkali (sodium phosphate or calcium chloride) infiltration and blanching and their order of application were studied for their effect on the sensory and physico-chemical (moisture, fat, sugars, and shear force) quality of sweetpotato French fries (SPFF) made from sweetpotatoes (SP) stored for 3 months or 1 year. Sensory quality (taste, texture, and overall acceptability) were evaluated using a nine-point hedonic scale. Treatment of SP strips with sodium phosphate solutions prior to blanching caused an increase in firmness as compared with untreated strips. For SPFF produced from SP stored 3 months, sensory quality of treated SPFF was indistinguishable from untreated SPFF. However, for SP processed at 1 year of storage, the sensory texture of treated samples was more acceptable than the sensory texture of untreated samples. Shear force data indicated that the firmest samples did not have the most acceptable sensory texture, indicating that there is an optimal level of shear force that gives the "right" amount of resistance to chewing to result in a more acceptable product. This process can be used in the manufacture SPFF from SP stored up to 1 year.

INTRODUCTION

Sweetpotatoes (SP) have high nutritional value and processing potential (Lund and Smoot 1982; Picha 1985; USDA 1984). However, per capita consumption of

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SP in the United States until recently has been in a declining pattern, reaching a level of approximately 4.5 lb/person/year (Lucier 1993). Approximately 60% of this commodity is sold in the fresh market (USDA 1982). The remainder is processed and then consumed (largely canned), or used as seed. In order to improve this consumption pattern, value-added SP products must be explored. One approach is deep-fat, fried-type products, which constitute an increasingly large proportion of the consumer market. The USDA (1982) reported that 50.7% of the white potatoes produced in the United States were utilized as processed products; 46.5% of which were frozen French fries. SP processors have faced long-term difficulty in controlling textural properties of processed SP products, especially firmness (McConnell and Gottschall 1957). Several factors influence the firmness of SP, such as cultivar, location, length and temperature of storage, and processing techniques. Kelley *et al.* (1958) reported good texture for SP fried slices when the product was made from SP cured and stored for about 1 month, but a product of inferior taste and texture resulted when using roots stored for 6 months.

SP processed immediately after harvest are firmer than those processed after curing and storage. Even a few days' delay in processing after harvesting results in a significant loss of firmness (Anonymous 1980). A number of studies have suggested that dry matter, starch, specific gravity, cell and grain size, pectic substances, and nonstarch polysaccharides greatly influence the overall textural and cooking quality of potatoes and SP (Jaswal 1989; Johnston *et al.* 1970; Sterling and Aldridge 1977). The length of storage of the SP is critical to changes in weight, volume, and intracellular space. As storage time progresses and SP undergoes various physiological changes, the intracellular space in the roots increases and tissue pithiness occurs, resulting in soft textured products (Kushman and Pope 1972). The possibility to manufacture products with increased firmness from SP that have been cured and stored for more than 3 weeks would be highly desirable, enabling producers to extend the processing season.

For SP, as for most fruits and vegetables, texture depends on the pectic substances which are cell wall components which can be altered by preprocessing treatments and thermal processing. Several researchers have reported that calcium treatment increases the firmness of processed roots and vegetables (Javeri *et al.* 1991; McFeeters and Fleming 1990; Sistrunk 1971; Van Buren 1979). Soaking roots in calcium solutions has a toughening effect on the outer layer of the tubers. However, the slight increase in firmness of this outer layer was judged not worth the effort of soaking for long periods of time (Ammerman *et al.* 1980).

In place of soaking as a pretreatment, vacuum-infusion or -infiltration (VI) of compounds such as acetic acid, sodium phosphate and carbonate, calcium chloride, pectinmethylesterase, etc., has also been used to increase the firmness of fruits and vegetables (Javeri *et al.* 1991; Moreira *et al.* 1994; Walter *et al.* 1992, 1993). Vacuum infusion of acetic and hydrochloric acids increased firmness of a SP French fries (SPFF)-type product, but its application was limited due to flavor changes and loss of firmness when the tissue was returned to its original pH

(Walter *et al.* 1992). According to Walter *et al.* (1993), the greatest firmness retention of SP tissue was obtained when either sodium carbonate (Na_2CO_3) or trisodium phosphate (Na_3PO_4) were vacuum-infiltrated prior to heating, even after infiltrating a second time (with an acetate solution) to return tissue to its initial pH. Furthermore, when alkali-treated tissue was vacuum-infiltrated with calcium chloride, tissue firmness was further enhanced. Most recently, Sylvia and Walter (1994) reported that panelists preferred Na_3PO_4 -infiltrated SPFF to those infiltrated with Na_2CO_3 . According to panelists, the latter had an unpleasant aftertaste. Therefore, Na_3PO_4 was chosen for this study.

Blanching is one of the most important thermal treatments in the vegetable industry. It leads to the inactivation of enzymes and removal of air from the vegetable tissue (Lee 1958). Commonly used blanching temperatures (90-100C) may lead to undesirable tissue softening (Bourne 1987). Lower blanching temperatures (60-65C) with increased blanching time (45 min), has been reported to increase firmness of white potato French fries (Aguilar *et al.* 1995). Furthermore, panelists liked the firmer fries over the control.

In this study, VI of a sodium phosphate solution, or a sodium phosphate solution in conjunction with a calcium chloride solution, was used as an infusion treatment. The order of blanching, between and after sequential VI, was used as the thermal treatment. Throughout the paper, the order of blanching is referred to as blanching process. The purpose of this study was to evaluate the effect of alkali VI pretreatment and the blanching process on selected physico-chemical parameters and consumer acceptability of SPFF prepared from SP that had been stored for 3 months and 1 year.

MATERIALS AND METHODS

This research was conducted in two parts. Jewel cultivar SP were utilized in both experiments. Each of the experiments described below was performed on SP roots grown in different years and, thus, were not strictly comparable. Roots were cured (1 week at 32C and 80-90% RH) and stored (13-16C and 80-90% RH) prior to use. SP were hand-peeled, rinsed, and sliced into strips. Strip length was not controlled. In all cases, infiltration of strips was accomplished by VI, as previously described (Walter *et al.* 1993).

Experiment 1: Sample Preparation

SP harvested in September 1993 were stored for 3 months. In order to access the effect of strip thickness on the firmness, roots were sliced into two strip sizes (thickness), thin (0.9×0.9 cm) and thick (1.1×1.1 cm). This experiment consisted of three infusion treatments (Table Ia). Samples were subjected to two blanching processes, defined as: (1) Infiltration-Blanching-Infiltration (IBI) and (2)

TABLE IA.
DESCRIPTION OF THE BLANCHING PROCESS AND INFUSION TREATMENT FOR SWEETPOTATO FRENCH FRIES MADE FROM 'JEWEL' SWEETPOTATOES STORED FOR 3 MONTHS (EXPERIMENT 1)

Blanching Process ^a	Size ^b	Infusion treatment		Nomenclature
		Solution 1	Solution 2	
IBI	Thin (0.9 × 0.9 cm)	Water	> Water	Control ^c
IBB	Thick (1.1 × 1.1 cm)	0.05 M Na ₃ PO ₄	> 0.1 M NaC ₂ H ₃ O ₂	Phosphate ^d
		0.05 M Na ₃ PO ₄	> 0.1 M NaC ₂ H ₃ O ₂ + 0.6% CaCl ₂	Phosphate-calcium chloride ^e

TABLE IB.
DESCRIPTION OF THE BLANCHING PROCESS AND INFUSION TREATMENT FOR SWEETPOTATO FRENCH FRIES MADE FROM 'JEWEL' SWEETPOTATOES STORED FOR 1 YEAR (EXPERIMENT 2)

Blanching Process ^a	Size ^b	Infusion treatment		Nomenclature
		Solution 1	Solution 2	
IBI	Thin (0.9 × 0.9 cm)	Water	> Water	Control ^c
IBB		0.05 M Na ₃ PO ₄	> 0.1 M NaC ₂ H ₃ O ₂	Phosphate ^d
		0.05 M Na ₃ PO ₄	> 0.1 M NaC ₂ H ₃ O ₂ + 0.6% CaCl ₂	Phosphate-calcium chloride ^e

^aIBI = blanching between vacuum infiltrations (VI); IIB = blanching after sequential VI.

^bThin = 0.9 × 0.9 cm; thick = 1.1 × 1.1 cm. Lengths were not controlled. ^cBoth VI with water.

^dFirst VI for 10 min with 0.05 M trisodium phosphate, followed by a 10 min holding time in the same solution under atmospheric conditions; second VI for 10 min with 0.1 M sodium acetate buffer, followed by a 10 min holding time as described above.

^eFirst VI for 10 min with 0.05 trisodium phosphate, followed by 10 min holding time in the same solution under atmospheric conditions; second VI for 10 min with 0.1 M sodium acetate containing 0.6% calcium chloride, followed by holding time as described above.

Infiltration-Infiltration-Blanching (IIB). The strips were rinsed after each VI. After the first VI and rinse, the subsequent steps were: in the case of the IBI blanching process, to blanch the strips in water at 100C for 2 min and then VI with an acetate buffer solution; or in the case of the IIB blanching process, first infiltrate with the acetate solution and then blanch as described above (Fig. 1).

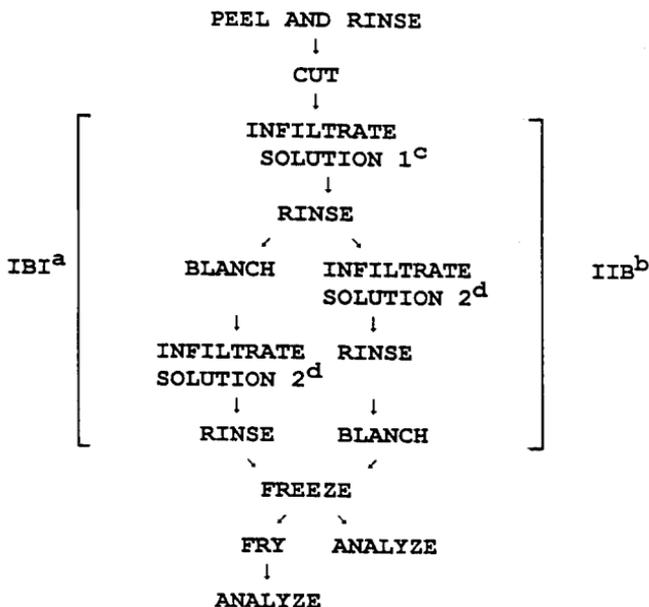


FIG. 1. PROCESS FLOW SHEET FOR SWEETPOTATO FRENCH FRIES

^aBlanching Process: IBI = blanching vacuum infiltrations (VI). ^bBlanching process: IIB = blanching after sequential VI. ^cVacuum infiltrate water for the control samples and phosphate solution for phosphate and phosphate-calcium chloride samples. ^dVacuum infiltrate acetate solution for the phosphate samples and an acetate-calcium chloride solution for the phosphate-calcium chloride samples.

Experiment 2: Sample Preparation

SP harvested in October 1992 and stored for approximately 1 year were sliced into strips 0.9×0.9 cm. Strips were treated as described in Table 1b. The same blanching processes described for experiment 1 were used.

For each part of the study, nonprefried (not prefried) samples were frozen at -20°C until tested. When required, frozen samples were deep-fried in vegetable oil for 2.5 min at a starting temperature of 180°C , which dropped to ca. 165°C and equilibrated at 170°C . In this manuscript, the term strip refers to the frozen but not fried samples, and the term SPFF refers to the resulting fried samples.

Moisture, Fat, and pH of Frozen Strips and SPFF

For both parts of the study, moisture of both the frozen nonfried strips and of the resulting SPFF was determined (AOAC 1990, section 984.25). The moisture (%) was calculated by the weight difference (this includes oil weight). A Soxhlet extraction (AOAC 1990, section 954.02) of samples previously dried for moisture was utilized to measure oil uptake. As the initial oil concentration of the strips was negligible (<1%), oil content and oil uptake were considered to be identical (Pinthus *et al.* 1993). The pH (AOAC 1990, section 981.12) of the frozen samples was determined using an Orion model 701A meter.

Tissue Firmness

For both experiments, firmness measured as shear force was tested at 25C using a Kramer shear cell coupled to an Instron Universal Testing Machine (Canton, MA) as described by Walter *et al.* (1992). Firmness for each sample was determined in triplicate.

Sugar Analyses

The liquid extract of alcohol-insoluble solids (Walter and Hoover 1984) containing the sugars (glucose, fructose, sucrose, and maltose) was used for analysis. For the quantification of sugars, 200 μL aliquots of centrifuged sample extract, 100 μL of cellobiose (internal standard), and 700 μL of deionized water were placed in 1 mL injection vials. Separation was carried out on a 4 mm \times 250 mm Dionex Carbopack PA1 column eluted with 0.15 M sodium hydroxide at 1 mL/min, using a Dionex HPLC System (Dionex Corp., Sunnydale, CA), operating with a pulsed amperometric detector. Output was processed with the LabCalc program (Galactic Enterprises, Salem, NH), and results expressed on a dry weight basis.

Sensory Analyses

For both parts of the study, the panels consisted of 30 to 36 members, 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 sweetpotatoes were selected. In addition, all panelists were generally familiar with taste panel procedures. Panelists were asked to rate SPFF for taste, texture, and overall acceptability (in that order) on a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. In addition, the questionnaire contained a section for panelist comments for each of the three attributes evaluated.

SPFF for sensory evaluation were prepared as previously described. Samples were covered with aluminum foil immediately after frying and held in 62C oven until served to panelists (within 15 min of preparation). Panelists were situated in

individual booths illuminated with red light (to mask any sample color differences) in a darkened room. At each sitting, four samples were served at random on partitioned plates with each sample coded with a three-digit number. There were three and two sensory panel replications, for experiments 1 and 2, respectively.

Statistical Analyses

For experiment 1, all physico-chemical data were subjected to a $2 \times 2 \times 4$ factorial in a Latin Square Design and analyzed using both the GLM and LSM procedures. For experiment 2, differences among variables and correlation coefficients for all data were generated using the General Linear Model (GLM) and Least Square Means (LSM) procedures (SAS 1989). A Lattice Design was applied to the sensory panel data, which was analyzed using the Mixed Model procedure (SAS 1989). Experiment 1 was replicated three times and experiment 2 was replicated twice.

RESULTS AND DISCUSSION

When the effect of varying the order in which the SP, stored for 3 months, were vacuum-infiltrated and blanched on the sensory attributes of the resultant SPFF was investigated, results showed (Table 2) that neither the order of blanching, between or after sequential VI, nor the infusion treatments, had a significant effect on the three sensory attributes tested. Size, however, affected the overall acceptability of the SPFF, as thinner SPFF were perceived as having a higher ($P = 0.0433$) overall acceptability than thicker ones, perhaps, because the moisture and fat content of SPFF was affected by the strip thickness.

Physico-chemical analyses of SP stored for 3 months (Table 3) showed that blanching between VI resulted in uncooked strips with significantly ($P = 0.001$) higher moisture than samples blanched after sequential VI. However, the order in which samples were blanched did not differ ($P > 0.05$) the moisture nor the fat content of the fried tissue. Infusion of the phosphate-calcium chloride solution decreased ($P = 0.0133$) the moisture of the uncooked strips, but the absolute differences were so slight as to be unimportant. Upon frying, infusion of the phosphate solution and the phosphate-calcium chloride solution decreased ($P = 0.0002$) the moisture of the resulting SPFF.

In the case of SP stored for 1 year, results indicated (Table 4) that the IIB order of processing the SP produced SPFF that were perceived as having significantly higher overall acceptability ($P = 0.0219$) and taste ($P = 0.0180$) than the SPFF produced using the IBI process. However, the order of processes did not significantly affect the panelists' perception of texture.

TABLE 2.
SENSORY PANEL SCORES* OF SWEETPOTATO FRENCH FRIES MADE FROM 'JEWEL'
SWEETPOTATOES STORED FOR 3 MONTHS (EXPERIMENT 1)

Sensory Attributes^e

Variables	Taste	Texture	Overall Acceptability
Blanching process^b			
IBI	6.36a	6.15a	6.58a
IIB	6.72a	6.28a	6.75a
Infusion treatment			
Control ^c	6.72a	6.05a	6.80a
Phosphate	6.75a	6.36a	6.77a
Phosphate-Calcium Chloride	6.28a	6.19a	6.58a
Size^d			
Thin	6.43a	6.00a	6.47b
Thick	6.62a	6.43a	6.86a

*On a 9-point hedonic scale, where 9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely.

^bIBI = blanching between vacuum infiltrations (VI); IIB = blanching after sequential VI.

^cControl = both VI with water; phosphate = first VI with phosphate solution, second VI with acetate solution; phosphate-calcium chloride = first VI with phosphate solution, second VI with an acetate-calcium chloride solution.

^dThin = 0.9 × 0.9 cm; thick = 1.1 × 1.1 cm. Lengths not controlled.

^ea, b = Means within columns for each variable not followed by the same letter differ (P < 0.05).

The effect of infiltrating SP with a phosphate buffer followed by an acetate buffer, as opposed to infusing with a phosphate buffer followed by an acetate buffer containing calcium chloride, on the sensory attributes of SPFF was also evaluated. Sensory data showed (Table 4) that the use of phosphate alone produced SPFF that were perceived to have significantly (P = 0.0003) higher texture acceptability than either the control (water infiltration) or the combination of phosphate and calcium infiltrations. No differences were found in the perception of taste or overall acceptability due to the infusion treatment.

Since there were no significant differences between the IBI and IIB order of processing on the sensory attributes of SPFF produced from SP stored for 1 year, only the IBI processed SPFF were further analyzed for moisture, fat, and for shear force (firmness). In addition, uncooked samples representing the same treatments were analyzed for moisture.

Data (Table 5) showed that the raw samples had different (P = 0.0013, but

TABLE 3.
 PHYSICO-CHEMICAL COMPOSITION AND SHEAR FORCE OF UNCOOKED STRIPS AND SWEETPOTATO FRENCH FRIES
 MADE FROM 'JEWEL' SWEETPOTATOES STORED FOR 3 MONTHS (EXPERIMENT I)

Variables	Uncooked strips		Fried strips					Total	Shear force at at 25C, kg
	Moisture, %	Moisture, %	Fat, % ^a	Fructose	Maltose	Sugars, %			
Blanching process^b									
IIB	80.48a	51.64a	7.99a	3.63b	13.69b		39.95b	42.56b	
IIB	77.37b	50.44a	6.60a	3.96a	15.20a		43.08a	53.10a	
Infusion treatment^c									
Control	79.00a	54.35a	6.79b	3.86a	15.01a		42.61a	28.63b	
Phosphate	79.54a	49.23b	7.91a	3.80a	14.55a		41.74a	54.51a	
Phosphate-calcium chloride	78.12b	50.31b	7.20b	3.64a	14.00a		40.04a	55.06a	
Size^d									
Thin	79.24a	48.02b	7.64a	3.76a	13.51b		40.76a	47.07b	
Thick	78.61b	54.06a	6.94b	3.83a	15.38a		42.27a	48.59a	

^aResults expressed as wet weight basis.

^bIIB = Blanching between vacuum infiltrations (VI); IIB = blanching after sequential VI.

^cControl = both VI with water; phosphate = first VI with phosphate solution, second VI with acetate solution; phosphate-calcium chloride = first VI with phosphate solution, second VI with an acetate-calcium chloride solution.

^dThin = strips 0.9 × 0.9 cm; thick = 0.11 × 0.11 cm.

^ea, b = Means within columns for each variable not followed by same letter differ (P < 0.05).

TABLE 4.
SENSORY PANEL SCORES* OF SWEETPOTATO FRENCH FRIES MADE FROM
SWEETPOTATOES STORED FOR 1 YEAR (EXPERIMENT 2)

Variables	Sensory attributes ^d		
	Taste	Texture	Overall Acceptability
Blanching process^b			
IBI	5.8b	5.3a	6.0b
IIB	6.2a	5.7a	6.4a
Infusion treatment^c			
Control	6.2a	5.4b	6.3a
Phosphate	5.9a	6.1a	6.3a
Phosphate-calcium chloride	5.9a	5.0b	5.9a

*On a 9-point hedonic scale, where 9 = like extremely, 5 = neither like nor dislike, and 1 = dislike extremely.

^bIBI = Blanching between vacuum infiltrations (VI); IIB = blanching after sequential VI.

^cControl = both VI with water; phosphate = first VI with phosphate solution, second VI with acetate solution; phosphate + calcium = first VI with phosphate solution, second VI with an acetate-calcium chloride solution.

^da, b = Means within columns for each variable not followed by the same letter differ ($P < 0.05$).

differences too small to be meaningful) levels of moisture, such that the phosphate treated product had the greatest moisture (84.87%) level followed by the control (84.29%) followed by the phosphate-calcium treatment (83.64%). When these samples were fried, large differences in moisture were found. In the fried samples, the control had the highest moisture (63.93%); the phosphate-treated samples had a 57.43% and the phosphate-calcium treated samples had a 46.52% moisture level. The fat content (Table 5) in the fried samples showed the opposite and significant ($P = 0.0001$) effect. The control absorbed the least fat (9.49%), the phosphate had the next lowest fat content (15.20%), and the phosphate-calcium chloride-treated SPFF had the highest fat content (23.89%). This is consistent with literature data which reflects that, as the moisture is removed from the strip during frying, there is a replacement with fat (Gamble *et al.* 1987; Hoover and Miller 1973). Also, factors such as pre-frying treatments, porosity, and product chemistry could have affected the amount of moisture released and oil uptaken (Pinthus *et al.* 1993).

With regard to firmness, for SP stored for 3 months, results showed (Table 3) that blanching after sequential VI significantly ($P = 0.0001$) increased shear force of the SPFF. Infusion with phosphate and phosphate-calcium chloride solutions almost doubled the shear force (significant increase, $P = 0.0001$) compared with the

TABLE 5.
PHYSICO-CHEMICAL COMPOSITION AND SHEAR FORCE OF THIN^a IBP^b SWEETPOTATO STRIPS MADE FROM
'JEWEL' SWEETPOTATOES STORED FOR 1 YEAR (EXPERIMENT 2)

Infusion treatment ^c	Blanched strips		Fried strips		Shear force at 25C, kg
	Moisture, %	Moisture, %	Fat, % ^e	Moisture, %	
Control	84.29b	63.93a	9.49c		31.40c
Phosphate	84.87a	57.43b	15.20b		57.00b
Phosphate + calcium chloride	83.64c	46.52c	23.89a		74.20a

^aStrips with thickness of 0.9 × 0.9 cm. Length not controlled.

^bBlanching between vacuum infiltrations (VI).

^cResults expressed on wet weight basis.

^dControl = both VI with water; phosphate = first VI with phosphate solution, second VI with acetate solution; phosphate + calcium = first VI with phosphate solution, second VI with an acetate-calcium chloride solution.

^ea,b,c = Means within columns followed by the same letter are not different (P < 0.05).

water-infused control SPFF. Even though, instrumental data showed differences in tissue firmness, sensory data indicated that neither the sequence of blanching nor the infiltration treatments affected the taste, texture, or overall acceptability of SPFF made from SP stored for 3 months.

Results of the shear force (firmness) analysis (Table 5) of SPFF made from SP stored for 1 year indicated that infiltration with the combination of phosphate and calcium produced SPFF with a significantly ($P = 0.0001$) greater level of firmness than that found with the phosphate treatment or the control samples. This data in conjunction with the texture evaluation in the sensory data indicated that the most acceptable texture was not found in samples with the highest shear value. The most acceptable texture was found in the samples with the moderate level of shear force. This indicates that there may be an optimal level of shear force that gives the "right" amount of resistance to chewing.

Sugars were measured in order to determine if the blanching process and the infusion solutions affected the glucose, fructose, sucrose, and maltose content of the frozen strips made from SP stored for 3 months. Sucrose and glucose were not affected by the blanching process (IBI nor IIB), and none of the sugars were affected by the infusion treatments. However, results indicated that fructose and maltose concentrations were higher ($P < 0.003$) for strips blanched after sequential VI, which resulted in significantly higher total sugars for the IIB blanching process. The effect of the order of blanching on the sugar content could be attributed to the tissue pH during blanching. That is, for the IBI process, the tissue pH at the point of blanching is ca. 7.0 (Walter *et al.* 1993); the optimum pH for sweetpotato amylases is ca. 5.8 (Hagenimana *et al.* 1994). Hence, the neutral environment would have decreased amylolytic activity. On the other hand, the IIB process returned the pH of the tissue to ca. 6.0 before any heat treatment took place. Therefore, most likely the enzymes would have been more active. The strip thickness also influence the maltose content which was higher ($P = 0.0121$) in thicker samples. Possibly, because for this size the strip internal temperature was within the optimum range for amylolytic hydrolysis of starch for a longer period of time than that of the thin strips.

These differences in sugars did not affect the taste sensory results, as panelists did not perceive a difference in taste acceptability due to the blanching process, the infusion treatment or the size of the SPFF.

CONCLUSIONS

Firmness of French fries made from SP stored for 3 months before processing was increased (compared to roots which were not treated) by vacuum infiltrating a phosphate salt, neutralizing the tissue, and blanching. However, sensory panelists did not perceive the texture to be more acceptable than the control. Similarly, increased firmness retention was also demonstrated for the roots stored 1 year prior to processing. In this case, the phosphate-treated SPFF were perceived by sensory

panelists as having more acceptable texture than the control. On the other hand, sensory panel scores for all attributes were higher for the 3 month samples than for the 1 year samples, indicating that SP stored for a long period of time result in lower quality SPFF. Comparing shear force data with texture evaluation (sensory data) showed that the most acceptable texture was found in the samples with moderate levels of shear force, not the highest shear force levels. This indicates that there may be an optimal level of shear force that gives the "right" amount of resistance to chewing, thus resulting in a more acceptable product.

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