Textural Properties and Sensory Quality of Processed Sweetpotatoes as Affected by Low Temperature Blanching

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ABSTRACT

Sweetpotatoes (SP) stored for 9–12 mo after harvest were cut into cylindrical pieces and, following factorial experiments and response surface design, were blanched at 50–80°C for 15–274 min. Instrumental textural properties were measured by uniaxial compression and texture profile analysis. Samples of selected blanching treatments were canned in syrup for textural and sensory evaluations. Both blanching temperature and time had significant effects on firmness. Optimal temperature for maximal firmness retention was about 62°C. For canned SP, the 62°C blanched samples were more intact (2–3-fold) and firmer (2–7-fold) than controls. Sensory texture and overall acceptability were greatest for samples blanched at 62°C for 30 or 45 min before canning.

Key Words: sweetpotato texture, low-temperature blanching, canned foods, sensory

INTRODUCTION

TEXTURAL PROPERTIES OF PROCESSED SWEETPOTATOES (SP) DEpend on the length of time the roots are stored before processing. SP are canned only for a short period each year because those processed after being stored a few months tend to soften and disintegrate. Increased firmness retention of processed SP has been accomplished by calcium chloride treatment, and vacuum infiltration with acids or bases has been reported (Bouwkamp, 1985; Walter et al., 1992, 1993). We hypothesize that low-temperature blanching (LTB) treatment without additives should have a good potential to increase the firmness retention in cooked and canned SP.

The beneficial effects of LTB in increasing firmness of processed fruits and vegetables long have been recognized and applied commercially for canned snap beans and canned or frozen cauliflower, tomatoes, potatoes, and carrots. The maximal firming effects on these vegetables could be obtained by blanching at 55–80°C for times ranging from a few minutes to several hours. This firming effect has been attributed to the action of pectin methyl esterase (PME) on cell wall materials, particularly pectic substances, resulting in the de-esterification of carboxyl groups in pectin molecules and cross-linking between carboxyl groups and calcium ions (Van Buren, 1979). Several models have been proposed to explain interactions of pectin molecules with divalent ions and other cell wall components as affected by heat treatment (Bartolome and Hoff, 1972; Grant et al., 1973; Chang et al., 1993). However, the mechanisms of firming, as well as softening, in thermally processed plant foodstuffs are not well understood. McFeeters and Fleming (1989) hypothesized that conformational changes of pectin molecules may be an important factor in tissue softening in acid-brined cucumbers. Parker and Waldron (1995) hypothesized that the phenolic and cell wall cross-links were involved in the thermal stability of the texture of Chinese water chestnut.

Reports on LTB effects on textural properties and microstructure of canned and frozen carrots, potatoes, and green beans have been published (Anderson et al., 1994; Fuchigami et al., 1995; Stanley et al., 1995). LTB has been applied to peppers, stem vegetables, and bananas (Wu and Chang, 1990; Dominguez et al., 1996; Jackson et al., 1996; Howard et al., 1997). However, such information on SP is limited. Being a starchy material with high amylase activity, the textural changes due to heat treatment in SP may be different from effects on other vegetables or fruits.

Our objectives were: (1) to determine if the firmness of cooked SP could be controlled by LTB without food additives, (2) to determine the optimum blanching conditions for maximizing firmness retention using response surface methodology, and (3) to evaluate the effects of LTB on textural changes and sensory acceptability of canned SP.

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MATERIALS AND METHODS

Sample preparation

Jewel cultivar SP were utilized. The roots (6.0–7.5 cm diam) were cured (30°C, 75–85% RH for 7 days) and stored at 13–16°C and 80–90% relative humidity for 9–12 mo prior to use. Middle portions of each root were cut perpendicular to the long axis into 3.5 cm thick sections. Using a no. 10 cork borer, cylindrical samples (1.35 cm) were taken from the section. Samples were taken from the inner tissue of the roots at about 1 cm from the root skin (Truong et al., 1997).

Low temperature blanching was performed by submerging samples in tap water at 50–80°C for 15–274 min, cooling in ice water for 5 min, and draining. Control treatments were: (a) unblanched and (b) blanched in boiling water (BW) for 2 min and quickly cooled. Half of each sample was steam-cooked at atmospheric pressure for 20 min, while the other half was uncooked. Both uncooked and cooked samples were subjected to instrumental texture measurements.

For canned SP, the cylindrical pieces were blanched at 62°C for 30, 45, 60, or 90 min and cooled in ice water. The materials (ca 250g) were placed in cans (no. 303, "C" enamel), filled with 30° Brix sucrose syrup, exhausted for 5 min, sealed, and retorted for 35 min at 103.4 kPa. The cans were stored for 4 wk at room temperature before instrumental and sensory analysis.

Instrumental measurements

The cylindrical pieces were trimmed to a height of 2.2 cm prior to texture measurement. Uniaxial compression tests and texture profile analysis (TPA) were performed at ca 25°C using a Texture Analyzer TA.XT2 (Texture Technologies Corp., Scarsdale, New York/ Stable Microsystems, Hoslemere, Surrey, United Kingdom). The instrument was fitted with a TA-25 probe (5.0 cm diam cylinder). The specimen was compressed longitudinally for 75% of its initial height at a constant crosshead speed of 1.6 cm/sec. The waiting time between the 2 cycles of the TPA tests was 5 sec. Data collection and calculation were accomplished electronically by the XTRAD Dimension software of the TXA.XT2. TPA fracturability, hardness, adhesiveness, cohesiveness, and gumminess were calculated (by software) following the definitions described by Bourne (1978). Springiness was calculated as the proportion of compression distance recovered between the first and the second compression. For uniaxial compression tests, the data from the force-deformation curves were peak force (firmness) and deformation at failure. Fracture shear strain was calculated as described by Hamann and Foegeding (1994). At least 20 measurements were performed for each set of samples.

Sensory evaluation

Cans of cylindrical SP pieces were shaken 5 times before opening to simulate commercial handling of canned SP. The cylindrical pieces were separated from the syrup, drained 5 min, and placed in small plastic cups labeled with 3-digit random numbers.

Samples were submitted to an untrained sensory panel for intensity and acceptance tests following a completely randomized design (CRD) with 2 replications. The panel had 51 members (32 female, 19 male, aged 20–64) who like SP. They were recruited from faculty, staff, and students from the Dept of Food Science at North Carolina State Univ. Each panelist received 3-4 cylinders (1.3.5 × 3.5 cm) of canned samples (15–20 g) per treatment. At each session, panelists evaluated 4 samples which were served one at a time in random order. At each testing, panelists were asked to evaluate each sample for: (a) firmness intensity on a 9-point intensity sale (9=very firm, 1=very soft), and (b) texture, flavor, and overall acceptability using a 9-point hedonic scale (9=like extremely, 1=dislike extremely). Panelists were provided water for rinsing and palate cleaning. All sessions were conducted in sensory panel booths under fluorescent white light.

Disintegration index

A weighed aliquot of syrup from canned SP was centrifuged at 26,890 × g for 20 min. The supernatant was decanted and the sediment was weighed. Disintegration index (DI) was calculated as g sediment/100g syrup.

Experimental design and data analysis

Initial 4 × 4 factorial experiments in CRD with blanching temperatures of 50, 60, 70, and 80°C and times of 45, 90, and 150 min were performed and analyzed to examine main and interaction treatment effects. Based on the results, a second series of experiments were conducted following a central composite design (CCD), with blanching temperature (55–75°C) and blanching time (146.4–273.6 min) as independent variables. The design required 13 variable combinations, including 5 replicates of the center region to generate a second order response surface (Myers and Montgomery, 1995). Model fitting was performed to determine optimum blanching conditions for maximizing firmness retention in cooked SP. Independent variable terms ($P \leq 0.05$) in the full model were retained in the reduced model for generating contour plots. Data from physical measurements and sensory evaluation were analyzed by analysis of variance using General Linear Models Procedure. Differences ($P \leq 0.05$) between treatment means were determined by Least Square Means Procedure. All statistical analyses and graphics were performed using the Statistical Analysis System (SAS Institute, Inc., 1994). The Taguchi's signal to noise ratio (SNR) was calculated according to Gacula (1993):

$$SNR = -10 \log \{(1/y^2)(1 + 3s^2/y^2)\}$$

where y and s^2 are sample mean value and variance, respectively.

RESULTS & DISCUSSION

Effects of blanching temperature and time

Typical force-deformation curves of cylindrical SP specimens were compared (Fig. 1). The fresh SP (unblanched, uncooked) exhibited curves with steep slope and sharp peak force at fracture (Fig. 1a), a typical deformation pattern of stiff plant materials under loading. The fracture was the shear type along 45° rupture plane, as previously reported (Truong et al., 1997). Similar force-deformation curves and fracture type under uniaxial compression have been reported in fresh apples and potatoes (Khan and Vincent, 1993). It has been recognized that, in raw plant tissue, cell turgor pressure and cell wall strengths account for tissue stiffness and the mode of failure (Lin and Pitt, 1986). High temperature blanching disrupts cell integrity and cell adhesion, resulting in decrease in tissue rigidity. The SP samples blanched in BW were softer than the fresh SP, as exhibited by less steep curve with low fracture force (Fig. 1a). However, the two samples behaved similarly after steam-cooking.

For samples blanched at 60°C, there was a transition in the shape of the force-deformation curves as blanching time lengthened. The graphs of both uncooked (Fig. 1a) and steam-cooked (Fig. 1b) LTB samples exhibited a nonlinear increase in force at the beginning of compression, especially for samples blanched for >45 min. They then increased linearly to peak forces higher than those of fresh and BW blanched samples. LTB resulted in increased deformation before rupture. It appears that the materials were deformed and compacted during the initial force loading, and the compacted mass then began to behave as a viscoelastic solid, as indicated by a linear and sharp increase in force with deformation until fracture. Aside from shear fracture, compressive failure was observed in many samples. Furthermore, a bioyield point, defined as the first initial peak in the force-deformation curve, was noted in most curves of the cooked samples blanched at 60°C for 90 min (Fig. 1b) and longer (data not shown). Jackman and Stanley (1992) hypothesized that the bioyield in green and ripe tomato tissue could be due to compaction of interstitial air spaces or plastic deformation of the middle lamella which allowed cell re-arrangement during compression. In canned green beans, difference in resistance to force between the lignified, thick-wall sclereid cells close to the bean surface and the underlying tissue possibly accounted for the occurrence of bioyield (Stanley et al., 1995). Studies on changes in cell wall components and microstructure of SP tissue need to be addressed to better understand the cause and significance of bioyield as affected by LTB.

The mean values of fracture force and strain of SP blanched at various temperatures and times were compared (Fig. 2). For uncooked samples (Fig. 2a), blanching at 50°C had no effect ($P \geq 0.05$) on fracture force. At 70°C or higher, decreases in firmness occurred ($P \leq 0.05$), suggesting that thermal disruption of SP tissue during blanching exceeded the firming effect. Apparently, the blanching temperatures which resulted in increases in firmness were in the 60°C range. This firming effect increased with blanching time, especially from 45 to 150 min. For the steam-cooked samples (Fig. 2b), there was no difference ($P \geq 0.05$) in fracture force among the unblanched SP, the samples blanched at 50°C, 80°C and in BW. However, firmness of the samples blanched at 60°C and 70°C was higher ($P \leq 0.05$) than unblanched-cooked SP. Analysis of variance showed main and interaction effects ($P \leq 0.001$, Table 1). Compared to the unblanched-cooked SP, the steam-cooked samples of the SP blanched at 60°C and 70°C for 45–150 min were about 4.2–13.6-fold and 3.8–6.2-fold firmer, respectively (Fig. 2b). With regards to deformation before rupture, blanching at 50°C, 70°C, 80°C, and in BW did not result in changes ($P \geq 0.05$) in fracture strain of materials as compared to unblanched SP. However, blanching at 60°C, particularly for 45 min or longer, increased ($P \leq 0.001$) the fracture strain in both uncooked

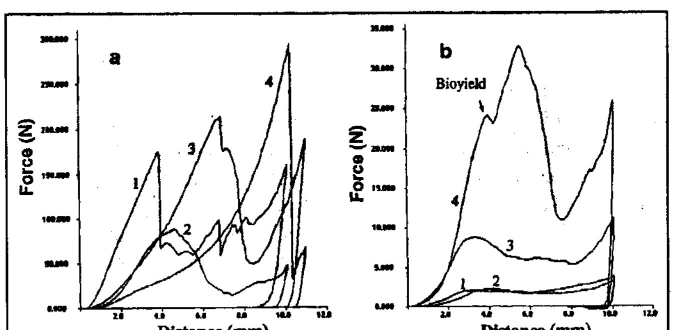

Fig. 1—Force-deformation curves of uniaxial compression tests: (a) uncooked sweetpotato = unblanched or blanched samples without subjecting to further cooking, and (b) steam-cooked sweetpotatoes = unblanched or blanched samples which were cooked by steaming. 1 = unblanched, 2 = blanched in boiling water for 2 min, 3 = blanched at 60°C for 45 min, 4 = blanched at 60°C for 150 min.

and steam-cooked samples (Fig. 2c and 2d). It appears that a stronger "gel" was formed in the 60°C blanched SP. These samples behaved as elastic solids and had tough (rigid and deformable) texture. Springiness and gumminess were higher ($P \leq 0.001$) than those of unblanched and BW blanched treatments (Fig. 3).

TPA fracturability and hardness exhibited similar trends (data not shown) and correlated highly with compression peak force (r=0.969–0.974). The 60°C blanching treatment showed a similar firming effect on the commercial cultivars, Beauregard and Hernandez (Fig. 4). Demethylation of pectin by PME may not be the only mechanism of such pronounced firming effect of LTB in SP. PME in SP tissue has long been known to have a relatively low inactivation temperature. The enzyme activity has been markedly reduced after preheating at 60°C for 30 min and completely inactivated at 70°C for 15 min, followed by lye peeling. Quite different results were found for our 60°C blanched treatment (Fig. 2b and 4).

Table 1—ANOVA for firmness of blanched-cooked sweetpotatoes from the factorial experiments with added controls

Source of variation	D.F.	S.S.	M.S.	F	Pr > F
Replication	1	3.58	3.58	0.57	0.46
Controls	1	0.002	0.002	0.0003	0.985
Control vs treatments	1	110.63	110.63	17.64	0.0006
Temperature	3	752.46	250.82	40.00	0.0001
Time	3	376.62	125.54	20.02	0.0001
Temperature x time	9	453.15	48.35	7.71	0.0002
Residual	17	106.60	6.27		
Total	35	1785.10			

Optimization of blanching conditions

Based on our results, the steepest ascent procedure (Meyers and Montgomery, 1995) was used to estimate the ranges of blanching temperatures and times for response surface evaluation. The treat-

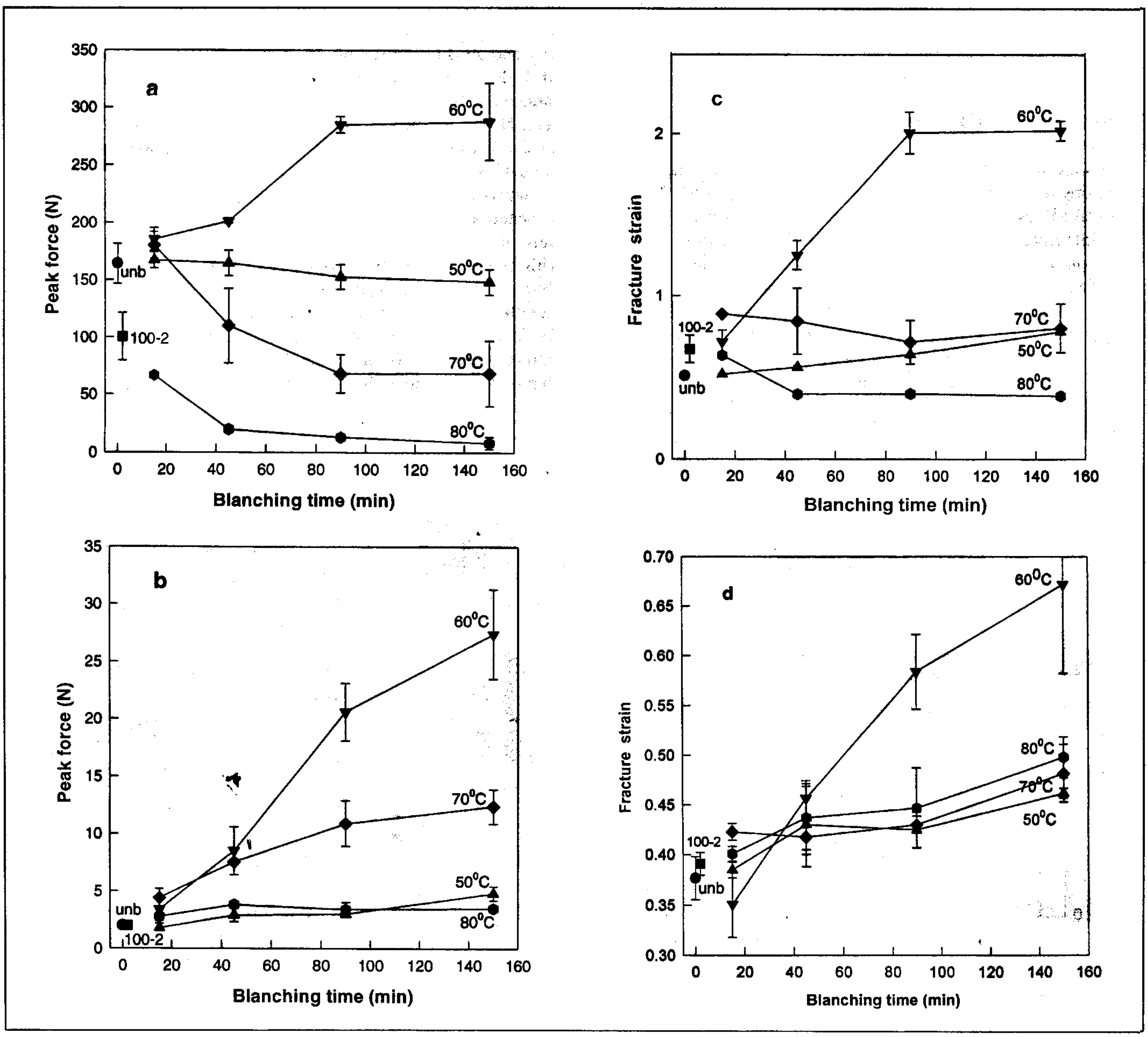

Fig. 2—Effects of blanching temperature and time on firmness of uncooked (a) and steam-cooked sweetpotatoes (b), and deformation of uncooked (c) and steam-cooked sweetpotatoes (d). Unb=unblanched, 100-2=blanched in boiling water for 2 min.

ment combinations and the mean values of the corresponding fracture force of the blanched-cooked samples were compiled (Table 2). Multiple regression analysis resulted in the following full model ($P \leq 0.05$, $R^2=0.865$) for the two independent variables, blanching temperature and time:

$$\text{Fracture force} = -1139.2 + 34.745\,(\text{Temp}) + 0.771\,(\text{Time}) - 0.261\,(\text{Temp})^2 + 0.004\,(\text{Time})^2 - 0.011\,(\text{Temp} \times \text{Time}) \quad (1)$$

$$\text{Fracture force} = -1017.34 + 32.892\,(\text{Temp}) + 0.189\,(\text{Time}) - 0.265\,(\text{Temp})^2 \quad (2)$$

Stepwise regression analysis resulted in a reduced model (Eq 2) with significant linear and quadratic terms for temperature and a significant linear term for time. The reduced model was not different ($P \geq 0.05$, $R^2=0.854$) from the full model, based on the F-test. It was used to generate the contour plot of firmness (peak force in Newton) as a function of temperature and time (Fig. 5). For the ranges of temperatures (55–75°C) and times (146.4–273.6 min) used in the CCD experiments, blanching temperature apparently had a stronger effect on SP firmness than blanching time. The firmness increased linearly with blanching time. Optimum temperature for LTB firming effect was calculated at about 62°C. Taguchi et al. (1991) reported that 75°C prewarming for 30 min gave maximum firmness retention in boiled potato. Our result was, however, in the range of 60–70°C, reported for other vegetables (Lee et al., 1979; Chang et al., 1986; Fuchigami et al., 1995; Jackson et al., 1996).

Texture profiles and sensory acceptability of LTB-canned SP

We determined firmness after LTB and canning to find out how processing affected the sensory quality of the canned SP. The 62°C blanched SP (cv Jewel) were canned in 30° Brix syrup and analyzed for disintegration, instrumental texture profiles, and sensory quality. The amount of SP particles and broken parts in the drained syrup of canned SP was taken as an index of the tendency of product sloughing or disintegration and termed the disintegration index (DI). Blanching appeared to have an effect on reducing disintegration. Samples blanched in BW and at 62°C had DI values one-half and one-third that of the unblanched SP, respectively (Table 3).

Table 2—Coded and uncoded variables of the response surface design and the peak force values of the blanched-cooked sweetpotatoes

	Code		Conditions		
Design point	X1	X2	Temperature (C)	Time (min)	Peak force (N)
1	-1	-1	60	165	41.4
2	-1	1	60	255	63.2
3	1	-1	70	165	19.2
4	1	1	70	255	30.7
5	1.414	0	75	210	3.9
6	-1.414	0	55	210	22.5
7	0	1.414	65	273.6	51.3
8	0	-1.414	65	146.4	26.8
9	0	0	65	210	40.2
10	0	0	65	210	35.1
11	0	0	65	210	47.4
12	0	0	65	210	38.7
13	0	0	65	210	39.8

For texture profiles, samples blanched at 62°C for 45 min or longer had higher fracturability and hardness, and, therefore, were firmer than controls (Table 3). As with the blanched-cooked samples, firmness in the canned samples also increased with blanching time. Fracturability values of the LTB samples were about 1.8–8.0-fold higher than those of controls. The 62°C-90 min blanched samples had a firm and gel-like texture which may not be desirable for canned SP. LTB also caused increases in springiness and gumminess of the canned SP. However, it had no effects on cohesiveness or adhesiveness. However, the two controls had similar values of all TPA parameters (Table 3), suggesting that high temperature blanching (BW) did not increase firmness retention.

Sensory evaluation was performed on canned samples of unblanched and three LTB treatments. Scores for firmness (Table 4) were in accordance with the instrumental data and correlated highly with TPA fracturability ($r=0.988$) and hardness ($r=0.940$). Acceptability scores for sensory texture of the LTB samples were higher than those for the unblanched treatment. Among the LTB samples, the 45 min blanching resulted in canned product with the highest texture score. For overall acceptability, samples blanched for 30 and 45 min were scored highest. Flavor scores for all tested samples were

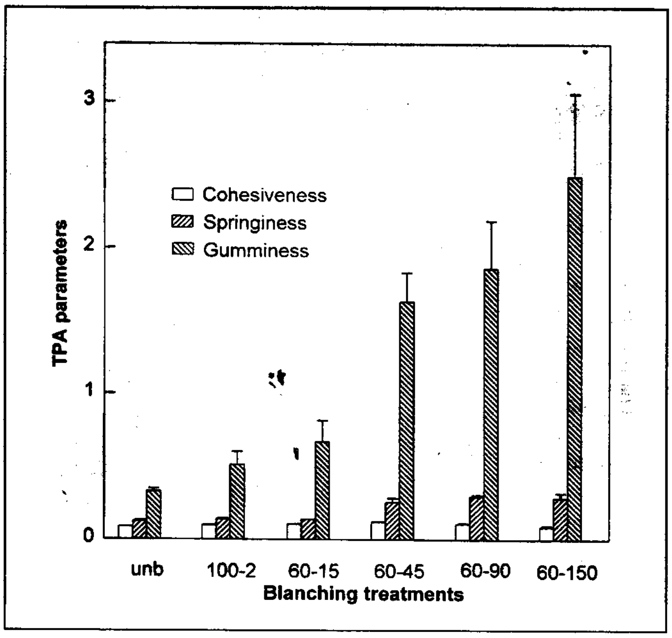

Fig. 3—Effect of blanching treatments on instrumental texture profile values of steam-cooked sweetpotatoes. Unb=unblanched, 100-2=blanched in boiling water for 2 min; 60-45, 60-90, and 60-150=blanched at 60°C for 45, 90, and 150 min.

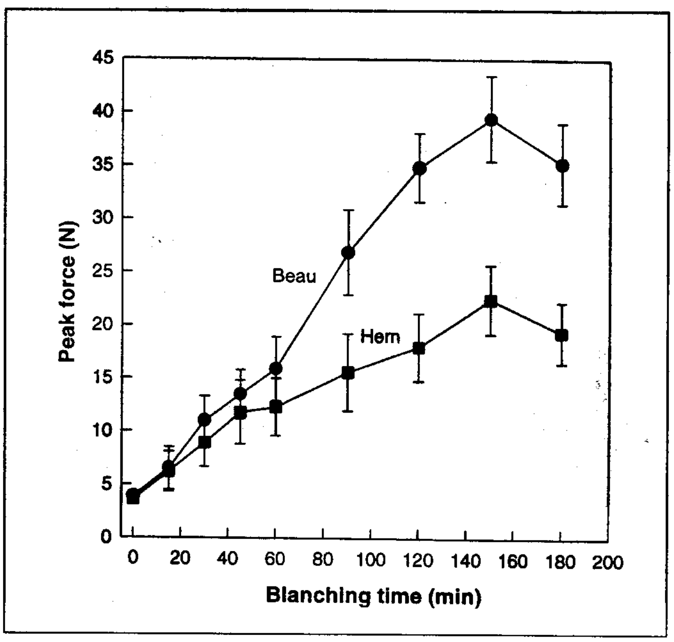

Fig. 4—Firming effects of 60°C blanching for various times on steam-cooked samples of Beauregard (Beau) and Hernandez (Hern) cultivars of sweetpotatoes.

Table 3—Mean values of disintegration index (D.I.) and instrumental texture profile parameters of unblanched and blanched, canned 'Jewel' sweetpotatoes[a]

Treatment	D.I. (mg/100g)	Fracturability (N)	Hardness (N)	Cohesiveness	Adhesiveness (mJ)	Springiness	Gumminess (N)
Unblanched	275.00a	0.67c	1.84c	0.11ns[b]	0.22ns[b]	0.14b	0.20b
Blanched							
100°C, 2 min	170.00b	0.67c	1.97c	0.11	0.2	0.14b	0.22b
62°C for:							
30 min	78.50c	1.14c	2.14c	0.11	0.18	0.16bc	0.24b
45 min	67.90c	2.40b	3.03b	0.11	0.15	0.19ac	0.30b
60 min	64.30c	3.13b	4.25a	0.10	0.15	0.19ac	0.44a
90 min	78.60c	5.00a	4.92a	0.11	0.16	0.22a	0.52a

<[a]Means in the same column with a common letter are not significantly different (P>0.05).
[b]ns = not significant.

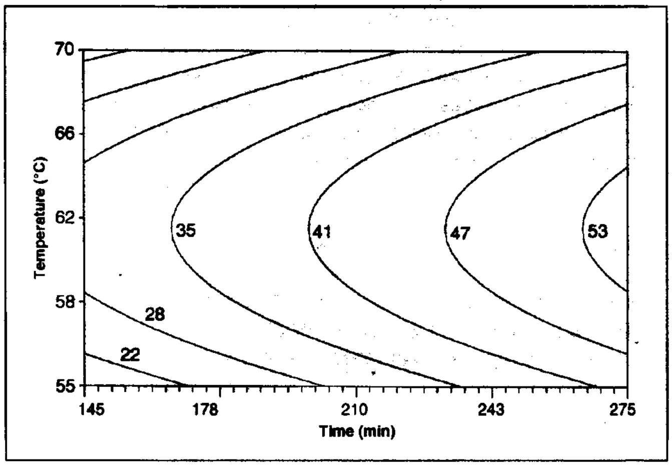

Fig. 5—Contour plot of peak force at fracture of blanched-cooked sweetpotatoes as a function of blanching temperature and time. Number on each contour line indicates the peak force value in Newtons.

not different. Results from ANOVA were supported by Taguchi's signal to noise ratio values, which take into account the variability of individual sensory scores and measure the robustness of the data (Gacula, 1993). In this ratio, the larger values of SNR indicate more effects of the treatment (signal) and less of the noise (random/systematic error). As indicated (Table 4), the SNR values of samples blanched at 62°C for 30 and 45 min were greatest. Therefore, blanching SP at 62°C for 30–45 min before canning was beneficial in improving sensory acceptability, and retaining firmness and wholeness of canned SP.

CONCLUSIONS

A WIDE RANGE OF FIRMNESS IN COOKED AND CANNED SP COULD be obtained by LTB prior to processing. Both blanching temperature and time had significant effects on firmness of products. Optimum temperature was about 62°C blanching which retained firmness, wholeness, and sensory quality of SP canned after long-term storage. This process would provide processors an opportunity to improve quality of canned product of SP roots after long-term storage, thus considerably extending the canning season. Furthermore, use of this process would help facilitate development of other processed products from SP.

Table 4—Mean sensory scores and SNR of unblanched and LTB blanched-canned 'Jewel' sweetpotatoes[a]

Treatment	Firmness[b]	Texture[c]	Flavor[c]	Overall[c]	SNR[d]
Unblanched	1.8d	4.7d	5.9ac	5.1d	12.8
Blanched at 62°C for:					
30 min	2.8c	5.5c	6.0a	5.7ab	14.0
45 min	4.1b	6.3a	6.0a	6.0a	14.5
60 min	4.8a	5.8b	5.5bc	5.5bc	13.8

[a]Mean values in same column with common letter are not significantly different (P > 0.05).
[b]Intensity scale: 1=very soft; 9=very firm.
[c]Hedonic scale: 1=dislike extremely; 9=like extremely.
[d]SNR=signal to noise ratio.

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Ms received 7/18/97; revised 12/12/97; accepted 2/12/98.
We express our appreciation to Dr. Francis G. Giesbrecht and Dr. David A. Dickey, Dept. of Statistics, NCSU, for statistical advice.