Effect of Pre-Processing Storage Conditions on the Composition, Microstructure, and Acceptance of Sweet Potato Patties

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ABSTRACT

'Jewel' and 'Centennial' sweet potatoes were processed into frozen patties at harvest, after curing 1 wk, and after curing and storing up to 26 wk. Sugar, starch, and pectin contents were determined on raw roots, cooked slices, and finished patties. The starch content after cooking was correlated with consumer acceptance and is the most important factor in the preparation of a patty of consistent quality from both fresh and stored roots. Scanning electron microscopy showed that in the cooked, pureed sweet potatoes most of the cells had been ruptured and that the patty was held together by an amorphous matrix consisting of added ingredients and spilled cellular contents.

INTRODUCTION

SWEET POTATOES in the form of pre-cooked, frozen patties are presently manufactured only during the harvest season since stored roots undergo internal changes which make production of a patty of consistent quality difficult. The nature of these changes is due in part to the increase in activity during storage of amylolytic enzymes (Walter et al., 1975). These enzymes cause starch breakdown during cooking and thereby strongly influence the textural properties and flavor of the processed product. It is likely that other as yet undefined microstructural changes mediated by storage may also affect the flavor and texture of the final product.

An earlier paper described the ingredients and processing conditions necessary to produce consumer acceptable patties from freshly harvested, cured, and cured and stored 'Jewel' and 'Centennial' sweet potatoes (Hoover et al., 1983). The present study was undertaken to evaluate the effect of processing steps and storage history on the carbohydrate content and microstructure of sweet potatoes and sweet potato patties.

MATERIALS & METHODS

Sweet potato patties

The patties were prepared from 'Jewel' and 'Centennial' sweet potatoes which were freshly harvested, cured 1 wk at 32°C and 80-90% relative humidity (RH), and cured roots held for up to 6 months at 13-16°C and 80-90% RH (Wilson et al., 1980). The patty preparation process was as described by Hoover et al. (1983). Briefly, the peeled, sliced roots were cooked 5 min in steam in a continuous cooker, blended with the other ingredients, comminuted in a hammer mill, and finish cooked in a steam injector (steam at 160°C) flow system. The cooked puree was then vacuum cooled to 68°C, molded into patties, and then frozen at −20°C. When all of the stored roots had been processed, patties were removed in batches from the freezer and cooked 2 min in a deep fat cooker in peanut oil at 171°C before sensory evaluation. Each batch of patties was prepared from 4.53 kg cooked potatoes, 381g cornstarch, 453g sucrose, 45.4g mono- and diglyceride mixture, 13.6g sodium chloride, 2.3g sodium acid pyrophosphate, and 0.7g FD & C yellow No. 6.

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Analysis

Samples (in duplicate) were taken from the raw sweet potato strips, cooked strips, and patties. Dry matter, sugar and starch content, alcohol-insoluble solids, and pectin content were determined. In addition, oil absorption was measured on deep fat fried patties. Dry matter content also was measured on the comminuted mixture.

Sugars

Ten-gram samples were blended with 50 mL 95% ethanol and 8 mL water for 1 min. The mixture was transferred to a 100-mL volumetric flask and held for 1 wk at room temperature. One-milliliter aliquots were placed in 20 mL vials and lyophilized. Before analysis, each vial was derivitized (Oupadissakoon et al., 1979), and 2-μL samples were injected into a Packard model 800 gas-liquid chromagraph (GLC). Separation was carried out on a 1.82 m x 6.4 mm i.d. glass column packed with 3% OV-17 on 100/120 Chromosorb W. Carrier gas (N_2) flow rate was 30 mL/min. The injector was at 240°C and detector at 300°C. Peaks were detected with a flame ionization detector. The column oven was held at an initial temperature of 200°C for 8 min and then programmed at 25°C/min to 290°C. A Hewlett Packard model 3390A integrator operating in the internal standard mode was used for integration. The integrator was calibrated daily using duplicate standards containing fructose, glucose, sucrose, and maltose at levels near those found in the samples.

Alcohol-insoluble solids

Twenty-five gram samples were blended 1 min with 150 mL 80% ethanol. The solution was clarified by centrifugation and the liquid phase discarded. This procedure was repeated using 250 and 150 mL boiling 80% ethanol and 0.5 min blending times for the second and third extractions. The final residue was removed, put into a tared weighing dish, air dried at room temperature overnight, dried at 95°C for 24 hr in a forced draft oven, cooled, and reweighed. The alcohol-insoluble solids (AIS) was calculated on the basis of fresh sample weight.

Starch

From 12-15 mg alcohol-insoluble solids were weighed into 50 mL Erlenmeyer flasks, 5 mL distilled water added, and the samples heated to 121°C in an autoclave. After cooling, 1 mL 0.01M acetate (pH 4.6) and 0.01M NaCl buffer containing 2 mg amyloglucosidase (*Rhizopus* mold; 5,000-10,000 units/g) and 2 mg α-amylase (*Bacillus subtilis*; 1,400 units/g) were added to each sample. The samples were incubated at 50°C for 1 hr. Fifteen milliliters acetate-NaCl buffer were added to bring the pH to 4.6, and the samples were incubated at 50°C for 2 hr. The solution was transferred to a 25-mL volumetric flask. The glucose content was measured on a suitable aliquot using the glucose oxidase procedure (Dekker and Richards, 1971). The starch content was calculated from the amount of glucose released.

Pectins

Pectin content, expressed as hexuronic acids, was determined on 0.1g samples alcohol-insoluble solids as described by Scott (1979). Galacturonic acid was used as a standard. The method described above was evaluated using laboratory samples containing 80% starch, 16% cellulose and 4% pectin to simulate the alcohol-insoluble solids fraction. The starch and cellulose were shown to cause no significant interference.

Microscopy

Tissue was fixed in 3% glutaraldehyde, dehydrated, critical point dried, gold-coated, and photographed at various magnifications at 20 KeV in an ETEC Autoscan microscope (Walter and Schadel, 1982).

Fat absorption

'Jewel' patties were dried in a forced-draft oven overnight at 60°C, followed by 4 hr at 98°C. The patties were crumbled and extracted overnight with boiling hexane:ether (1:1). The solvent was evaporated and the amount of fat was determined. Fat absorption was calculated by subtracting the fat content before frying from the fat content after frying.

Statistical analysis

Statistically significant differences ($P \leq 0.05$) in the amount of each compositional component (i.e. sugars, starch, pectin, etc.) over time were determined by a one-way analysis of variance procedure and the Waller-Duncan K-ratio 't' test (SAS, 1982).

RESULTS & DISCUSSION

FOR BOTH CULTIVARS, as length of storage increased, starch content decreased and sugar levels increased (Fig. 1 and 2), reflecting root metabolic activity. In addition, fructose and glucose content increased more rapidly in 'Jewel' than in 'Centennial' during storage. Sucrose levels increased during storage in 'Centennial' more than in 'Jewel' until the 16-wk sampling date. The total sugar content, however, was similar for both varieties at each sampling date. No maltose was detected in raw roots.

When the sliced roots were cooked, no change occurred in the content of sucrose and glucose plus fructose (Fig. 1 and 2). The apparent decrease in these sugars for cooked roots can be explained by slight changes in dry matter. The same pattern was found for both cultivars.

Cooking caused a significant decrease in starch content and attendant maltose formation in both cultivars, which reflected heat-mediated enzymatic conversion of the starch (Fig. 1 and 2). The maltose content and starch remaining after cooking decreased with length of storage of the raw roots prior to cooking. However, the percentage of starch converted during cooking was dependent upon the cultivar. For 'Jewel' the percentage of starch converted by cooking decreased from 38% at harvest to 26% after roots had been stored for 6 months (Table 1). 'Centennial' root starch was converted during cooking at about the same rate (33–40%) regardless of the length of storage prior to cooking. This is unlike baked roots in which the starch conversion percentage increased from around 65% at harvest to more than 90% after 2 months of storage (Walter et al., 1975).

It has been demonstrated (Deobald et al., 1969; Walter et al., 1975) that α-amylase activity increased during storage, and thus, starch conversion would be expected to increase with length of storage due to increased enzymatic activity. This was observed for baked roots (Table 1), but

Table 1—Percentage of starch converted[a] during cooking of sweet potatoes

Time after harvest	Cooked strips		Baked, whole
	'Jewel'	'Centennial'	'Centennial'[b]
0 (at harvest)	38.8	38.2	65
1 wk	42.5	36.0	–
6 wk	39.0	37.6	75
2 months	37.3	32.6	95
4 months	30.6	35.7	–[c]
6 months	25.6	39.9	–[c]

[a] Amount of starch in raw sample — amount of starch in cooked sample ÷ amount of starch in raw sample x 100.
[b] Data from Walter et al. (1975).
[c] Experiment conducted for 2 months.

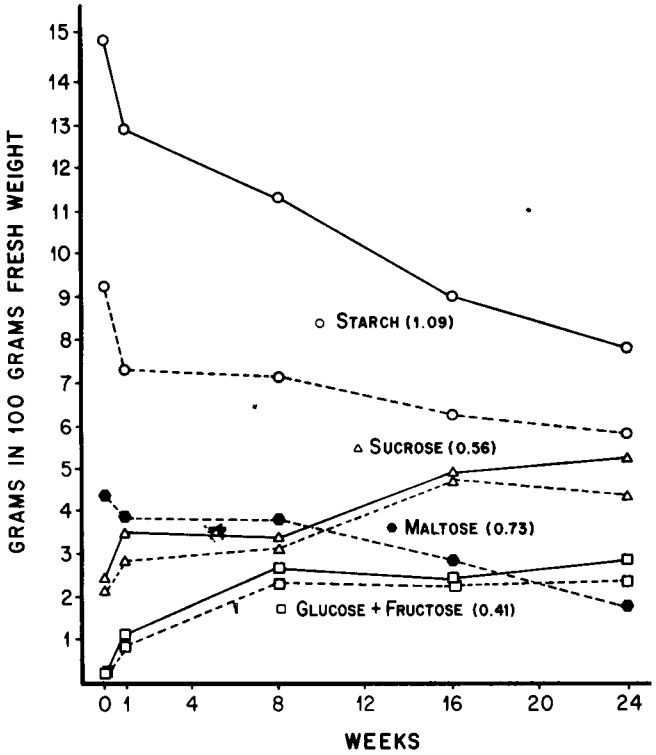

Fig. 1—Starch, ○ (1.09); sucrose, △ (0.56); fructose plus glucose, □ (0.41); and maltose, (0.73) content for raw (——) and cooked (---) 'Jewel' cultivar sweet potatoes. Numbers in parentheses are least significant differences ($P \leq 0.05$). Maltose was not detected in raw sweet potatoes.

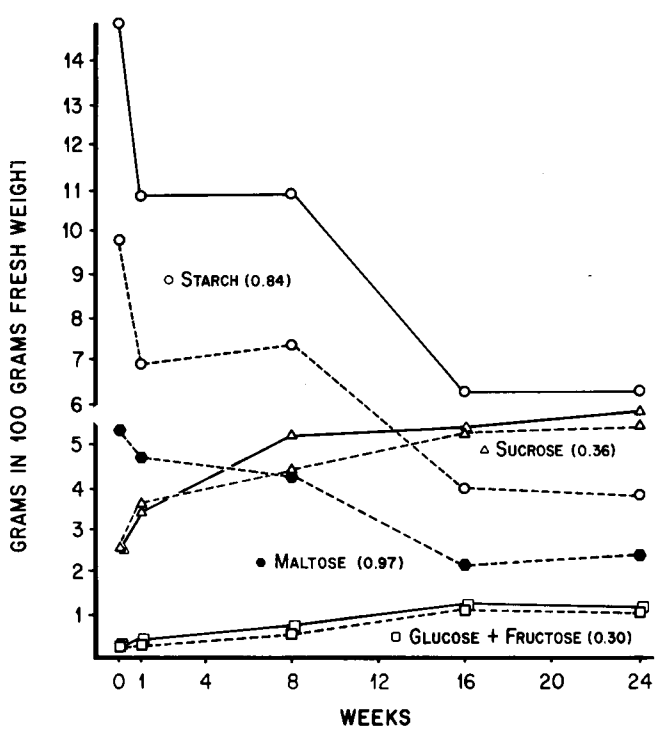

Fig. 2—Starch, ○ (0.84); sucrose △ (0.36); fructose plus glucose, □ (0.30); and maltose, (0.97) content for raw (——) and cooked (---) 'Centennial' cultivar sweet potatoes. Numbers in parentheses are least significant differences ($P \leq 0.05$). Maltose was not detected in raw sweet potatoes.

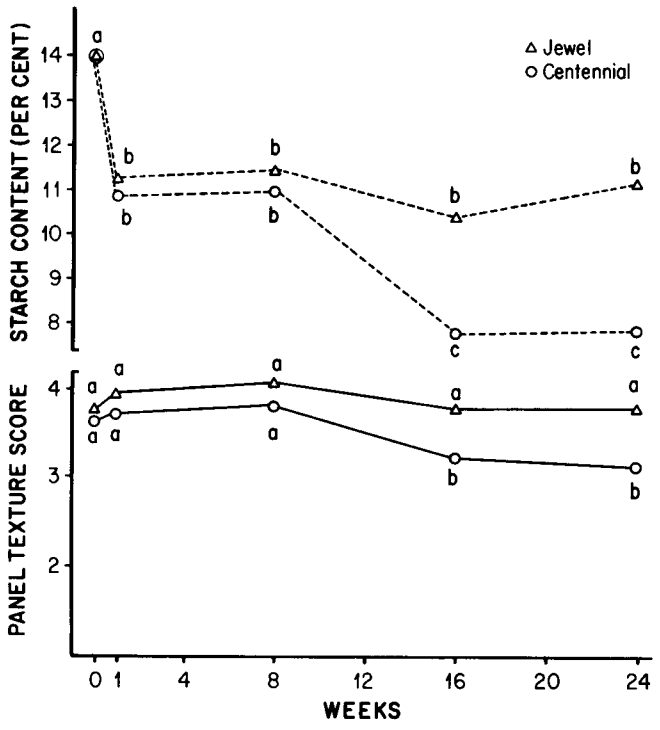

Fig. 3—Comparison of starch content of sweet potato patties and taste panel texture score data from Hoover et al. (1983) for 'Jewel' and 'Centennial' patties. Data points with different letters are different at $P \leq 0.05$.

not cooked strips. Probably the cooking procedure produced such a rapid temperature increase in the strips that the enzymes were inactivated before extensive starch conversion could occur. Thus, starch conversion and maltose formation exhibited an apparent dependence on starch content.

Since the goal of producing a consistent product requires that the starch content be constant, it would be advantageous to use cultivars such as 'Jewel' in which the percent starch conversion decreased with storage. In such a situation, starch added at a constant level yielded a finished product with similar starch levels, except for the zero time sample (Table 2). In contrast, 'Centennial' patties showed a decreasing level of starch over time due to a constant percentage of starch conversion. These differences in patty starch content were reflected by the taste panel data (Hoover et al., 1983; Fig. 3). 'Jewel' patties had a constant texture score declined significantly after the 2-month sample, thus, paralleling the decline in starch content. The total sugar content of patties (Table 2) for both cultivars was fairly constant, and included the natural sugars, the maltose formed during cooking, and the sucrose added after cooking. Pectin levels in patties for both cultivars fluctuated with no definite trend.

Scanning electron microscopy

Examination of the SEM photomicrographs revealed that cooking caused some cells to assume a wrinkled, crumpled appearance together with cellular separation (Fig. 4A and 4B), but with little cell rupture. Starch remained compartmentalized within the cells and, therefore, was not available to bond the cells together.

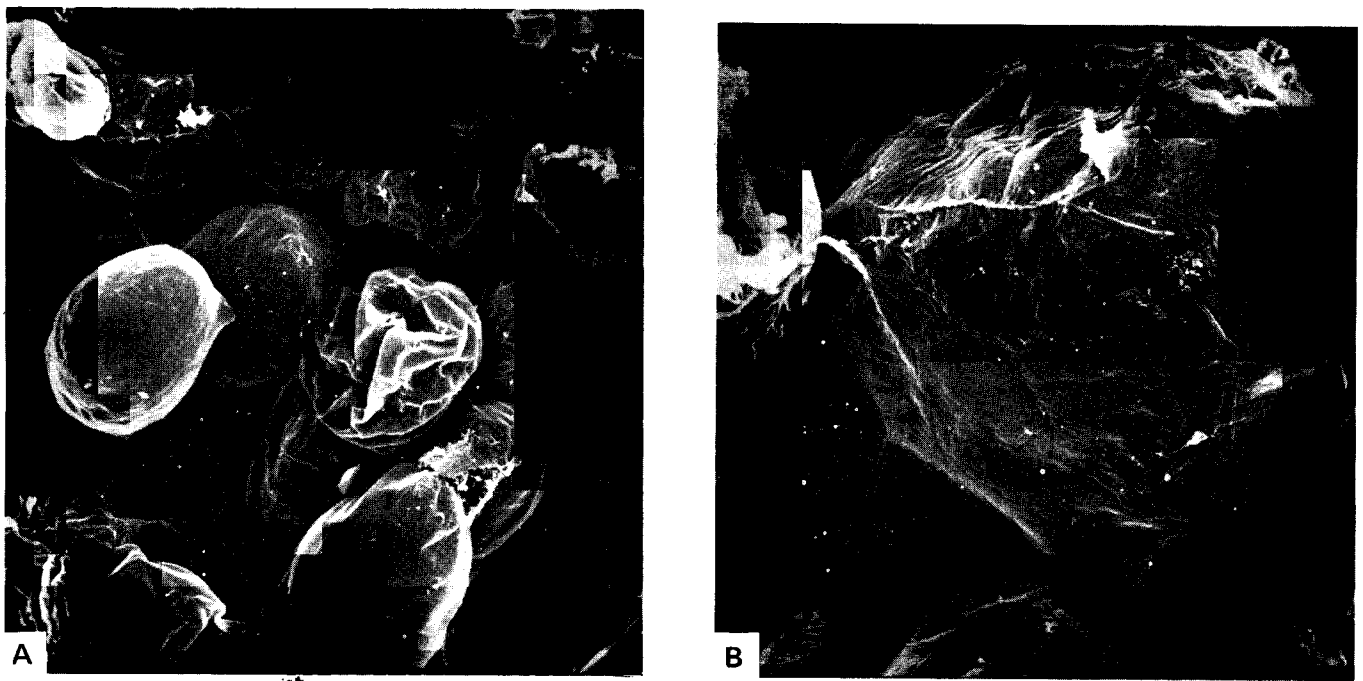

Fig. 4—Scanning electron photomicrographs of cooked, 'Jewel' sweet potato slices. (A) cured 1 wk, bar = 100μ. (B) cured 1 wk, bar = 10μ

Table 2—Starch, total sugar and pectin content[a] of sweet potato-based patties[b]

Time after harvest	Starch		Total sugar		Pectins	
	'Jewel'	'Centennial'	'Jewel'	'Centennial'	'Jewel'	'Centennial'
0 time	14.10^{a}	14.10^{a}	10.15^{b}	11.38^{a}	$0.45^{b,c}$	0.47^{b}
1 wk	$11.20^{b,c}$	10.72^{b}	11.36^{a}	10.53^{a}	0.50^{b}	0.56^{a}
2 months	11.41^{b}	10.89^{b}	11.50^{a}	10.84^{a}	0.43^{c}	$0.45^{b,c}$
4 months	10.15^{c}	8.25^{c}	12.21^{a}	11.19^{a}	0.81^{a}	$0.45^{b,c}$
6 months	$11.08^{b,c}$	8.38^{c}	12.08^{a}	11.73^{a}	0.29^{d}	0.42^{c}

[a] Grams in 100g of patty.
[b] Means within columns followed by the same letter are not significantly different at the 5% level.

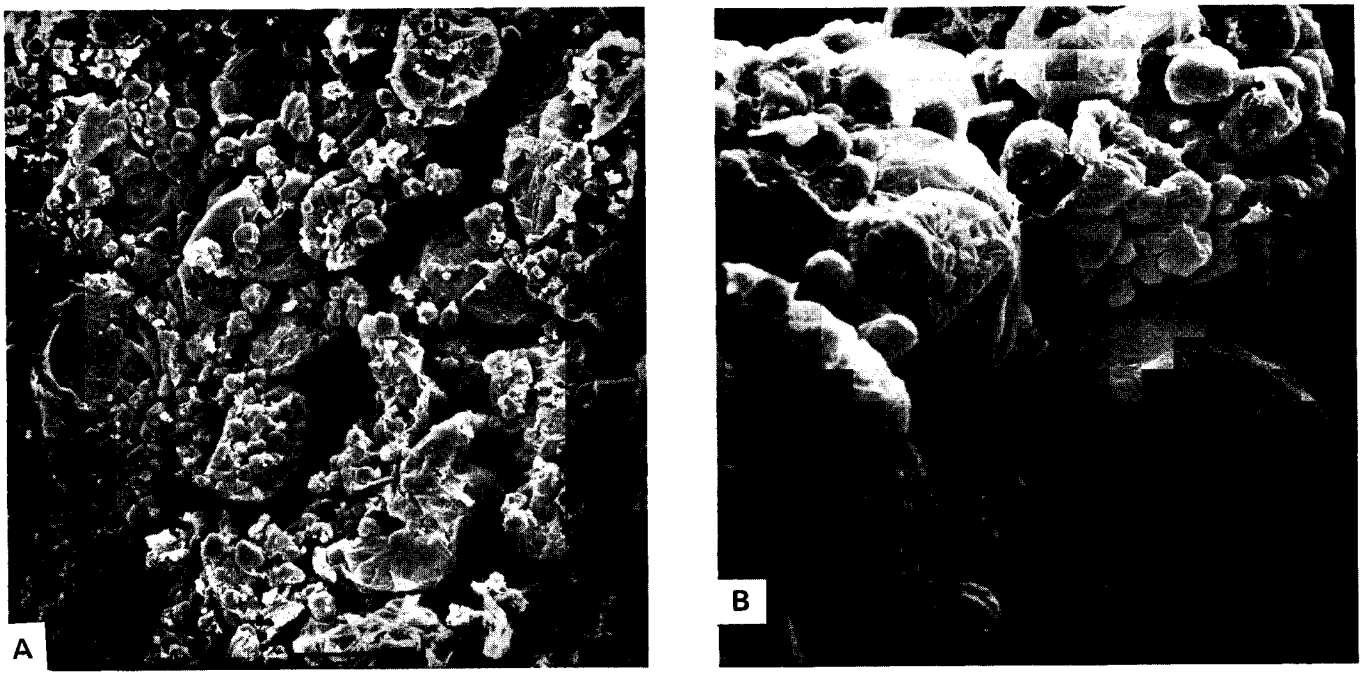

Fig. 5—Scanning electron photomicrographs of puree prepared from cooked, 'Jewel' strips plus added ingredients. (A) bar = 100μ. (B) bar = 10μ.

The step after cooking involved addition of starch, sugar, and other ingredients, followed by pureeing in a hammer mill. Photomicrographs (Fig. 5A and 5B) of this material showed that the added material was attached to the surface of the cells, perhaps bonded by the cellular starch released by the shearing action of the hammer mill. Steam injection of the puree completed the cooking process. In the steam injected material, cells were bonded together by a formless material (Fig. 6) with only the cell outlines visible. This amorphous, glue-like material provided the rigidity necessary to retain the patty shape.

Fat absorption

When patties were fried, the 0 time and 1 wk samples absorbed more oil than did patties prepared from roots stored for longer periods. The fat content (corrected for fat present before frying) was 3.2 and 5.7% ('Jewel' and 'Centennial,' respectively) for patties prepared from freshly harvested roots and ca. 7% (both cultivars) for patties prepared from roots cured 1 wk. The fat content of patties prepared from roots stored 2 months or longer ranged from 1.3–2.8%. There was no correlation between the amount of oil absorbed during cooking and the sensory panel ratings (Hoover et al., 1983), indicating that oil absorption was not a factor in panel acceptance

Fig. 6—Scanning electron photomicrograph of sweet potato patties prepared from 'Jewel' puree. Bar = 10μ.

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