Effect of Long-Term Storage on Cell Wall Neutral Sugars and Galacturonic Acid of Two Sweetpotato Cultivars

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Jewel and Beauregard sweetpotatoes were sampled at harvest and after 49, 119, and 217 days of storage. At each sampling date for each cultivar, the concentrations of galacturonic acid (GA), galacturonic methyl esters, and cell wall neutral sugars were determined for both water-soluble and water-insoluble cell wall substances. For both cultivars, the GA content of water-soluble materials increased during storage, but the GA content of water-insoluble substances decreased, reflecting decreases in pectin size. The percent methyl ester content did not change for either cultivar. Cell wall neutral sugar concentrations declined in the order glucose ≫ galactose > xylose > rhamnose > mannose > arabinose > fucose. Changes in cell wall neutral sugars were minimal and were not observed in both cultivars. For both cultivars, the few cell wall sugar changes that occurred over time were best fit to a quadratic model. Thus, the only observed change in cell wall components that is known to affect firmness was the decrease in water-insoluble pectic substances and concurrent increase in water-soluble pectic substances.

Keywords: *Pectic substances; Jewel cultivar; Beauregard cultivar*

INTRODUCTION

Processing characteristics of sweetpotatoes are dependent on post-harvest storage history. Generally, longer storage periods of the raw roots prior to processing results in products with decreased firmness (Woolfe, 1991; Collins and Walter, 1992). This variation in firmness makes it difficult for processors to manufacture products of consistent quality throughout the year. This tendency toward decreased firmness has been reported many times over the years for canned sweetpotatoes (Woolfe, 1991). In fact, most sweetpotato canning operations in the United States are suspended in early January because products made after this date tend to disintegrate and, thus, cannot meet the requirements for wholeness.

Food textural properties, including firmness, are dependent on tissue organization (microstructure). Microstructure is determined by chemical composition and physical forces (Stanley and Tung, 1976). In sweetpotato, starch and cell walls exert a significant influence on textural properties and, whereas starch has been the object of a considerable amount of the research (Collins and Walter, 1992), only isolated reports of the composition of sweetpotato cell wall exist. Pectin content and pectin classes based on solubility have been determined for a number of cultivars at harvest and after storage (Ahmed and Scott, 1957). Decline in protopectin (Baumgardner and Scott, 1965) and hemicellulosic material (Sistrunk, 1971) has been correlated with decline in firmness of canned sweetpotatoes. Shen and Sterling (1981) reported that baked, moist-type sweetpotatoes exhibit large declines in hemicellulose, whereas the firmer, dry-type roots, when baked, show much lower declines in hemicellulose. Walter et al. (1990, 1993) reported that for sweetpotato French fries, as firmness retention increased, water-soluble pectin content increased. They also showed that firmness retention increased as the pectin methyl ester content of the pectic substances decreased. Recently, Noda et al. (1994) fractionated and analyzed the cell wall material from Koganesingane cultivar sweetpotato.

In view of the importance of cell wall composition to textural properties, the objective of this research was to measure the concentrations and changes in selected sweetpotato cell wall components occurring during long-term storage of Beauregard and Jewel cultivars. These types are the most widely grown commercial sweetpotato cultivars produced in the United States, comprising ≈85−90% of the total crop. Both cultivars are typical of the sweetpotato type preferred by many U.S. consumers; that is, they are orange fleshed, contain 16−30% dry matter, and, when cooked, generate large amounts of maltose due to interaction of their active amylolytic enzyme systems with endogenous starch.

MATERIALS AND METHODS

Jewel and Beauregard sweetpotato cultivars were harvested at the Horticultural Crops Research Station at Clinton, NC, 120 days after transplant. They were transported to the laboratory immediately after harvest. Samples were removed for analysis (at-harvest samples), and the remainder of the roots were cured 7 days at 31 °C and 85% relative humidity and stored at 13 °C and 85% relative humidity until used. Subsequently, samples were removed from storage at 49, 119, and 217 days and analyzed.

Analysis. *Extraction.* Alcohol-insoluble solids (AIS) were prepared by extracting grated sweetpotato tissue three times with boiling 80% ethanol (Walter et al., 1993).

Water-Soluble Cell Wall Material. Weighed AIS samples were extracted three times by shaking each AIS sample in 10 volumes of water for 30 min at 200 rpm on a rotary shaker and centrifugated. The supernatant was collected, and the pellet was resuspended. The supernatants were combined, the volume was measured, 10 mL was removed for determination of the uronic acid content, and the remainder was mixed with 3 volumes of 95% ethanol. This mixture was held at 5 °C for 1 week, and then centrifuged. The pellet was removed, washed with ethanol and acetone, allowed to air dry, and weighed.

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Table 1. Percent Dry Matter of Jewel and Beauregard Sweetpotatoes

	% dry matter	
time, days	Jewel	Beauregard
at harvest	27.28	18.70
39	28.19	20.07
119	27.62	18.74
217	25.98	19.01

Table 2. Percent Esterification of Pectic Substances from Jewel and Beauregard Sweetpotatoes[a]

	esterification, %				
cell wall fraction	at harvest	49 days	119 days	217 days	statistical significance
Jewel soluble	112	99.5	129	103	NSD[b]
Jewel insoluble	58.9	65.5	57.9	49.8	NSD
Beauregard soluble	105	84.1	128	102	NSD
Beauregard insoluble	53	56.1	62.6	53	NSD

[a] Results are means of two replicate samples run in duplicate. [b] NSD, no time-dependent, statistically significant difference was found.

Water-Insoluble Cell Wall Material. To remove starch, the residue from the water extraction was homogenized with 150 mL of 90% dimethyl sulfoxide, sonicated for 10 min, and then shaken overnight at 200 rpm. The mixture was centrifuged, the supernatant was discarded, and the residue was extracted in this way twice more. After the last extraction, the residue was extracted with ethanol twice and with water four times to remove DMSO, and the residue was freeze-dried and weighed.

Quantitation of Uronic Acids, Percent Pectin Esterification, and Neutral Cell Wall Sugars. Uronic acid content and percent pectin esterification of water-soluble and water-insoluble cell wall material were measured as described by Walter et al. (1993) by modifications of the methods of Scott (1979) and Wood and Siddiqui (1971), respectively. Neutral sugars for both water-soluble and water-insoluble fractions were measured by acid hydrolysis of the samples, conversion of the liberated sugars to alditol acetates, and separation and quantitation of the alditol acetates with gas−liquid chromatography (Walter et al., 1990; McFeeters and Lovdal, 1987; Blakeney et al., 1983). Cell wall sugars and galacturonic acid (GA) concentrations were expressed as g/1000 g of dry matter. Percent dry matter data are shown in Table 1.

Statistical Analysis. The experimental design was a 2 × 4 factorial with two or three samplings per treatment cell. The dependent variables were analyzed for time-dependent change with the General Linear Models procedure of SAS (SAS, 1988).

RESULTS AND DISCUSSION

For both Beauregard and Jewel cultivars, the degree of esterification for both water-soluble and water-insoluble fractions did not change during storage (Table 2). Other workers (Sajjaanantakal et al., 1989) have reported that when carrot tissue is heat processed, the rate of pectin cleavage decreases as percent esterification decreases. Decreased pectin cleavage results in increased firmness retention. However, processed sweetpotato products exhibit a progressive decrease in firmness with storage time of the raw roots prior to processing increases (Collins and Walter, 1992; Woolfe, 1991). There was no time-dependent change in the percent esterification for the two cultivars we investigated, so this parameter apparently does not affect firmness retention for the stored roots of these cultivars.

The data also show that for both cultivars, the water-soluble substances were close to 100% esterified. In contrast, for the water-insoluble fraction, which makes up ≈80% of the total pectins, the percent esterification ranged from ≈50 to 66%.

For both cultivars, the storage time-dependent increase in water-soluble GA was accompanied by a decrease in water-insoluble GA (Tables 3 and 4), indicating that the molecular size of the uronic acid-containing material was decreasing with increased storage time. Indeed, this size change could relate to decreased firmness retention observed in products made from stored roots because pectin cleavage possibly caused the observed decrease in molecular size. Because the middle lamella, which is the "cement" holding the cells together, is made up largely of pectic substances, pectin cleavage could easily cause the cell-to-cell junctions to weaken. This weakening would then permit the tissue to disintegrate more easily when force is applied. The total GA concentration of both cultivars did not change significantly during storage.

For both cultivars, the relative quantities of neutral sugars obtained by acid hydrolysis of the cell wall fractions were as follows: glucose ≫ galactose > xylose ≫ rhamnose > mannose > arabinose > fucose. Our results are somewhat different from those of Noda et al. (1994), who found the following order for sweetpotato cell wall material: glucose ≫ galactose > arabinose > xylose > rhamnose > mannose. These workers were

Table 3. Neutral Sugar and Galacturonic Acid Concentrations of Beauregard Sweetpotato Cell Walls[a]

		concentration[a]				
sugar	fraction	at harvest	49 days	119 days	217 days	statistical significance
glucose	WS[b]	3.40	4.18	1.89	5.99	NSD[e]
	IS[c]	30.38	40.64	33.52	56.44	NSD
galactose	WS	1.24	1.56	1.00	0.74	NSD
	IS	8.46	11.61	13.63	8.28	quad ($p < 0.01$)[f]
xylose	WS	0.65	0.75	0.90	1.23	NSD
	IS	5.04	5.703	7.622	4.00	quad ($p < 0.02$)
rhamnose	WS	0.24	0.19	0.17	0.43	NSD
	IS	0.79	1.02	1.91	1.01	quad ($p < 0.02$)
mannose	WS	0.06	0.05	ND[d]	ND	NSD
	IS	0.14	0.38	0.73	0.19	quad ($p < 0.01$)
arabinose	WS	0.10	0.07	0.03	0.07	NSD
	IS	0.21	0.22	0.51	0.36	NSD
fucose	WS	0.03	0.03	0.03	0.04	NSD
	IS	0.01	0.15	0.17	0.03	NSD
galacturonic acid	WS	12.27	10.19	19.97	21.14	$p < 0.05$
	IS	10.22	11.21	9.54	6.62	$p < 0.05$

[a] Concentration is grams of sugar in 1000 g of dry matter. [b] WS, water-soluble cell wall material. [c] IS, water-insoluble cell wall material. [d] ND, not detected. [e] NSD, no statistically significant difference. [f] Quad, data fit a quadratic equation at p value indicated.

Table 4. Neutral Sugar and Galacturonic Acid Concentrations of Jewel Sweetpotato Cell Walls

		concentration[a]				
sugar	fraction	at harvest	49 days	119 days	217 days	statistical significance
glucose	WS[b]	2.31	2.36	1.35	2.97	NSD[e]
	IS[c]	40.64	45.06	59.52	37.67	NSD
galactose	WS	1.83	1.15	0.80	2.00	NSD
	IS	9.67	12.31	11.42	7.67	NSD
xylose	WS	0.82	0.49	0.48	0.84	NSD
	IS	4.13	4.46	4.54	3.48	NSD
rhamnose	WS	0.38	0.12	0.11	0.24	NSD
	IS	0.76	0.92	0.90	0.82	NSD
mannose	WS	0.05	0.05	ND	ND	NSD
	IS	0.63	0.27	0.40	ND	quad ($p < 0.01$)[f]
arabinose	WS	0.15	0.04	0.01	0.01	NSD
	IS	0.26	0.24	0.19	0.16	NSD
fucose	WS	0.05	0.02	0.02	0.03	NSD
	IS	ND[d]	0.07	0.08	0.01	quad ($p < 0.01$)
galacturonic acid	WS	6.67	5.27	10.96	12.84	$p < 0.05$
	IS	9.98	11.31	6.87	6.28	$p < 0.05$

[a] Concentration is grams of sugar in 1000 g of dry matter. [b] WS, water-soluble cell wall material. [c] IS, water-insoluble cell wall material. [d] ND, not detected. [e] NSD, no statistically significant difference. [f] Quad, data fit a quadratic equation at p value indicated.

studying a Japanese cultivar, so it is possible that the relative amounts of the cell wall neutral sugars are different.

The water-soluble cell wall fraction contained ≈14% of the total amount of sugars present, and the water-insoluble cell wall fraction contained the remainder. This is less than the 80−20% water-insoluble−water-soluble ratio we found for the total GA concentration. Glucose, the most abundant sugar, did not change during the storage period (Tables 3 and 4), but we experienced a high degree of variability that undoubtedly was related to the inability of DMSO to remove all of the starch.

The time response for the cell wall neutral sugars is provided in Tables 3 and 4. In the water-insoluble fraction from the for Beauregard cultivar, the two most abundant neutral sugars (excluding glucose), galactose and xylose, tended to follow a quadratic model. That is, sugar concentrations increased until 119 days and then declined until at 217 days the concentrations were close to the initial concentrations. For the Jewel cultivar, neither sugar concentration changed. For the water-soluble fraction, there was no statistically significant time response for either cultivar.

For the Beauregard cultivar, the time response pattern for rhamnose and mannose was similar to that observed for galactose and xylose, except that their concentrations were ≈4−10 times less, depending on the sampling date (Table 3). For the Jewel cultivar, rhamnose exhibited no statistically significant time response for either fraction, but mannose in the water-insoluble fraction exhibited a statistically significant quadratic response. Arabinose content did not change during storage for either cultivar. Fucose, the least abundant cell wall sugar, showed a quadratic relationship with storage time for the water-insoluble fraction of the Jewel cultivar, but did not change in the Jewel water-soluble fraction or either fraction of the Beauregard cultivar.

In this study, we observed no consistent pattern with regard to changes in concentrations for the neutral sugars of sweetpotato cell wall material during long-term storage. Apparently, if neutral cell wall sugars play a role in the decreased firmness of products made from stored sweetpotatoes, it is the result of more subtle changes than we were able to detect. In conclusion, the only change we observed in cell wall components due to long-term storage of the roots known to affect firmness was the decrease in water-insoluble pectic substances and the concomitant increase in water-soluble pectic substances.

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