Changes in Insoluble and Soluble Dietary Fiber of White Asparagus (*Asparagus officinalis* L.) during Different Conditions of Storage

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Changes occurring in the content and composition of dietary fiber of white asparagus during storage in different conditions were studied (room temperature; 2 °C in polyethylene bags; 2 °C and 95% relative humidity). The neutral sugars and uronic acid composition of dietary fiber was determined by gas chromatography and by a spectrophotometric method. In the insoluble dietary fiber, glucose was found in a major amount followed by galactose, xylose, arabinose, mannose, rhamnose, and fucose. In the soluble dietary fiber, galactose was the predominant neutral sugar followed by arabinose, mannose, glucose, and rhamnose. The content of uronic acids was significantly higher in the soluble dietary fiber than in the insoluble one. The modifications observed in dietary fiber of the asparagus stored at room temperature are more rapid and pronounced than those in the refrigerated conditions, which prolong the conservation. Statistical analysis indicated that the changes were significantly affected by the type of storage and time.

Keywords: *Dietary fiber; asparagus; changes; storage*

INTRODUCTION

White asparagus (*Asparagus officinalis* L.) is a vegetable product with a very high metabolism and, therefore, extremely pronounced respiratory activity, even after harvesting (Day, 1993; Powrie and Skura, 1991; Kader, 1985). This quickly causes irreversible structural and functional degeneration that affects the quality of asparagus, for instance, the texture (Haard et al., 1974; Clore et al., 1976).

Changes in asparagus texture are related to structural and compositional modifications of the cell wall. The major components of dietary fiber are derived from cell wall polymers, and the amount and relative proportions of these can be modified during storage. During vegetable maturation, toughening occurs due to the deposition of lignin in certain cell walls. This cross-links cell-wall polysaccharides and greatly increases cell-wall strength (Selvendran and MacDougall, 1995). The other marked change that can be seen in plant cell walls during storage is the decrease in galactose content of all the pectic polysaccharides examined (Waldron and Selvendran, 1992).

Excessive fiber is an undesirable textural quality in asparagus that can make this plant material unacceptable as a food (Clore et al., 1976). Therefore, it is important to avoid or to slow postharvest degradation to increase the product's shelf life. The most widely extended conservation method for fresh vegetables is refrigeration (−1 to 8 °C depending on the product). Low temperatures act by slowing many of the deteriorative processes, making the life of vegetables longer (King et al., 1993; Esteve et al., 1995). On the other hand, the depletion of O_2 and enrichment of CO_2 are natural consequences of the progress of respiration when fresh fruits or vegetables are stored in a hermetically sealed package or container. Such modification of the atmospheric composition results in a decrease in the respiration rate of plant material (Day, 1989). Loss of moisture, with consequent wilting and shriveling, is one of the obvious ways in which freshness of fruit and vegetables is lost. Since fruit, and vegetables are 80−95% water, they lose moisture rapidly whenever the relative humidity is <80−95%. Moisture losses of 3−6% are usually enough to cause marked deterioration of quality for many kinds of produce. Consequently, it is important to reduce such moisture losses by lowering the temperature, raising the relative humidity, and reducing air movement (Day, 1993).

The aim of this work is to determine the evolution of the composition of dietary fiber of white asparagus stored under different conditions. Three factors of great importance that affect the shelf life of vegetables have been considered: temperature, relative humidity, and the atmosphere surrounding the commodity. Nonstarch polysaccharides (NSP) form the major components of insoluble and soluble dietary fiber. These polysaccharides are constituted by neutral sugars (rhamnose, fucose, arabinose, xylose, mannose, galactose, and glucose), as well as by uronic acids. The postharvest modifications affect the NSP and therefore the proportion of each of these monomers. This work studies the changes in the dietary fiber in terms of the modifications of each monomer in both the insoluble and the soluble fractions, analyzed by gas−liquid chromatography.

MATERIALS AND METHODS

White asparagus spears of 17−22 cm length were selected because Spanish legislation authorizes them for internal consumption and external markets. The asparagus spears were harvested manually in Alcalá del Río (Sevilla, Spain). They were transported to the laboratory immediately after harvesting. They were washed, and nonedible parts were eliminated. Samples were removed for analysis (at-harvest samples), and the remainder of the spears were stored at room

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Table 1. Temperature and Relative Humidity Conditions of Storage I

days	max temp, °C	min temp, °C	mean rel humidity, %
0	17.6	7.1	51
2	23.0	9.0	33
6	19.1	10.9	49
9	18.4	11.8	60

temperature (storage I), at 2 °C and in sealed polyethylene bags (storage II), and at 2 °C and 95% relative humidity (storage III). The temperature and relative humidity conditions for storage I are given in Table 1.

In each type of storage, samples were analyzed after 2, 6, 9, 13, 16, and 28 days. Each sample was comprised by a group of seven spears in the case of storages I and III and by a bag containing seven spears in the case of storage II. Three samples were used for each storage at each sampling point. Results were obtained in duplicate for each sample.

Preparation of Samples for Analysis. At the corresponding time, samples were dried in a freeze-dryer (Telstar, S.A., Model Cryodos) at −45 °C and 25 mbar and kept in hermetically closed bottles at −20 °C until analysis. The water content was evaluated by the mass loss of the freeze-dried material in relation to the fresh material. It was determined for aliquot parts that were freeze-dried at the same time as the samples.

Dietary Fiber Analysis. Dietary fiber was obtained according to the method of Prosky et al. (1988), which is based on the enzymatic removal of starch and protein from material and the separation into insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) by filtration.

Hydrolysis. Insoluble and soluble dietary fibers are hydrolyzed in two steps according to the procedure of Englyst et al. (1992): primary hydrolysis with 12 M H_2SO_4 (35 °C/1 h) and secondary hydrolysis with 2 M H_2SO_4 (100 °C/2 h).

Neutral Sugars Composition. Neutral sugars from both IDF and SDF were derivatized to alditol acetates after reduction with sodium borohydrate in ammonium hydroxide solution and finally analyzed by gas−liquid chromatography using allose as the internal standard (Englyst et al., 1992). A Perkin-Elmer Autosystem GC chromatograph with flame ionization detector was used, with injector and detector temperatures of 275 °C, oven temperature of 235 °C, carrier gas nitrogen at 22 psi, and a 007 cyanopropyl methyl silicon capillary column (30 m long, 0.25 mm inner diameter and 0.25 μm film thickness).

Uronic Acid Content. Uronic acid content of IDF and SDF was determined colorimetrically with 3,5-dimethylphenol according to the method of Scott (1979), using D-galacturonic acid as the standard.

Neutral sugars and galacturonic acid concentrations were expressed as grams per 100 g of dry matter.

Statistical Analysis. The data from each type of storage were statistically analyzed by one-way analysis of variance. Duncan's multiple range test was applied to establish differences between storage date means. Two-way analysis of variance was employed to determine significant interaction between time and storage.

RESULTS AND DISCUSSION

The fresh white asparagus were stored in the described conditions during a period of time that depended on the sample behavior. The longest time of conservation was determined by evident degradation of the samples. Samples were originally taken 2, 6, 9, 13, 16, and 28 days after harvesting. In storage I a period of 9 days was established as the maximum due to evident degradation of the spears. In storages II and III, 28 days was established for the same reason.

Water content of samples stored at room temperature (storage I) descreases in an important way ($p < 0.001$), and this contributes to deterioration. In samples stored at 2 °C both in polyethylene bags (storage II) and at 95% relative humidity (storage III), modifications are very slight though statistically significant ($p < 0.01$ and 0.05) (Table 2).

Table 2. Water Content of the Different Samples[a]

days	storage I	storage II	storage III
0	91.60 ± 0.04^{a}	91.60 ± 0.04^{b}	91.60 ± 0.04^{a}
2	90.96 ± 0.52^{a}	91.45 ± 0.26^{b}	92.11 ± 0.44^{a}
6	87.01 ± 0.83^{b}	92.95 ± 0.33^{a}	90.98 ± 0.44^{ab}
9	79.14 ± 0.64^{c}	92.44 ± 0.20^{a}	90.02 ± 1.98^{b}
13		91.62 ± 0.29^{b}	91.94 ± 0.41^{a}
16		90.21 ± 1.16^{c}	91.61 ± 0.94^{a}
28		92.82 ± 0.32^{a}	91.18 ± 0.54^{ab}
sign	***	**	*

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

The most important modifications of asparagus during storage are located in the cell wall, and for this reason the monomeric composition of polysaccharides, expressed as dietary fiber, has been analyzed. In the present work, the Prosky et al. (1988) method was used, which allows the separation of insoluble and soluble dietary fiber. The IDF is constituted mainly by cellulose and hemicellulosic polysaccharides and the SDF by pectic polysaccharides.

The IDF in asparagus samples at harvest point (day 0) is rich in glucose, followed by galactose and uronic acids, xylose, and, in minor proportions, mannose, rhamnose, and fucose. This composition indicates a major proportion of cellulose and pectic polysaccharides followed by hemicelluloses, which are mainly of xylan type. In the SDF uronic acids are the main component, followed by galactose, arabinose, and mannose, glucose and xylose being the lowest (Tables 3 and 6).

In the IDF of samples corresponding to storage I a clear increase during the storage period in xylose and arabinose is observed, as is a minor increase in glucose. Galactose undergoes an evident decrease ($p < 0.001$). In the SDF, xylose increases and galactose diminishes ($p < 0.01$), while arabinose, mannose, and glucose increase but experience a slight decrease at the end ($p < 0.01$, $p < 0.001$, $p > 0.05$) (Table 3). In terms of polysaccharides an increase of xylans and to a lesser extent an increase of glucans could be deduced, as well as losses of galactans.

Other authors have performed studies on the postharvest modifications of white asparagus, observing that galactose and arabinose decrease while xylose and glucose increase after 7 days of storage (Waldron and Selvendran, 1990). These modifications are attributed probably to the breaking of lateral chains of galactans and arabinans in the pectic polysaccharides of parenchymatic tissues and to the production of xylans possibly in the vascular tissues. Selvendran and MacDougall (1995) indicate that a marked change produced in vegetable cell walls during storage is the loss of galactose from the pectic polysaccharides. Selvendran and Robertson (1994) point out that xylose, the main constituent of hemicelluloses, is in a low proportion but increases during maturation.

In spears stored in polyethylene bags at 2 °C (storage II) after 28 days, in the IDF arabinose ($p < 0.05$) and xylose and glucose ($p < 0.001$) increase to a lesser extent than that observed in asparagus stored at room temperature (storage I) and in a slower way throughout the assay. Galactose and, in a minor proportion, mannose decrease significantly ($p < 0.001$, $p < 0.01$). The neutral sugars of the SDF have a similar behavior as those of

Table 3. Storage I: Evolution of Neutral Sugar Composition of Dietary Fiber (Expressed as Grams per 100 g of Dry Matter)[a]

days	rhamnose	fucose	arabinose	xylose	mannose	galactose	glucose
			Insoluble Dietary Fiber				
0	0.293 ± 0.004	0.091 ± 0.047	0.880 ± 0.011^{c}	1.248 ± 0.057^{b}	0.319 ± 0.010	2.156 ± 0.021^{a}	5.206 ± 0.343^{c}
2	0.294 ± 0.047	0.144 ± 0.048	0.981 ± 0.069^{b}	2.151 ± 0.286^{a}	0.390 ± 0.079	2.087 ± 0.072^{a}	6.179 ± 0.490^{b}
6	0.327 ± 0.063	0.149 ± 0.048	1.005 ± 0.043^{b}	2.501 ± 0.237^{a}	0.375 ± 0.065	1.291 ± 0.142^{c}	7.434 ± 0.540^{a}
9	0.376 ± 0.051	0.128 ± 0.011	1.308 ± 0.029^{a}	2.422 ± 0.259^{a}	0.370 ± 0.032	1.713 ± 0.006^{b}	6.165 ± 0.417^{b}
sign	ns	ns	***	***	ns	***	***
			Soluble Dietary Fiber				
0	0.051 ± 0.012		0.352 ± 0.013^{bc}	0.026 ± 0.006^{c}	0.156 ± 0.003^{b}	0.784 ± 0.043^{a}	0.058 ± 0.014
2			0.369 ± 0.025^{ab}	0.039 ± 0.002^{b}	0.156 ± 0.024^{b}	0.773 ± 0.011^{a}	0.083 ± 0.022
6			0.401 ± 0.040^{a}	0.048 ± 0.005^{a}	0.210 ± 0.012^{a}	0.726 ± 0.034^{b}	0.080 ± 0.017
9			0.321 ± 0.008^{c}	0.047 ± 0.007^{ab}	0.195 ± 0.014^{a}	0.680 ± 0.011^{c}	0.077 ± 0.018
sign			**	***	***	**	ns

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$; ns, nonsignificant. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

Table 4. Storage II: Evolution of Neutral Sugar Composition of Dietary Fiber (Expressed as Grams per 100 g of Dry Matter)[a]

days	rhamnose	fucose	arabinose	xylose	mannose	galactose	glucose
			Insoluble Dietary Fiber				
0	0.293 ± 0.004	0.091 ± 0.047	0.880 ± 0.011^{b}	1.248 ± 0.057^{f}	0.319 ± 0.010^{bc}	2.157 ± 0.021^{b}	5.206 ± 0.343^{c}
2	0.289 ± 0.008	0.104 ± 0.004	0.890 ± 0.032^{b}	1.489 ± 0.066^{e}	0.331 ± 0.020^{b}	2.205 ± 0.061^{b}	5.767 ± 0.269^{b}
6	0.286 ± 0.028	0.109 ± 0.016	1.003 ± 0.045^{a}	2.101 ± 0.053^{b}	0.380 ± 0.005^{a}	2.567 ± 0.022^{a}	7.247 ± 0.157^{a}
9	0.273 ± 0.009	0.116 ± 0.011	1.040 ± 0.025^{a}	2.482 ± 0.099^{a}	0.348 ± 0.055^{ab}	2.470 ± 0.077^{a}	7.535 ± 0.312^{a}
13	0.276 ± 0.064	0.114 ± 0.013	0.993 ± 0.052^{a}	1.763 ± 0.035^{d}	0.286 ± 0.003^{cd}	1.869 ± 0.196^{c}	5.862 ± 0.142^{b}
16	0.288 ± 0.073	0.110 ± 0.019	0.990 ± 0.096^{a}	1.798 ± 0.067^{d}	0.278 ± 0.017^{d}	1.797 ± 0.090^{c}	5.624 ± 0.198^{b}
28	0.282 ± 0.025	0.116 ± 0.009	0.981 ± 0.068^{a}	2.004 ± 0.034^{c}	0.268 ± 0.008^{d}	1.743 ± 0.017^{c}	5.526 ± 0.208^{bc}
sign	ns	ns	*	***	**	***	**
			Soluble Dietary Fiber				
0	0.051 ± 0.012^{d}	---	0.352 ± 0.013^{bc}	0.026 ± 0.061^{e}	0.156 ± 0.003^{a}	0.784 ± 0.044^{a}	0.058 ± 0.014^{bc}
2	0.057 ± 0.006^{cd}	---	0.354 ± 0.013^{b}	0.029 ± 0.001^{de}	0.165 ± 0.004^{a}	0.681 ± 0.055^{b}	0.065 ± 0.008^{ab}
6	0.059 ± 0.005^{cd}	---	0.364 ± 0.016^{ab}	0.033 ± 0.002^{bcd}	0.167 ± 0.010^{a}	0.608 ± 0.063^{c}	0.064 ± 0.006^{ab}
9	0.066 ± 0.005^{bc}	---	0.413 ± 0.032^{a}	0.051 ± 0.004^{a}	0.161 ± 0.012^{a}	0.535 ± 0.037^{d}	0.075 ± 0.003^{a}
13	0.075 ± 0.011^{ab}	---	0.329 ± 0.062^{bc}	0.037 ± 0.003^{b}	0.158 ± 0.020^{a}	0.522 ± 0.033^{d}	0.071 ± 0.006^{a}
16	0.083 ± 0.005^{a}	---	0.303 ± 0.046^{cd}	0.036 ± 0.005^{bc}	0.127 ± 0.007^{b}	0.500 ± 0.022^{d}	0.048 ± 0.010^{c}
28	0.082 ± 0.002^{a}	---	0.264 ± 0.007^{d}	0.030 ± 0.003^{cde}	0.106 ± 0.012^{c}	0.496 ± 0.010^{d}	0.056 ± 0.002^{bc}
sign	**		**	**	**	**	*

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$; * $p < 0.05$; ns, nonsignificant. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

Table 5. Storage III: Evolution of Neutral Sugar Composition of Dietary Fiber (Expressed as Grams per 100 g of Dry Matter)[a]

days	rhamnose	fucose	arabinose	xylose	mannose	galactose	glucose
			Insoluble Dietary Fiber				
0	0.293 ± 0.004^{b}	0.091 ± 0.047	0.880 ± 0.011^{b}	1.248 ± 0.057^{d}	0.319 ± 0.010^{c}	2.155 ± 0.021^{b}	5.206 ± 0.343^{d}
2	0.292 ± 0.011^{b}	0.107 ± 0.015	0.905 ± 0.079^{ab}	1.884 ± 0.080^{c}	0.343 ± 0.011^{bc}	2.172 ± 0.068^{b}	5.879 ± 0.512^{c}
6	0.319 ± 0.037^{ab}	0.108 ± 0.017	1.012 ± 0.095^{a}	2.389 ± 0.088^{a}	0.375 ± 0.033^{ab}	2.660 ± 0.310^{a}	7.130 ± 0.498^{b}
9	0.348 ± 0.013^{a}	0.114 ± 0.018	1.062 ± 0.154^{a}	2.384 ± 0.090^{a}	0.398 ± 0.008^{a}	2.718 ± 0.284^{a}	7.277 ± 0.181^{b}
13	0.351 ± 0.047^{a}	0.114 ± 0.012	1.066 ± 0.209^{a}	2.431 ± 0.045^{a}	0.368 ± 0.016^{ab}	2.770 ± 0.147^{a}	7.423 ± 0.421^{ab}
16	0.294 ± 0.004^{b}	0.123 ± 0.009	1.080 ± 0.015^{a}	2.331 ± 0.033^{ab}	0.365 ± 0.016^{b}	2.625 ± 0.052^{a}	7.925 ± 0.206^{a}
28	0.286 ± 0.065^{b}	0.123 ± 0.018	0.913 ± 0.107^{ab}	2.311 ± 0.064^{b}	0.352 ± 0.031^{b}	1.914 ± 0.116^{b}	6.142 ± 0.429^{c}
sign	*	ns	*	***	*	**	**
			Soluble Dietary Fiber				
0	0.051 ± 0.012^{c}		0.352 ± 0.013^{a}	0.026 ± 0.061^{b}	0.156 ± 0.003^{d}	0.784 ± 0.044^{a}	0.058 ± 0.014
2	0.055 ± 0.003^{bc}		0.317 ± 0.081^{a}	0.027 ± 0.001^{b}	0.157 ± 0.004^{cd}	0.688 ± 0.025^{b}	0.056 ± 0.007
6	0.056 ± 0.008^{bc}		0.218 ± 0.021^{b}	0.028 ± 0.004^{b}	0.168 ± 0.015^{bc}	0.620 ± 0.042^{c}	0.060 ± 0.007
9	0.058 ± 0.006^{b}		0.210 ± 0.006^{b}	0.031 ± 0.002^{b}	0.177 ± 0.008^{ab}	0.523 ± 0.019^{d}	0.060 ± 0.009
13	0.065 ± 0.003^{b}		0.221 ± 0.004^{b}	0.038 ± 0.002^{a}	0.185 ± 0.004^{a}	0.520 ± 0.064^{d}	0.056 ± 0.008
16	0.082 ± 0.013^{a}		0.333 ± 0.013^{a}	0.028 ± 0.007^{b}	0.162 ± 0.004^{c}	0.509 ± 0.017^{d}	0.066 ± 0.009
28	0.080 ± 0.002^{a}		0.364 ± 0.004^{a}	0.026 ± 0.001^{b}	0.161 ± 0.003^{cd}	0.553 ± 0.022^{d}	0.063 ± 0.012
sign	**		**	*	**	**	ns

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; ns, nonsignificant. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

storage I, but in this case arabinose, mannose, and galactose experience a more marked decrease ($p < 0.01$) (Table 4).

During storage III the changes detected in the IDF were increases for arabinose ($p < 0.05$), xylose ($p < 0.001$), and glucose ($p < 0.01$) and losses for galactose ($p < 0.01$). In the SDF, arabinose increases slightly ($p < 0.01$), contrary to what occurs in the former assay. Xylose and glucose also vary slightly, though modifications are statistically significant for xylose ($p < 0.05$). Mannose increases and losses of galactose are also observed ($p < 0.01$) (Table 5).

From the results obtained it can be deduced that the neutral sugars most affected by the vegetable metabo-

Table 6. Storage I: Neutral Sugars, Uronic Acids, and NSP Content of Dietary Fiber (Expressed as Grams per 100 g Dry Matter)[a]

	insoluble dietary fiber			soluble dietary fiber			
days	neutral sugars	uronic acids	NSP	neutral sugars	uronic acids	NSP	total NSP
0	10.194 ± 0.386^{b}	1.728 ± 0.025^{a}	11.921 ± 0.387^{b}	1.428 ± 0.042^{a}	2.238 ± 0.051^{a}	3.666 ± 0.088^{a}	15.588 ± 0.358^{c}
2	12.228 ± 0.867^{a}	1.659 ± 0.051^{a}	13.885 ± 0.887^{a}	1.419 ± 0.034^{a}	2.206 ± 0.139^{a}	3.625 ± 0.164^{a}	17.510 ± 0.870^{a}
6	13.082 ± 0.668^{a}	1.290 ± 0.190^{b}	14.372 ± 0.485^{a}	1.465 ± 0.043^{a}	1.764 ± 0.008^{b}	3.229 ± 0.035^{b}	17.601 ± 0.512^{a}
9	12.493 ± 0.383^{a}	1.237 ± 0.036^{b}	13.730 ± 0.408^{a}	1.321 ± 0.025^{b}	1.546 ± 0.040^{c}	2.867 ± 0.040^{c}	16.596 ± 0.439^{b}
sign	***	***	***	***	***	***	**

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

Table 7. Storage II: Neutral Sugars, Uronic Acids, and NSP Content of Dietary Fiber (Expressed as Grams per 100 g of Dry Matter)[a]

	insoluble dietary fiber			soluble dietary fiber			
days	neutral sugars	uronic acids	NSP	neutral sugars	uronic acids	NSP	total NSP
0	10.194 ± 0.386^{d}	1.728 ± 0.025	11.922 ± 0.387^{d}	1.428 ± 0.042^{a}	2.238 ± 0.051^{ab}	3.666 ± 0.088^{a}	15.588 ± 0.358^{e}
2	11.076 ± 0.234^{c}	1.729 ± 0.143	12.805 ± 0.367^{c}	1.350 ± 0.067^{ab}	2.334 ± 0.214^{a}	3.684 ± 0.185^{a}	16.489 ± 0.255^{c}
6	13.693 ± 0.212^{b}	1.754 ± 0.115	15.448 ± 0.238^{b}	1.295 ± 0.065^{b}	2.139 ± 0.124^{b}	3.434 ± 0.166^{b}	18.820 ± 0.283^{b}
9	14.263 ± 0.262^{a}	1.838 ± 0.045	16.102 ± 0.223^{a}	1.300 ± 0.040^{b}	2.112 ± 0.038^{b}	3.412 ± 0.077^{b}	19.514 ± 0.281^{a}
13	11.162 ± 0.299^{c}	1.773 ± 0.042	12.935 ± 0.336^{c}	1.190 ± 0.064^{c}	2.119 ± 0.066^{b}	3.309 ± 0.111^{b}	16.245 ± 0.349^{cd}
16	10.886 ± 0.205^{c}	1.759 ± 0.032	12.645 ± 0.218^{c}	1.096 ± 0.087^{d}	2.177 ± 0.052^{ab}	3.274 ± 0.130^{b}	15.919 ± 0.212^{de}
28	10.921 ± 0.170^{c}	1.727 ± 0.037	12.648 ± 0.138^{c}	1.035 ± 0.023^{d}	2.260 ± 0.028^{a}	3.295 ± 0.028^{b}	15.944 ± 0.125^{de}
sign	***	ns	***	**	**	**	***

[a] Significance levels of ANOVA: ***, $p < 0.001$; **, $p < 0.01$; ns, nonsignificant. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

Table 8. Storage III: Neutral Sugars, Uronic Acids, and NSP Content of Dietary Fiber (Expressed as Grams per 100 g of Dry Matter)[a]

	insoluble dietary fiber			soluble dietary fiber			
days	neutral sugars	uronic acids	NSP	neutral sugars	uronic acids	NSP	total NSP
0	10.194 ± 0.386^{c}	1.728 ± 0.025^{b}	11.922 ± 0.387^{c}	1.428 ± 0.042^{a}	2.238 ± 0.051^{c}	3.666 ± 0.088^{bc}	15.588 ± 0.358^{c}
2	11.581 ± 0.579^{b}	1.750 ± 0.014^{b}	13.331 ± 0.580^{b}	1.301 ± 0.091^{b}	2.809 ± 0.047^{a}	4.110 ± 0.070^{a}	17.440 ± 0.598^{b}
6	13.994 ± 1.068^{a}	1.765 ± 0.047^{b}	15.769 ± 1.073^{a}	1.150 ± 0.026^{de}	2.684 ± 0.116^{a}	3.834 ± 0.099^{b}	19.593 ± 0.966^{a}
9	14.301 ± 0.439^{a}	2.293 ± 0.099^{a}	16.595 ± 0.443^{a}	1.059 ± 0.028^{f}	2.558 ± 0.105^{ab}	3.618 ± 0.130^{bcd}	20.212 ± 0.530^{a}
13	14.503 ± 0.771^{a}	2.142 ± 0.172^{a}	16.646 ± 0.881^{a}	1.086 ± 0.073^{ef}	2.357 ± 0.439^{bc}	3.443 ± 0.378^{cd}	20.089 ± 0.797^{a}
16	14.744 ± 0.262^{a}	1.772 ± 0.170^{b}	16.526 ± 0.120^{a}	1.180 ± 0.013^{cd}	2.182 ± 0.194^{c}	3.363 ± 0.205^{d}	19.964 ± 0.222^{a}
28	12.041 ± 0.520^{b}	1.443 ± 0.285^{c}	13.485 ± 0.239^{b}	1.248 ± 0.035^{bc}	2.102 ± 0.017^{c}	3.335 ± 0.016^{d}	18.820 ± 0.245^{b}
sign	**	**	**	**	**	**	**

[a] Significance levels of ANOVA: **, $p < 0.01$. Duncan's test ($p < 0.05$): values with different superscripts differ significantly.

lism are arabinose and galactose, from the pectic polysaccharides, and xylose, the main constituent of the hemicelluloses.

In the IDF during storage I, arabinose increases progressively, but during storages II and III there are practically no changes. In the SDF, there is a noteworthy increase in the storage II samples up to day 9, after which losses are observed.

Galactose suffers losses in the IDF during storages I and II, although less in the latter, where they occur only at day 13 with no further changes. During storage III there are practically no modifications. In the SDF in the three types of storage, this sugar suffers losses, which are more important during storages II and III, during which they occur progressively up to day 9 and then cease.

Xylose in the IDF increases at the start of storage I up to day 2 and then remains unchanged and also increases during storage II up to day 9 and then decreases. During storage III there is an increase only up to day 6. In the SDF, there is an initial increase up to day 6 during storage I and up to day 9 during storage II with subsequent losses. During storage III the modifications are slight.

Furthermore, the phenomena observed in these monomers affect the samples in all of these storage conditions, although their evolution is very different in the room temperature storage compared with the two refrigerated conditions.

Uronic acids, the main constituents of pectic polysaccharides, experience important losses ($p < 0.001$) in samples stored at room temperature (storage I) in both IDF and SDF (Table 6). These losses are imperceptible in storage II (Table 7) and only slight in storage III ($p < 0.01$) (Table 8). This shows that degradation of pectic polysaccharides naturally occurring in the vegetable metabolism is clearly influenced by refrigeration conditions, especially when the spears are stored in impermeable polyethylene bags and the surrounding atmosphere is modified with an enrichment in CO_2 and a decrease of O_2.

NSPs, considered as the sum of neutral sugars and uronic acids, have a different behavior in each fraction of dietary fiber. In the three types of storage, NSP contents of the IDF vary significantly, with slight increases being observed from the initial point to the final one. In the NSP content of the SDF decreases are observed. These are more pronounced in storage I ($p < 0.001$) in relation to the other types of storage ($p < 0.01$). The total value of NSPs increases in the three types of storage, but the increases were more important in storages I and III (Tables 6−8).

The analysis of interactions (two-way ANOVA, General Linear Model procedure) indicates that the variations of the monomers (neutral sugars and uronic acids) of polysaccharides which form insoluble, soluble, and total dietary fiber are due to both factors (storage and time) (Table 9). Duncan's multiple range test ($\alpha = 0.05$)

Table 9. Analysis of Interactions[a]

	insoluble dietary fiber		soluble dietary fiber		total dietary fiber	
	F value	*p* value	*F* value	*p* value	*F* value	*p* value
storage (S)	65.76	<0.0001	36.12	<0.0001	100.48	<0.0001
time (T)	75.31	<0.0001	21.09	<0.0001	68.54	<0.0001
S × T	22.38	<0.0001	4.06	<0.0005	25.76	<0.0001

[a] Two-way ANOVA. General Linear Model procedure.

indicates that IDF and total dietary fiber are significantly different in storage III compared with storages I and II and SDF is significantly different in each storage (I, II, and III).

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