Modification of Cell Wall Composition of Apricots (*Prunus armeniaca*) during Drying and Storage under Modified Atmospheres

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Fresh apricots (*Prunus armeniaca*) were treated with $Na_2S_2O_5$ and acetic acid solutions before dehydration. Dehydrated apricots were stored at 25 °C in five different modified atmospheres (MAs) [100% N_2 (N), 20% CO_2 and 80% N_2 (2C8N), 40% CO_2 and 60% N_2 (4C6N), 60% CO_2 and 40% N_2 (6C4N), 100% CO_2 (C)]. An additional sample was stored at 25 °C under air. The yield of apricot cell wall material decreased substantially during drying pretreatments and also during dehydration, by 9.5 and 4.7%, respectively. In particular, acetic acid solubilized a large amount of pectic polysaccharides. Further degradation of pectic substances was produced during drying, probably due to the high temperature used. However, MAs retarded browning in comparison to the sample stored under air. The content of SO_2 decreased markedly for the sample stored in air, whereas gradual losses were observed for MA samples. In general, samples stored under atmospheres containing relatively low percentages of CO_2 (20 and 40%) and N_2 showed minor disruption of cell wall components and maintained better the initial characteristics of dehydrated apricots.

Keywords: *Apricots; dehydration; modified atmospheres; cell wall polysaccharides; shelf life*

INTRODUCTION

Dehydration of perishable fruits such as apricots, grapes, or plums is a traditional method commonly used to extend their shelf life. In fact, dehydrated fruits possess nutritional and organoleptic properties highly valued by many consumers (Simal et al., 1996) and, in particular, can be considered as important sources of dietary fiber (Valiente et al., 1995; Femenia et al., 1998). Storage of dehydrated fruits under modified atmospheres (MAs) may help the preservation of the physical, chemical, nutritional, and organoleptic characteristics of the dried fruit.

Both the color and the texture of dehydrated fruits are often the first of many quality attributes judged by the consumer and are, therefore, extremely important in overall product acceptance. Changes in texture that occur during processing and/or storage result from changes in the cell wall material of plant tissues (Cañellas et al., 1993).

The use of different solvents as drying pretreatments, to prevent both enzymic and nonenzymic browning, may promote important modifications in the cell wall components of the fresh fruit (Femenia et al., 1998). Furthermore, during the drying procedure, β-eliminative degradation of pectic polysaccharides may occur due to the heating process or through the heat activation of pectinmethylesterase (Femenia et al., 1997). Thus, processing and drying may have significant effects on the texture of the apricot tissues.

Although MA extension of the shelf life of fruits and vegetables is well documented (Albersheim and Anderson, 1971; Kader et al., 1989), very little is known about the effect of MA on specific cell wall components that determine the textural characteristics of fruit and vegetable tissues (McDougall et al., 1996).

Pectic hydrolytic changes have been shown to be retarded by controlled amosphere (CA) conditions (Smock, 1979). Most reports have shown that CA reduces the rate of softening, but varied findings concerning pectic changes have been reported (Brecht, 1980).

In this investigation we have evaluated the main effects of drying pretreatments, dehydration, and storage under modified atmospheres on the cell wall components of apricot tissues. In addition, the degree of browning was monitored during storage by measuring the color and SO_2 content of dehydrated apricots. Thus, the food quality of dehydrated apricots could be evaluated not only in terms of organoleptic properties but also on a nutritional basis determined by the quality of apricot dietary fiber.

MATERIALS AND METHODS

Fresh apricots (Canino variety) obtained from a local supermarket were used as the starting material for this investigation. All treatments and analyses were carried out from a single lot of apricots (~50 kg). Apricot fruits were washed, halved, and destoned. About 2 kg of fresh apricots was used to carry out an overall chemical characterization. The rest (~48 kg) were split into two separate lots of ~24 kg, and then a full set of drying pretreatments, dehydration, and storage treatments was performed on each lot so that two separately prepared samples could be analyzed.

Before drying, the two 24 kg lots of fresh apricots were pretreated by dipping in a $Na_2S_2O_5$ (31.6 g/L) solution for 25 min at 20 °C followed by immersion in an acetic acid (10 g/L) solution for 15 min at 20 °C. The fruit surfaces were then dried with filter paper and the apricots stored at 4 °C for 20 h prior to drying.

Dehydration of the two 24 kg lots of pretreated apricot lots was performed in a pilot-scale air drier (Simal et al., 1996) at 70 °C for 22 h. Final moisture content of the product was ~22.3 ± 0.1 g of water/100 g of apricots.

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Table 1. Changes in Carbohydrate Composition of Apricots during Drying Pretreatments and Dehydration[a]

sugar	fresh	$Na_2S_2O_5$	acetic acid	dehydrated
rhamnose	0.99	0.98	0.81	0.76
fucose	0.12	0.12	0.11	0.12
arabinose	5.78	5.63	5.02	4.24
xylose	2.54	2.51	2.25	2.11
mannose	1.20	1.25	1.10	1.34
galactose	3.34	3.18	2.56	2.22
glucose	18.61	18.54	18.32	18.22
Glc (1 M)	[1.99]	[1.96]	[1.83]	[1.80]
uronic acids	16.14	16.05	13.90	12.98
total	48.73	48.26	44.08	42.01
DE (%)	68 ± 3	67 ± 2	63 ± 2	57 ± 2

[a] Results are expressed as milligrams of cell wall sugar per gram of fresh apricot matter.

Dehydrated apricot samples of ~100 g were placed in 0.250 L twist-off glass containers, filled with the gas or mixture [100% N_2 (N), 20% CO_2 and 80% N_2 (2C8N), 40% CO_2 and 60% N_2 (4C6N), 60% CO_2 and 40% N_2 (6C4N), 100% CO_2 (C), and air (A)] and stored at 25 °C.

Fresh, pretreated, dehydrated, and stored apricot samples were subjected to physical and chemical determinations. In particular, analyses of stored apricot samples were performed after 30, 60, 90, 125, 160, 190, and 220 days.

Analytical Methods. An overall chemical characterization of the fresh apricots was carried out by measuring moisture, lipids, soluble sugars, protein, and ashes. All of these analyses were performed in duplicate.

To measure the moisture content, fresh apricots were dried overnight at 60 °C in the presence of silica gel and reweighed.

Total content of lipids of fresh apricots was determined gravimetrically by extraction with diethyl ether using Soxhlet equipment (Femenia et al., 1995).

Soluble sugars of fresh apricots were determined according to the method of Wilson et al. (1981) based on the sum of individual sugar content obtained by HPLC.

The nitrogen content of fresh apricots was measured using a Tecator Kjeltec 1035 autosampler system analyzer. Protein was estimated by multiplying the nitrogen value by 6.25.

Ash content of fresh apricots was determined by overnight heating at 550 °C (AOAC, 1990).

During storage, browning was monitored by measuring the color of the outer surface of dried apricots. CIE $L^*a^*b^*$ values were measured using a Minolta model CR-300 chromameter with specular component included, C illuminant, and an observer with an angle of 2° (Cano et al., 1997).

The SO_2 content of stored apricot samples was determined by using the method proposed by DeVries et al. (1986).

Alcohol insoluble residues (AIRs) were prepared from fresh apricots, after drying pretreatments, after dehydration (control sample), and for each of the storage periods. AIRs were obtained by immersing the apricot samples (~80 g) in boiling ethanol [final concentration = 85% (v/v) aqueous] as described by Waldron and Selvendran (1990). Prior to further analysis, the AIRs were milled using a laboratory type grain mill and passed through a 0.5 mm aperture sieve. The occurrence of starch in the apricot AIR samples was tested for by staining the tissues with I_2/KI solution and examination by light microscopy. All samples were free of starch, and they were used in subsequent analyses.

Carbohydrate analysis was performed as in the study of Femenia et al. (1998) for neutral sugars. Sugars were released from polysaccharides by acid hydrolysis. AIRs (~5 mg) were dispersed in 72% H_2SO_4 for 3 h, followed by dilution to 1 M, and hydrolyzed at 100 °C for 2.5 h (Saeman et al., 1954). A second sample of AIR was hydrolyzed only with 1 M sulfuric acid (100 °C for 2.5 h). The cellulose content was estimated by the difference in glucose obtained by Saeman hydrolysis and this milder hydrolysis method. Neutral sugars were derivatized as their alditol acetates and isothermally separated by GC (Selvendran et al., 1979) at 220 °C on a 3% OV225 Chromosorb WHP 100/120 mesh column. Uronic acids were colorimetrically determined, as total uronic acid (Blumenkrantz and Asboe-Hansen, 1973), using a sample hydrolyzed for 1 h at 100 °C in 1 M H_2SO_4. The values for carbohydrates given in this paper correspond to the means of duplicate determinations, and the variation between duplicates was <3%. No significant differences in sugar values were observed between either type of hydrolysis except for the case of glucose.

The degree of esterification (DE) of pectic polysaccharides, that is, the percentage of total uronic acids which are esterified, was colorimetrically determined according to the method of Lurie et al. (1994). DE analyses were performed in triplicate.

FTIR spectra were obtained on a Bruker IFS 66 instrument, at a resolution of 3 cm^{-1}, after a KBr disk containing approximately 2 mg of AIR had been prepared. The intensity of the single beam traversing each sample was expressed as a ratio with the intensity of the single beam of the corresponding background. Equivalent samples from different experimental runs gave the same spectra in all cases.

Statistical Analysis. Results were analyzed by means of a one-way and multifactorial analysis of variance, using the LSD test with a 95% confidence interval for the comparison of the test means (Best, 1990).

RESULTS AND DISCUSSION

Initial Characterization. Fresh apricots (*Prunus armeniaca*) of the Canino variety had an initial moisture content of ~84.3%. On a fresh weight basis, apart from water, soluble sugars (mainly glucose, fructose, and sucrose) and dietary fiber (as cell wall polysaccharides) were the predominant fractions, accounting for 10.3 and 4.9% of the fresh apricot, respectively. Ashes (1.1%), protein (0.7%), and lipids (0.2%) were minor fractions. The pH of the fresh apricots was 4.56.

Light microscopic examination of apricot tissues after treatment with I_2/KI showed the absence of starch. Thus, an AIR could be used as a suitable preparation of cell wall material (CWM). In fact, for fresh apricot, carbohydrate represented ~94% of the AIR.

The results shown in Table 1 indicated that pectic polysaccharides and cellulose were the predominant type of polysaccharide constituent of the CWM isolated from fresh apricot tissues. The occurrence of pectic polysaccharides was inferred from the relatively large amounts of uronic acids, arabinose, galactose, and, to a minor extent, rhamnose. This latter sugar is usually diagnostic of pectins (Waldron and Selvendran, 1990). The presence of cellulose was inferred from the fact that the bulk of glucose could be released only after Saeman hydrolysis. In addition, the presence of xylose, fucose, and noncellulosic glucose suggested the possible occurrence of xyloglucans, hemicellulosic polysaccharides characteristic of primary cell walls (Aspinall, 1980).

Drying Pretreatments. Before dehydration, the fresh apricots were treated by subsequent dipping in $Na_2S_2O_5$ and acetic acid solutions to reduce the darkening due to enzymic and nonenzymic browning during their storage. However, such pretreatments had an important effect on the cell wall composition of apricot tissues (see Table 1). In particular, after acetic acid treatment, the overall yield of CWM decreased by ~10%. This was mainly due to the solubilization of important amounts of pectic polysaccharides, as could be inferred from the decrease in uronic acids (galacturonic acid), arabinose, galactose, and rhamnose contents, and xyloglucans, as was deduced from the relatively important decrease in the levels of xylose and noncellulosic glucose. Sodium metabisulfite solution caused minor modifica-

Table 2. Changes in Carbohydrate Composition of Dehydrated Apricots during Storage in MAs[a]

atmosphere	time (days)	cell wall sugars									total	DE (%)
		Rha	Fuc	Ara	Xyl	Man	Gal	Glc	Glc (1 M)	UA		
A	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.63	0.12	4.08	2.09	1.06	1.95	18.01	(1.83)	11.52	39.46	52
	60	0.53	0.11	3.71	1.93	0.79	1.67	17.38	(1.39)	8.96	35.07	51
	90	0.51	0.10	3.66	1.93	0.74	1.68	17.18	(1.27)	8.39	34.19	50
	125	0.48	0.08	3.49	1.91	0.55	1.65	16.97	(1.21)	8.11	33.24	49
	160	0.44	0.08	3.23	1.87	0.56	1.42	16.92	(1.19)	7.82	32.34	48
	190	0.37	0.08	3.08	1.86	0.56	1.32	16.39	(1.07)	6.89	30.55	46
	220	0.27	0.08	2.98	1.82	0.55	1.17	16.60	(1.05)	6.31	29.78	46
N	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.74	0.12	4.24	2.11	1.29	2.09	18.01	(1.88)	12.04	40.64	55
	60	0.69	0.12	4.25	2.05	1.06	2.09	17.60	(1.63)	8.75	36.60	52
	90	0.68	0.11	4.22	2.00	1.05	2.05	17.65	(1.61)	8.18	35.94	52
	125	0.65	0.09	4.23	1.88	0.87	1.88	16.87	(1.57)	7.17	33.75	49
	160	0.62	0.11	4.17	1.87	0.90	1.93	17.17	(1.55)	7.18	33.95	48
	190	0.53	0.11	4.08	1.87	0.94	1.88	16.82	(1.37)	6.87	33.11	49
	220	0.52	0.10	3.96	1.79	0.80	1.83	16.86	(1.11)	6.77	32.64	46
2C8N	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.75	0.13	4.18	2.09	1.29	2.20	18.25	(2.03)	12.93	41.82	51
	60	0.74	0.12	3.98	2.08	1.11	2.21	18.00	(1.91)	12.55	40.79	45
	90	0.74	0.12	3.82	2.00	1.06	2.23	18.06	(1.69)	12.49	40.53	43
	125	0.73	0.12	3.62	1.99	0.90	2.25	16.81	(1.42)	12.03	38.43	42
	160	0.63	0.13	3.61	1.98	0.86	2.18	17.08	(1.47)	11.67	38.12	36
	190	0.58	0.13	3.50	1.97	0.80	2.16	16.66	(1.22)	11.47	37.27	31
	220	0.57	0.12	3.24	1.95	0.74	2.11	16.98	(1.16)	11.06	36.76	27
4C6N	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.77	0.12	4.22	2.15	1.27	2.19	18.00	(1.85)	12.56	41.28	50
	60	0.69	0.13	4.18	2.11	1.21	2.15	17.80	(1.68)	12.29	40.55	46
	90	0.67	0.13	4.13	2.13	1.11	2.10	17.60	(1.65)	11.51	39.38	42
	125	0.58	0.13	3.99	2.17	0.80	1.99	17.20	(1.60)	10.37	37.24	35
	160	0.56	0.12	3.84	2.08	0.90	1.93	17.13	(1.57)	9.91	36.47	33
	190	0.46	0.12	3.77	2.10	0.84	1.90	17.03	(1.44)	9.49	35.72	31
	220	0.41	0.12	3.65	2.11	0.89	1.83	16.91	(1.26)	9.43	35.36	26
6C4N	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.72	0.12	4.19	2.05	1.26	2.15	17.80	(1.91)	12.30	40.59	54
	60	0.72	0.11	4.13	2.00	0.95	1.99	17.18	(1.74)	11.51	38.60	52
	90	0.70	0.11	4.07	2.09	1.05	1.87	17.06	(1.62)	10.67	37.63	51
	125	0.66	0.09	3.96	1.85	0.81	1.88	16.61	(1.57)	9.54	35.24	46
	160	0.63	0.10	3.94	1.95	0.89	1.81	16.86	(1.56)	9.01	35.20	45
	190	0.53	0.09	3.76	1.89	0.79	1.79	16.44	(1.37)	9.12	34.43	47
	220	0.38	0.09	3.59	1.93	0.75	1.67	16.70	(1.33)	8.86	33.98	45
C	0	0.76	0.12	4.24	2.11	1.34	2.22	18.22	(2.07)	12.98	42.01	57
	30	0.74	0.12	4.18	2.13	1.26	2.18	18.26	(1.91)	12.28	41.15	56
	60	0.71	0.12	4.03	2.10	1.11	2.11	17.95	(1.83)	10.68	38.81	54
	90	0.67	0.13	3.82	2.11	1.06	1.98	17.70	(1.69)	10.30	37.78	49
	125	0.56	0.13	3.56	2.13	0.89	1.97	17.58	(1.62)	9.13	35.94	51
	160	0.48	0.13	3.45	2.15	0.84	1.88	17.74	(1.60)	8.85	35.52	48
	190	0.46	0.12	3.50	2.04	0.78	1.78	16.92	(1.37)	8.44	34.06	46
	220	0.39	0.12	3.35	2.06	0.70	1.77	16.92	(1.22)	8.33	33.65	43

[a] Results are expressed as milligrams of cell wall sugar per gram of fresh apricot matter.

tions to cell wall polysaccharides; only small amounts of arabinose and galactose were solubilized, suggesting the partial degradation of pectic side chains. Similar effects were observed in grape tissues after $K_2S_2O_5$ solution of similar concentration had been applied as a drying pretreatment for the production of raisins (Femenia et al., 1998). Moreover, treatment with acetic acid reduced the pH of the fresh apricots to 3.18.

Dehydration. Dehydration allows the extension of the shelf life of apricots by reducing the water activity. However, during drying, modification of the cell wall components may occur, due to either heating or the effect of reduced water activity. In fact, as can be observed in Table 1, drying caused further degradation of pectic polysaccharides and, to a minor extent, xyloglucans. A prominent feature was the marked decrease in the DE, suggesting that structural rearrangement of pectic polysaccharides occurred during drying. This may have an important influence on the functional and nutritional aspects of the dietary fiber derived from dehydrated apricots. Decreases of the DE with heating above 40−50 °C have been reported for other plant tissues (Laats et al., 1994; Femenia et al., 1997). Such decreases have been attributed to the activation of pectinmethylesterase. Nevertheless, dehydrated apricots can be considered a rich source of dietary fiber. In fact, the samples used in this study contained ~20% of cell wall polysaccharides.

Changes in Cell Wall Composition of Dehydrated Apricots during Storage. Changes in both the overall amount of CWM and the component sugars of the cell wall polysaccharides present in the dehydrated apricots were monitored at different stages during the storage period (Table 2).

Some obvious changes related to the cell wall components of dehydrated apricots were detected during

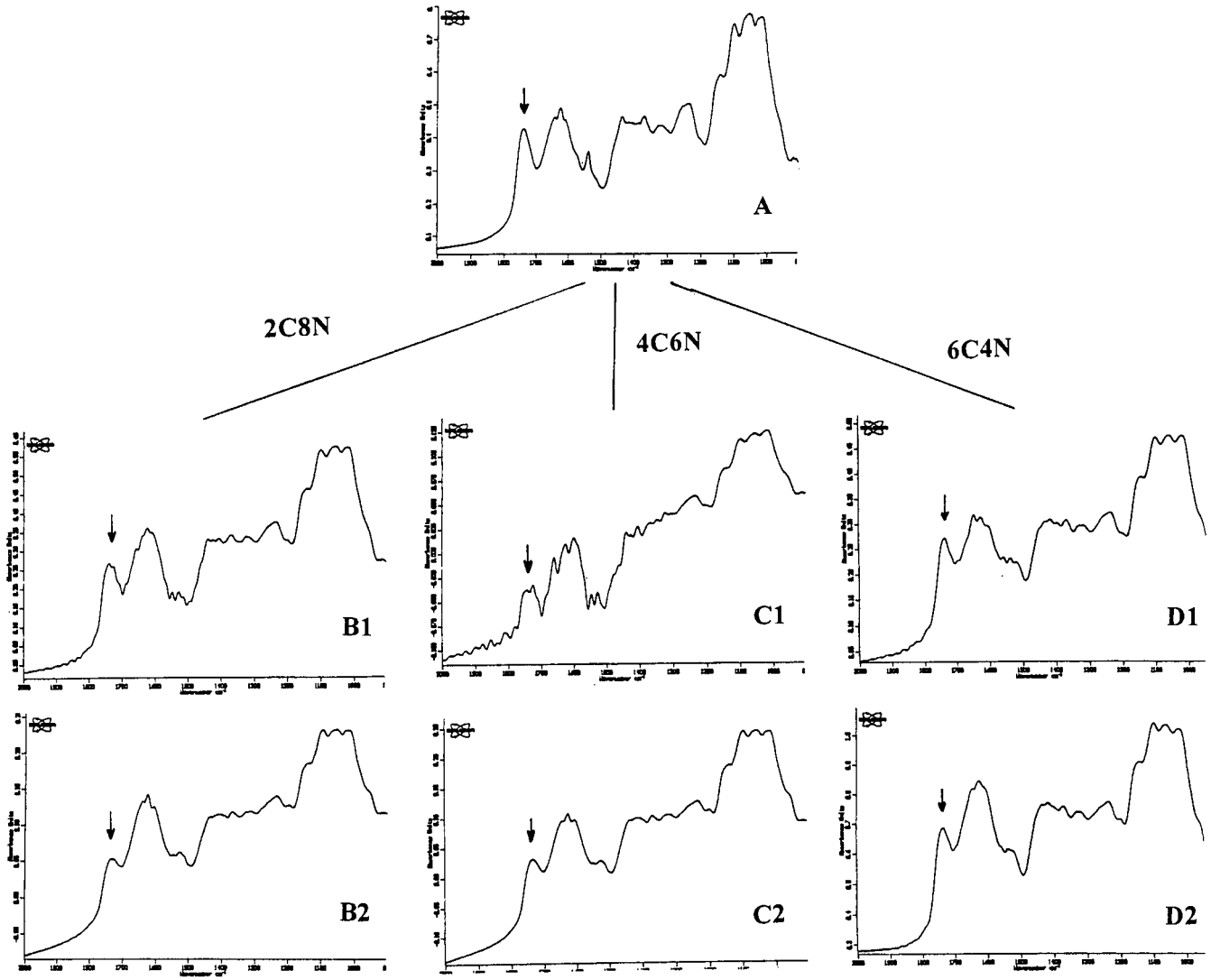

Figure 1. FTIR spectra obtained from the AIRs of dehydrated apricots before storage (A) and of dehydrated apricots stored under 2C8N after 125 days (B1) and after 220 days (B2), stored under 4C6N after 125 days (C1) and after 220 days (C2), and stored under 6C4N after 125 days (D1) and after 220 days (D2).

storage. The importance of these modifications depended on the type of atmosphere used for their storage. Throughout the storage period, the CWM of samples stored in air (A) degraded more rapidly than those stored under the different MAs used. Furthermore, samples stored under MAs containing relatively low percentages of CO_2, such as 2C8N and 4C6N, underwent a more minor level of degradation than those stored under N_2, CO_2, or 4C6N ($p > 0.05$). Thus, after a storage period of 220 days, the percentage of degradation of CWM from dehydrated apricots stored under 2C8N and 4C6N accounted for 12.5 and 15.8%, respectively, whereas for samples stored in either N_2, CO_2, or 6C4N, the percentages ranged from 19.1% for 6C4N to 22.3% for N_2. For samples stored in air, up to 29.1% of the CWM of dehydrated apricots was degraded.

The levels of most sugars decreased significantly in all atmospheres investigated. In particular, the decrease in the overall amounts of CWM was due to the partial degradation of pectic polysaccharides, xyloglucans, mannose-containing polysaccharides, and, to a lesser extent, cellulose. Thus, for dehydrated apricots kept under air, the losses of sugars related to pectic polymers such as uronic acids and galactose during storage were ~50% and up to 65% in the case of rhamnose. The loss of arabinose was lower, reaching ~30%. Thus, it is clear that during storage in air, not only do the pectic side chains, formed by arabinose and galactose, undergo some type of degradation, but also the pectic backbone breaks down, as indicated by the significant decrease in the amounts of uronic acids and rhamnose.

The use of MAs reduced significantly the degradation of pectic polymers. For instance, throughout the storage period, the 2C8N samples exhibited a significantly lower rate of degradation of the pectic backbone and, also, of the galactose-rich side chains. Galactose units are also characteristic of xyloglucans (Rupérez et al., 1985).

As can be observed in Table 2, the use of 2C8N atmosphere gave the best results in terms of preserving the structure of pectic polysaccharides. An increase in the proportion of CO_2 (to 40 and 60%) was accompanied by an increase in the rate of degradation of uronic acids, rhamnose, and, also, galactose. Moreover, the arabinose residues did not follow the same trend; thus, samples N, 4C6N, and 6C4N avoided to a higher extent the degradation of arabinose than did the sample 2C8N.

As can be observed in Table 2, a marked decrease in the DE occurred for samples 2C8N and 4C6N during

Table 3. Changes in Color Coordinates of Dehydrated Apricots during Storage in Different Atmospheres

	sample					
time (days)	A	N	2C8N	4C6N	6C4N	C
			Color Coordinate *L**			
0	58.5 ± 1.6	58.5 ± 1.6	58.5 ± 1.6	58.5 ± 1.6	58.5 ± 1.6	58.5 ± 1.6
30	58.3 ± 4.3	58.6 ± 3.8	58.5 ± 3.8	58.4 ± 2.6	58.7 ± 2.5	58.7 ± 4.8
60	53.7 ± 3.9	55.6 ± 4.1	57.4 ± 4.5	54.7 ± 4.2	52.8 ± 4.2	53.2 ± 4.2
90	51.9 ± 3.0	49.0 ± 2.2	51.4 ± 3.0	46.4 ± 2.9	47.9 ± 3.0	50.7 ± 3.5
125	46.6 ± 3.5	48.7 ± 3.1	48.4 ± 2.9	50.6 ± 3.1	43.7 ± 3.1	50.7 ± 3.2
160	41.6 ± 2.8	42.4 ± 3.9	43.3 ± 2.5	50.3 ± 3.4	41.7 ± 3.2	47.3 ± 3.4
190	43.8 ± 2.5	42.3 ± 2.6	45.1 ± 3.4	39.3 ± 2.0	44.9 ± 2.1	51.3 ± 4.0
220	40.7 ± 2.4	46.3 ± 3.6	40.1 ± 3.4	41.0 ± 3.2	36.8 ± 3.8	42.1 ± 2.1
			Color Coordinate *a**			
0	17.6 ± 1.4	17.6 ± 1.4	17.6 ± 1.4	17.6 ± 1.4	17.6 ± 1.4	17.6 ± 1.4
30	12.5 ± 1.5	14.7 ± 1.4	14.5 ± 1.8	15.9 ± 1.9	15.2 ± 1.5	15.7 ± 1.8
60	12.5 ± 1.1	14.7 ± 0.8	13.5 ± 1.6	13.9 ± 0.7	14.7 ± 1.1	14.9 ± 1.1
90	12.5 ± 1.2	14.6 ± 0.9	13.5 ± 1.2	13.8 ± 1.0	13.8 ± 1.5	14.6 ± 1.5
125	12.8 ± 0.8	14.5 ± 0.7	13.5 ± 0.8	14.2 ± 0.6	13.3 ± 0.9	14.8 ± 0.9
160	12.4 ± 0.9	13.7 ± 0.8	13.0 ± 0.7	14.1 ± 0.8	12.9 ± 1.1	14.0 ± 0.8
190	12.5 ± 0.8	13.4 ± 0.7	11.4 ± 0.8	13.2 ± 1.4	13.3 ± 0.9	14.4 ± 0.6
220	12.4 ± 0.7	13.2 ± 0.5	11.2 ± 0.8	13.0 ± 0.4	12.9 ± 0.5	13.2 ± 0.6
			Color Coordinate *b**			
0	46.9 ± 5.6	46.9 ± 5.6	46.9 ± 5.6	46.9 ± 5.6	46.9 ± 5.6	46.9 ± 5.6
30	46.8 ± 3.2	47.0 ± 3.9	47.8 ± 4.6	46.8 ± 3.9	44.7 ± 3.6	47.2 ± 3.2
60	43.9 ± 1.9	47.4 ± 3.7	49.3 ± 2.6	46.8 ± 3.5	42.8 ± 2.1	43.4 ± 2.8
90	36.8 ± 1.9	43.6 ± 3.2	46.6 ± 3.2	45.7 ± 3.3	40.3 ± 2.0	43.5 ± 2.1
125	35.5 ± 2.6	40.2 ± 2.4	42.2 ± 3.8	45.4 ± 2.5	34.2 ± 2.4	43.5 ± 1.7
160	32.2 ± 1.6	29.9 ± 1.9	38.7 ± 2.6	40.3 ± 2.1	33.9 ± 2.1	40.3 ± 1.2
190	31.0 ± 1.9	27.6 ± 1.8	33.3 ± 2.5	24.9 ± 0.9	33.8 ± 1.2	39.6 ± 2.7
220	28.9 ± 1.7	26.0 ± 1.1	31.9 ± 1.5	22.7 ± 0.9	23.9 ± 1.0	29.8 ± 2.2

the storage period. Such decrease was significantly lower in the remaining samples. Interestingly, the samples 2C8N and 4C6N underwent the lowest losses of uronic acids, galactose, and rhamnose during that period.

Degradation of pectic polysaccharides may be caused either by a β-elimination process, which breaks the backbone of pectic polymers in fragments of low molecular weight, or by the activity of enzymes such as polygalacturonase capable of degrading pectic substances. In all samples, the enzyme's mobility will be limited by the reduced water activity within the dehydrated apricot tissues. However, the fact that the samples N, C, 6C4N, and A exhibited a higher methyl ester content during storage may have promoted the process of β-elimination (Plat et al., 1991).

Pectic substances hold plant cells together; therefore, their degradation resulted in textural modifications to the apricot tissues such as fruit tissue softening.

Furthermore, a relatively important degradation of xyloglucans was detected in samples stored either under air (A) or under nitrogen (N), as indicated by the losses in xylose and noncellulosic glucose. A minor rate of degradation was observed in samples stored under other MAs; in fact, for 4C6N and C samples, the extent of degradation was not significant.

Mannose residues underwent important loses in all samples. However, the extent of degradation was significantly more extensive ($p < 0.05$) for samples stored under air. 4C6N samples exhibited the lowest losses in mannose residues.

Only a slight degradation of cellulose was detected for samples stored under MAs. Even for the sample kept under air, the cellulose content did not change significantly. This is in agreement with the idea of the cellulose being the more resistant type of cell wall polysaccharide (Franz and Blaschek, 1990).

Determination of Chemical and Structural Changes Using FTIR Spectroscopy. FTIR spectra of AIRs from dehydrated apricots were performed at 0 (control), 125, and 220 days of storage. Spectra of 2C8N, 4C6C, and 6C4N are shown in Figure 1. All samples have peaks in common at 1015, 1070, and 1105 cm^{-1} in the carbohydrate region, confirming the presence of a large amount of pectic substances (McCann et al., 1992). Moreover, the absorption between 1500 and 1600 cm^{-1} may be assigned to amide-stretching bands of contaminating protein in the AIRs (Femenia et al., 1998).

The most interesting feature of these spectra is the ester band at 1740 cm^{-1}. A marked decrease of this peak can be noted in samples 2C8N (Figure 1B1,B2) and 4C6N (Figure 1C1,C2) during storage, whereas in sample 6C4N (Figure 1D1,D2) only a slight decrease is observed at 1740 cm^{-1}. Results similar to those for 6C4N were obtained for samples A, N, and C (spectra not shown). This observation is in agreement with the main results obtained for the DE of pectic substances of dehydrated apricots. However, the disappearance of the ester band at 1740 cm^{-1} might also indicate not only a decrease in pectin esterification but also decarboxylation processes and/or the formation of carboxylic acid residues that have a shifted peak (Filippov et al., 1988).

Changes in Color and SO_2 Content of Dehydrated Apricots during Storage. As can be observed in Tables 3 and 4, both the three color coordinates and the SO_2 content decreased gradually throughout storage in all samples, involving an increase of browning. This was more evident in the samples stored under air as indicated by the decreases observed in the color coordinates *a** (transition from red to green) and *b** (transition from yellow to blue).

A marked decrease in the coordinate *a** occurred after an initial storage period of only 30 days for the sample kept in air, whereas such decrease occurred gradually in samples stored under MAs. For coordinate *b** a significant decrease was observed after 90 days of storage in the A sample; this was not detected in any of the samples stored under MA. However, significant

Table 4. Sulfur Dioxide Content of Dehydrated Apricots during Storage in Different Atmospheres[a]

time (days)	sample					
	A	N	2C8N	4C6N	6C4N	C
0	754 ± 42	754 ± 42	754 ± 42	754 ± 42	754 ± 42	754 ± 42
30	266 ± 14	405 ± 8	457 ± 23	474 ± 21	414 ± 19	422 ± 16
60	271 ± 12	271 ± 1	467 ± 30	332 ± 22	286 ± 28	223 ± 23
90	172 ± 11	256 ± 9	362 ± 21	326 ± 15	288 ± 15	221 ± 12
125	141 ± 9	295 ± 25	248 ± 18	337 ± 12	148 ± 9	237 ± 9
160	140 ± 8	212 ± 10	150 ± 11	199 ± 8	159 ± 5	212 ± 8
190	138 ± 1	135 ± 1	136 ± 17	153 ± 5	168 ± 6	205 ± 8
220	125 ± 8	133 ± 4	131 ± 8	140 ± 7	105 ± 4	120 ± 7

[a] Results are expressed as micrograms of SO_2 per gram of dried apricot.

decreases after longer periods occurred in the different samples, for example, after 160 days for sample N, after 190 days for sample 4C6N, and after 220 days for samples 6C4N and C.

After 125 days of storage, samples A and 6C4N presented the lowest values of the three color coordinates. *L**, *a**, and *b** values decreased by almost 12, 5, and 11 units for sample A and by almost 15, 4, and 13 units for sample 6C4N. After the same period, SO_2 losses were more pronounced in samples A and 6C4N, which retained ~140 ppm dm, whereas the other samples retained between 340 and 250 ppm dm, respectively. Nevertheless, at the end of the storage period (220 days), the SO_2 contents were similar in all samples.

Final Remarks. This investigation has shown how storage under MAs may improve the organoleptic characteristics of dehydrated apricots. The MAs used were able not only to retard browning but also to reduce or inhibit the activities of enzymes capable of degrading pectic polysaccharides, which play a major role in determining the textural properties of fruit and vegetable tissues. Both effects resulted in an extension of the shelf life of dehydrated apricots.

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