Carbohydrate Polymers **11** (1989) 113–125

Packaging of Solid-Pack Type Apples in Retort Pouches. Part 2: Pectin Behaviour in the Products during Processing and Storage

Elisabetta Forni, E. Senesi, Liliana Viganò, G. Bertolo & A. Maestrelli

Istituto Sperimentale per la Valorizzazione Tecnologica dei Prodotti Agricoli (IVTPA), Via Venezian n. 26, 20133 Milan, Italy

(Received 27 February 1988; revised version received 21 August 1988; accepted 25 August 1988)

ABSTRACT

The influence of processing on the degradation of pectic substances of apples ('Golden Delicious' variety) was studied. The three pectin fractions — water-soluble (WS), oxalate-soluble (OS) and residual pectin (protopectin, RP) — were determined in fresh apples, after blanching, after processing and in the following stored products: fruit slices packed both in retort pouches (half stored at 20°C, half at 4°C, both for 12 months) and in tinned cans (stored at 20°C for 12 months). The galacturonic acid content of the three fractions was determined by RP–IP–HPLC and the methanol content by GC. Due to the high protopectin level in apple, which comprises about 75% of the total pectins, the slices kept a good texture even after thermal processing in either cans or retort pouches. The analysis of the sugar content of the products showed that the sucrose from the syrup penetrated the slices during blanching and sterilising; this might produce gelling of the pectins giving the higher texture observed for these products.

INTRODUCTION

Technological research on the processing of apples has been carried out in our Institute, mainly with the aim of improving the quality of traditional solid-pack products (Crivelli *et al.*, 1985).

In previous work (Forni *et al.*, 1983), the influence of both ripeness and the period of cold storage before processing on the pectic composi-

Carbohydrate Polymers 0144-8617/89/$03.50

tion and on the texture of 'Golden Delicious' and 'Imperatore' apples was investigated.

In this paper attention is focused on the behaviour of the pectins of 'Golden Delicious' apples during a thermal processing (Senesi *et al.*, 1987) and also on the final products depending on the kind of packaging (vacuum packaging in retort pouches or canning), the temperature and the length of storage. The interaction of the pectic substances with the sugars in the syrup used in filling the pouches and cans was also studied.

A knowledge of the nature of the pectic substances of fruit and of their modifications during processing is required because the texture of the processed products is governed to a large extent by the pectins. Many authors have worked on the pectin changes during fruit processing, e.g. freezing of peaches (Polesello & Maltini, 1970), pears and strawberries (Polesello & Crivelli, 1971), canning of apricots (Souty & Jacquemin, 1976; Souty *et al.*, 1981; Navarro *et al.*, 1982), osmotic dehydration of apricots and peaches (Forni *et al.*, 1986). Pectic substances in apples in particular have been studied with regard to their changes during the storage of fresh fruit (Seipp, 1978*a,b;* O'Beirne *et al.*, 1981; Bartley & Knee, 1982) and their interactions with other polysaccharides in the fruit (Wiley & Stembridge, 1961; Tavakoli & Wiley, 1968; Aspinall *et al.*, 1983; Voragen *et al.*, 1986).

MATERIALS AND METHODS

Fruit and processing

'Golden Delicious' apples, picked at fresh market ripeness, were stored at 4°C (r.h. 90%) for 4 months and then processed as a 'solid pack'. The flow sheet for the process, as described by Senesi *et al.* (1987), is shown in Fig. 1. The cans used had a diameter of 100 mm and a height of 115 mm; the net content of the cans was 500 g (fruit 85%, syrup 15%). The size of the pouches (polyester/Al/modified polypropylene) was 290 mm × 140 mm; the thickness of the filled pouch (fruit 90%, syrup 10%) was 40 mm when the weight of the contents was about 500 g. The syrup used as the filling liquid was the same as that employed in the impregnation step (sucrose solution at 18° Brix). The time–temperature combinations for processing the cans and pouches were chosen on the basis of previous research (Crivelli *et al.*, 1985) and were checked experimentally.

Three tests were performed:

(1) Apple slices vacuum-packed in retort pouches, stored at room temperature (20°C) for 12 months (PA).

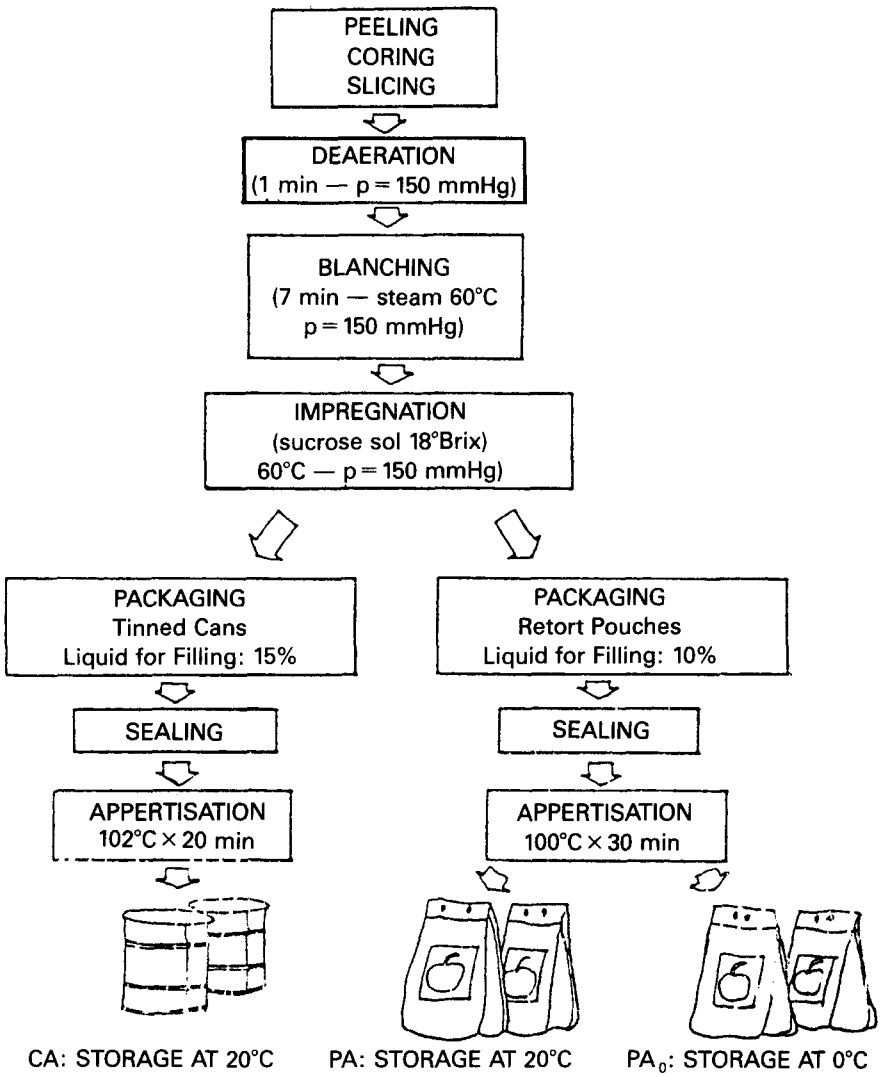

Fig. 1. Flow sheet of solid-pack process.

(2) Apple slices vacuum-packed in retort pouches stored refrigerated at 0°C for 12 months (PA_0).
(3) Apple slices in cans stored at room temperature (20°C) for 12 months as a comparison test (CA).

Analytical methods

The analytical techniques and the results regarding the organoleptic test, texture and colour measurements, pH, total acidity, dry matter (DM)

analysis have been reported in the first part of this work (Senesi *et al.*, 1987).

Here we report data for the alcohol-insoluble solids (AIS), total, water-soluble (WS), oxalate-soluble (OS) and insoluble residual (RP) pectic substances and free sugars (glucose, fructose, sucrose). Galacturonic acid was also determined in the syrup of the plastic pouches and the cans.

The determinations were made on fresh fruit, during the processing, before packaging and after 10 days (T_0) and after 3, 6, 9 and 12 months of storage.

Each sample was obtained by mixing the contents of two pouches or cans; the slices were separated from the syrup by draining, according to the AOAC method (1980).

Determination of pectic substances

The preparation of AIS and the extraction of pectic fractions were performed according to the method used by Barbier & Thibault (1982) as modified by Forni *et al.* (1986).

The pectin level was estimated by measuring the galacturonic acid content by RP–IP–HPLC (Forni & Polesello, 1986) and the methanol content by GC (Forni *et al.*, 1984) of the different extracts and calculated by the formula:

$$[(A - B) \times 176] + (B \times 190) = \% \text{ pectin}$$

where A = percentage of equivalents of free and esterified carboxyl group = percentage of galacturonic acid/176 and B = percentage of equivalents of esterified carboxyl group = percentage of methoxyl/31.

The pectin was then expressed as a percentage of fresh and dry weight of fruit and as a percentage of AIS.

The 'protopectin index' is the ratio between insoluble pectin and soluble pectins; it was calculated by the formula:

$$\text{'Protopectin index'} = \frac{\text{RP}}{\text{OS} + \text{WS}}$$

where RP, OS and WS were expressed as percentages of AIS.

Determination of sugars

Glucose, fructose and sucrose were extracted from the samples of the apple slices and analysed by HPLC according to Rizzolo *et al.* (1985).

RESULTS

Alcohol-insoluble substances (AIS) and total pectin

The percentages of AIS and of total pectin of fresh fruit (F), after blanching (BL) and during storage are reported in Table 1. The AIS content of the fresh apples was the same order of magnitude as the results of other workers using the same cultivar (Kertesz, 1951; Wiley & Stembridge, 1961; Forni *et al.*, 1983).

The percentage changes (on a dry weight basis) of AIS and total pectin during processing and storage are shown in Fig. 2(a). All values refer to the respective initial value. The AIS content of the processed slices increased about 20% after the blanching and the impregnation stages and decreased after thermal processing (appertisation). During storage the AIS contents increased for 6 months; after this period sample CA only showed a considerable decrease from 9 to 12 months. Apart from this last difference, the behaviour of the three samples examined was similar.

TABLE 1
AIS and Total Pectin Content of Fresh Fruit, After Blanching and During Storage

Stage of process	*Storage period (months)*	*% Dry weight*		*% Fresh weight*		*% AIS Total pectin*
		AIS	*Total pectin*	*AIS*	*Total pectin*	
F	—	1·79	0·28	11·32	1·76	15·59
BL	—	2·02	0·35	13·61	2·36	17·37
CA	T_0	1·82	0·33	12·17	2·27	18·64
	3	1·85	0·33	12·64	2·25	17·81
	6	2·09	0·36	14·69	2·57	17·52
	9	2·08	0·38	14·70	2·74	18·64
	12	1·78	0·34	12·60	2·44	19·35
PA	T_0	1·93	0·40	12·15	2·55	20·97
	3	1·82	0·37	12·74	2·59	20·34
	6	2·15	0·43	14·54	2·96	20·40
	9	2·03	0·43	13·65	2·88	21·08
	12	2·09	0·42	13·87	2·81	20·26
PA_0	T_0	1·85	0·39	12·19	2·60	20·96
	3	1·85	0·35	12·30	2·36	19·19
	6	2·30	0·46	15·67	3·17	20·25
	9	2·29	0·45	15·33	2·98	19·48
	12	2·34	0·42	15·50	2·93	18·12

CA = canned apples; PA = pouched apples stored at room temperature; PA_0 = pouched apples stored at 0°C; F = fresh fruit; BL = blanched fruit; T_0 = measured immediately after appertising.

As regards the total pectin content (on a dry weight basis), Fig. 2(a) (dotted line) shows increases after the pre-treatment. A similar increase was noted by Zyren *et al.* (1983) for apple and apple sauce both after cooking and canning. After thermal processing the behaviour of the products diverged: pectin increased in pouches (PA and PA_0) but slightly decreased in cans (CA). The PA product showed an increase in the pectin content from 3 to 6 months of storage and a slight decrease during the next period; the PA_0 pectin, apart from a decrease in the first 3 months, showed similar behaviour, while the CA pectin increased for 9 months and then decreased.

We report in Fig. 2(b) the percentage changes (on an AIS basis) of total pectin; all values refer to the respective initial value. The difference

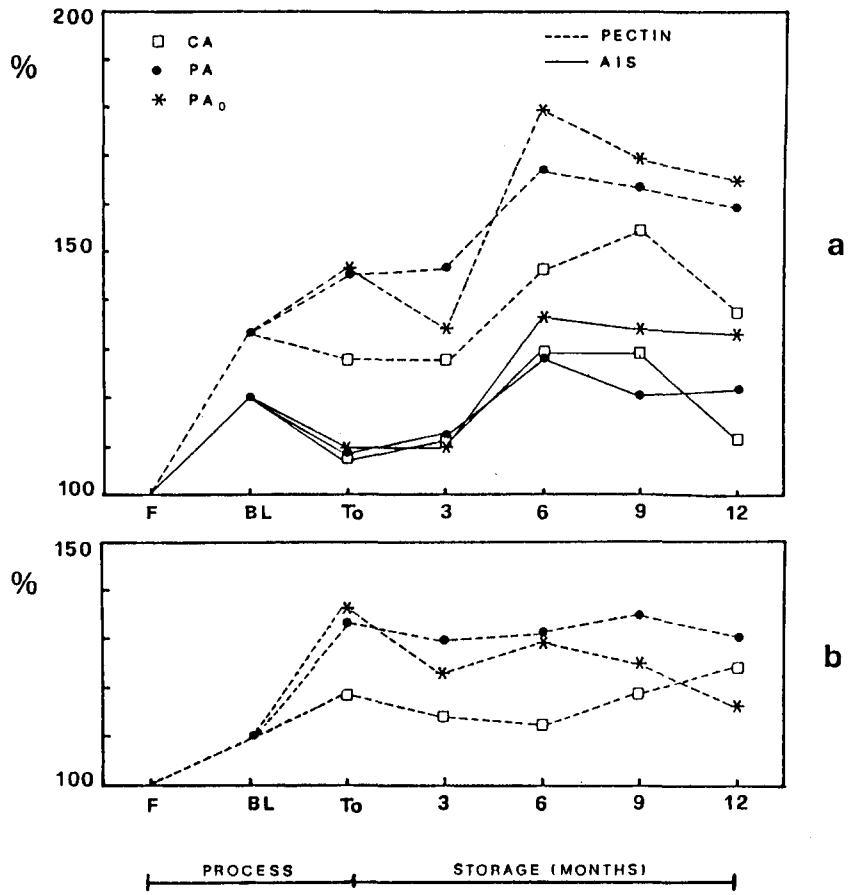

Fig. 2. (a) AIS and total pectin change during processing and storage as a percentage of the raw fruit values (on a dry weight basis). (b) Total pectin change as a percentage of the raw fruit values (on an AIS basis). F, BL, T_0 (see Table 1).

in behaviour between the canned and plastic pouched products was confirmed, mainly owing to the major increase of the pectin for the PA and PA_0 products with respect to the canned; this suggests processing differences for CA and PA samples. During storage the values did not change significantly, even though those of PA_0 tended to come down.

Pectic fractions

In Fig. 3 we report the pectic fractions extracted: water-soluble pectin (WS), oxalate-soluble pectin (OS), insoluble residual pectin (protopectin, RP). The values are expressed as a percentage of the AIS.

Fresh apple AIS showed a large content of RP even with respect to the WS and OS fractions. So the 'protopectin index', that had been proposed as an index of the ability of the fruit to withstand technological processes which have a tendency to collapse cellular tissues (Forni *et al.*, 1986), was consequently high (Table 2). A rise in this index was noted after the

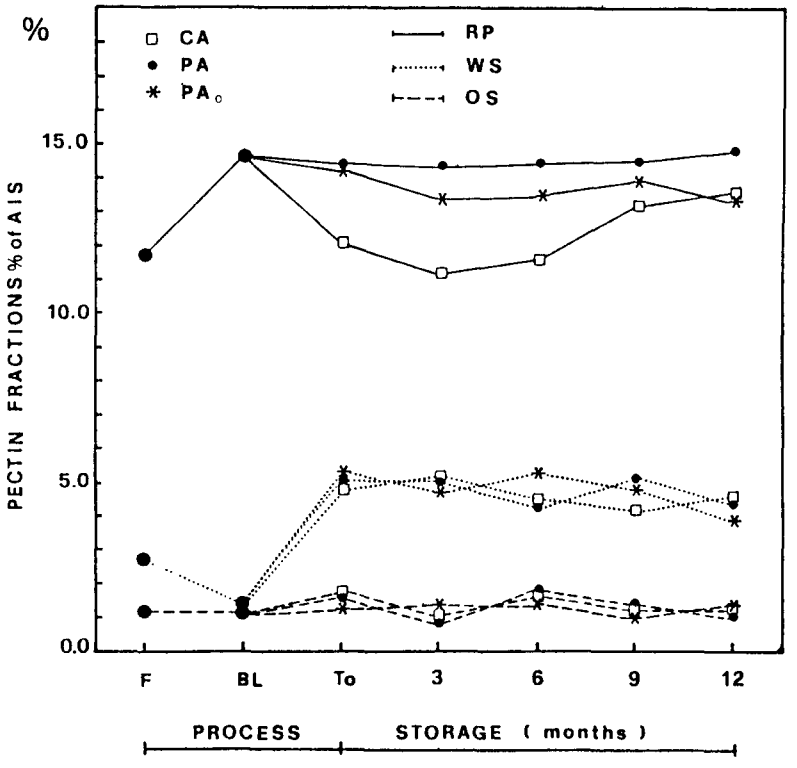

Fig. 3. Percentage of pectin fractions in the AIS during processing and storage. F, BL, T_0 (see Table 1).

pre-treatments that caused an increase of RP and a decrease in the WS fractions in all the products.

After thermal processing (T_0), the RP fraction decreased only in the AIS of CA, while the WS fraction increased in the AIS of all three. This enhancement resulted in a decrease in the 'protopectin index' to 1·9 for CA and 2·2 for PA and PA_0.

During storage the protopectin content as a proportion of the AIS remained stable in pouched products and slightly decreased in canned ones until the end of the storage. The WS and OS fractions (the latter was present in only small amounts in fresh and processed fruit) did not significantly change during storage. As a consequence of this the 'protopectin index' showed little change in all three types of product.

The same behaviour was found for pectin when expressed on a dry weight basis.

The relative distribution of pectic substances in the three fractions (WS, OS and RP) is reported in Fig. 4. RP was always the major component, though there was a decrease in this caused by processing that was slightly more evident in the canned products. WS pectin, in spite of the increase caused by the appertisation, never reached 30% of the total pectin and OS was very low. Therefore the 'protopectin index', which ranged from 2·3 to 2·6 at the end of storage, was sufficiently high to ensure a good product firmness (as already seen for peach by Forni *et al.*, 1986). This is shown by the previously reported texture measurements (Senesi *et al.*, 1987).

Sugars

Table 3 lists the glucose, fructose and sucrose contents of the products. The pre-treatments influenced the composition of the sugars in the apple

TABLE 2
'Protopectin Index'[a] of Fresh Fruit, After Blanching and Processing and During Storage

Stage of process	*Before canning*	T_0	*Storage period (months)*			
			3	*6*	*9*	*12*
F	3·0	—	—	—	—	—
BL	5·3	—	—	—	—	—
CA	—	1·9	1·7	1·9	2·4	2·3
PA	—	2·2	2·2	2·0	2·4	2·6
PA_0	—	2·2	2·2	2·0	2·4	2·6

F, BL, T_0 (see Fig. 1).
CA, PA, PA_0 (see Fig. 2).
[a] Insoluble/soluble pectin ratio (see Materials and Methods).

slices; in fact while sucrose increased, fructose and glucose decreased, suggesting a mutual diffusion of sugars between the fruit and the impregnating solution (sucrose solution at 18° Brix).

After thermal processing it was noted that there was an increase in the total sugar content due to sucrose migration from the syrup (this has the same composition as the impregnating solution) into the apple slices. Such penetration continued during the storage, especially in CA and PA products. During this period glucose and fructose increased, while sucrose, apart from the initial stage, decreased. These facts suggest that there was hydrolysis of the sucrose absorbed in the slices (apple slices pH = 3·6). Giangiacomo *et al.* (1987) observed the hydrolysis of sucrose permeated into the flesh of some fruit after the process of osmotic dehydration of fruit using sucrose syrup.

Galacturonic acid in the syrup

Table 4 reports the galacturonic acid contents of filling syrup in the pouches and in the cans. A diffusion of pectin from the apple slices into the syrup was noted just after processing (T_0). During the storage no other substantial modifications were observed.

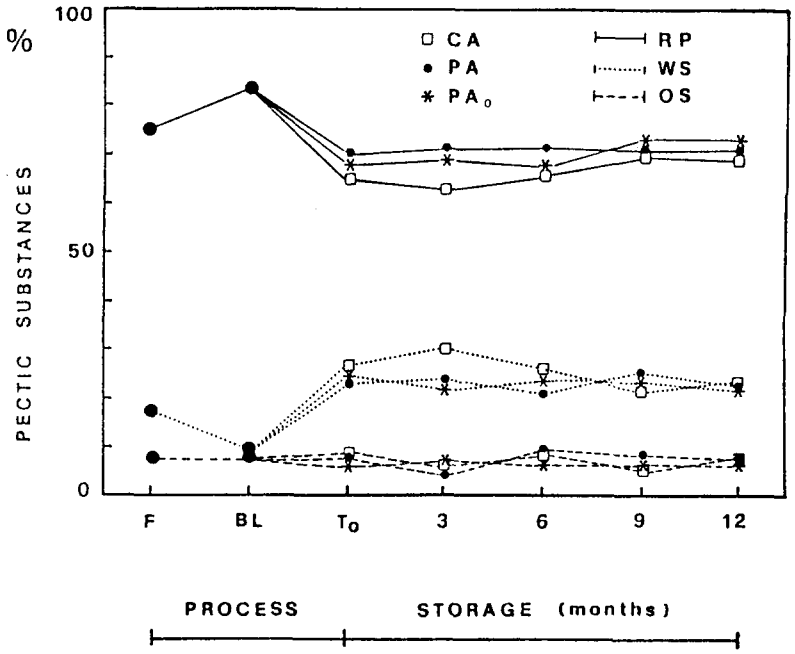

Fig. 4. Distribution of pectic substances in the fractions WS, OS, RP. F, BL, T_0 (see Table 1).

TABLE 3
Sugar Content of Fresh Fruit, After Blanching and Processing and During Storage

Stage of process	*Storage period (months)*	*Sugar level (% dry weight)*			
		Glucose	*Fructose*	*Sucrose*	*Total sugars*
F	—	14·94	32·85	11·77	59·56
BL	—	9·54	31·62	24·80	66·01
CA	T_0	16·05	32·57	31·10	79·73
	3	16·12	34·43	25·89	76·43
	6	19·96	38·65	23·19	81·80
	9	21·75	39·12	25·99	86·86
	12	24·61	41·23	21·54	87·37
PA	T_0	15·59	33·24	28·91	77·75
	3	17·36	37·56	28·51	83·43
	6	21·31	41·65	24·07	87·17
	9	22·39	39·68	20·24	82·31
	12	23·49	43·33	22·03	88·85
PA_0	T_0	14·70	32·72	26·03	73·46
	3	15·89	34·57	29·05	79·52
	6	15·61	35·97	24·31	75·89
	9	18·07	41·10	25·03	84·20
	12	19·42	37·77	28·43	85·62

F, BL, T_0, CA, PA, PA_0 (see Table 1).

TABLE 4
Galacturonic Acid Content of Syrup in Canned and Packed Products (mg/100 ml)

Products	T_0	*Storage period (months)*			
		3	*6*	*9*	*12*
CA	36	40	40	51	51
PA	54	64	65	68	83
PA_0	46	59	62	68	53

CA, PA, PA_0 (see Table 1).

DISCUSSION

The treatment carried out before packing consisted of taking the air out of the slices, then steam blanching and finally wetting in a sucrose solution. All these processes took place under vacuum. So both the enzymatic inactivation and the increase of the texture of the product

(Hoover & Miller, 1975) occurred; the latter effect was probably due to the substitution of the intercellular air of the slices by the water and sugar solution. During this part of the process there was an exchange between the apple and the sugar solution, which was shown by the increase in the water content and sucrose in the apple, and by the decrease in glucose and free acids, as already shown in Part 1 (Senesi *et al.*, 1987). As a result of this, alcohol-insoluble substances (AIS) and pectins increased in the apple slices. Specifically an increase in protopectin was noted as the soluble pectin dissolved.

The appertising of the products, performed at higher temperature and longer time than the blanching, produced a decrease in the AIS content of the fruit. This is probably because under these conditions of temperature, time and pH, hydrolysis of the major components of the AIS, e.g. starch, pectic substances, hemicellulose and cellulose, can occur (Gierschner, 1981). We supposed that this degradation was mostly suffered by the non-pectic components of the AIS, because we noted an increase in the pectic content of the AIS, which was associated with a simultaneous increase in the texture of the fruit (Senesi *et al.*, 1987).

Figure 3 shows that during this phase, besides a decrease in the protopectin that could be made soluble by hydrolysis, particularly in the canned product, there was a net increase in the WS fraction. Most of the WS was retained in the fruit even though there was a slight migration of the soluble pectin in the syrup which was shown by the presence of small amounts of galacturonic acid. The water-soluble pectin could be made insoluble if sufficient sucrose was adsorbed on the surface of the apple slices to cause gellation. The filling liquid in fact contained 18% sucrose and it was about 15% wt/wt of the total product in the can and 10% of that in the pouch; as a matter of fact, after appertisation the apple slices showed an increase of 34% (DM) in total sugars (Table 3). The pH value of 3·6, the high degree of esterification of about 80% and the heat treatment — about 100°C — are conditions which lead to the formation of a hydrophobic pectin–sugar interaction (Kertesz, 1951). According to Oakenfull & Scott (1984), the stabilisation of these interactions explained the pectic gel caused by the sucrose and its rheological properties. This phenomenon could justify the rise in the values of firmness and the higher amount of pectin in the AIS after appertisation, particularly considering that the fruit and the syrup were in contact for a long period of time.

All through storage the amounts of AIS and pectin slightly increased. Even though the values of the 'protopectin index' in the canned slices were lower than those of the pouched ones, this parameter was close to that of fresh fruit.

As already seen for peaches in a previous investigation on pectic substances in osmodehydrated fruit (Forni *et al.*, 1986), good scores in organoleptic tests and higher values in texture measurement values correspond with these 'protopectin index' values, emphasizing the usefulness of the high 'protopectin/soluble pectin' ratio as an index of the firmness stability of fruit.

We can conclude that as far as the chemical parameters considered in this work are concerned, no substantial differences were noted between the two kinds of processing used, measured both immediately after processing and after storage. This is consistent with the organoleptic, textural and colour parameters reported in Part 1.

REFERENCES

AOAC (1980). *Official Methods of Analysis* (13th edn.). No. 32.002.
Aspinall, G. O., Fanous, H. K. & Sen, A. K. (1983). In *Unconventional Sources of Dietary Fiber*, ed. Ivan Furda. ACS, Washington, D.C.
Barbier, M. & Thibault, J. F. (1982). *Phytochemistry*, **21**(4), 111.
Bartley, I. M. & Knee, M. (1982). *Food Chem.*, **9**, 47.
Crivelli, G., Senesi, E., Torreggiani, D., Bertolo, G. & Maestrelli, A. (1985). *Industrie Alimentari*, **21**(3), 249.
Forni, E. & Polesello, A. (1986). *Forum Analitico HP (Hewlett Packard)*. June 18–20, Marina di Ravenna, Italy.
Forni, E., Rizzolo, A. & Polesello, A. (1983). *Proceedings of European Food Chemists II*. March 15–18. Rome, Italy, 423 pp.
Forni, E., Rizzolo, A. & Gargano, A. (1984). *Conservazione degli Alimenti*, **3**, 38.
Forni, E., Torreggiani, D., Battiston, P. & Polesello, A. (1986). *Carbohydr. Polym.*, **6**, 379.
Giangiacomo, R., Torreggiani, D. & Abbo, E. (1987). *J. Food Process. Preserv.*, **11**, 183.
Gierschner, K. (1981). *Gordian.*, **7**, 171 and **9**, 205.
Hoover, M. W. & Miller, N. C. (1975). *J. Food Sci.*, **40**(4), 698.
Kertesz, Z. I. (1951). In *The Pectic Substances*. Interscience, New York.
Navarro, G., Lopez, J. M., Souty, M., Munoz, J. J. & Navarro, S. (1982). *Sci. Aliments*, **2**, 275.
Oakenfull, D. & Scott, A. (1984). *J. Food Sci.*, **49**, 1093.
O'Beirne, D., Van Buren, J. P. & Mattick, L. R. (1981). *J. Food Sci.*, **47**, 173.
Polesello, A. & Crivelli, G. (1971). *Industrie Agrarie*, **9**, 119.
Polesello, A. & Maltini, E. (1970). *Industrie Agrarie*, **8**(6), 199.
Rizzolo, A., Forni, E. & Polesello, A. (1985). *Atti del Convegno: Trasformazione e Valorizzazione della Frutta*. January 28–30. Bari, Italy.
Seipp, D. (1978*a*). *Gartenbauwissenschaft*, **43**(5), 222.
Seipp, D. (1978*b*). *Gartenbauwissenschaft*, **43**(6), 248.
Senesi, E., Forni, E., Bertolo, G., Viganò, L. & Maestrelli, A. (1987). *Industrie Alimentari*, **26**(4), 369.

Souty, M. & Jacquemin, G. (1976). *Ind. Alim. Agric.*, **2**, 391.
Souty, M., Breuils, L. & Andrè, A. (1981). *Sci. Aliments*, **1**(3), 265.
Tavakoli, M. & Wiley, R. C. (1968). *Proc. Am. Soc. Hort. Sci.*, **92**, 780.
Voragen, F. G. J., Schols, H. A. & Pilnik, W. Z. (1986). *Lebensm. Unters Forsch.*, **183**, 105.
Wiley, R. C. & Stembridge, G. E. (1961). *Proc. Am. Soc. Hort. Sci.*, **77**, 60.
Zyren, J., Elkins, E. R., Dudek, J. A. & Hagen, R. E. (1983). *J. Food Sci.*, **48**, 600.