

# INFLUENCE OF CHEMICAL TREATMENT ON QUALITY OF CUT APPLE (cv. JONAGORED)

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## ABSTRACT

*The quality of a new variety of apple, 'Jonagored', after peeling and cutting was evaluated during ten days of storage in air at 4C. The objective was to evaluate the shelf-life of apple cubes by detecting the limiting parameter and to test the influence of different chemical dips on the cut apple quality with the aim of extending shelf-life. Color, i.e. browning at the cut surface, was found to be the critical quality parameter determining the shelf-life of the cut apple to less than three days. There were no significant differences between the dip treatments in measurements of CIE values. When apple cubes were treated with ascorbic acid, ascorbic acid plus calcium chloride or ascorbic acid plus calcium chloride and citric acid, the 0.75% ascorbic acid dip was found to be the most effective preservation treatment in terms of reducing color change of the cut surface. Both 0.75% ascorbic acid and 0.75% ascorbic acid plus 0.75% calcium chloride inhibited the loss of firmness of apple cubes. When citric acid was added to the dip treatment, there were color changes similar to those of the control.*

## INTRODUCTION

Changes in consumer life-styles together with the increasing desire for fresh quality in all food products, has led to the development of a new category of fruits, minimally processed fruits (Burns 1995). However, they have increased perishability and shorter shelf-life as compared with fresh/intact fruits (Floros

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1993). Most steps in minimal processing such as peeling, slicing, coring and cutting result in loss of physical integrity, and allow enzymes and substrates to come together promoting browning and other breakdown reactions (Huxsoll *et al.* 1989).

Quality attributes expected in minimally and traditionally processed fruits by consumers are similar, although a greater emphasis is put on visual characteristics of the former. The shelf-life is the time required for any of these quality attributes to become unacceptable (Huxsoll *et al.* 1989). The key to designing practical minimal processing systems would be to select a set of treatments that would uniformly preserve all quality parameters while maintaining overall fresh-like quality. There is no single treatment available that will preserve all quality parameters since the potential degrading reactions are quite variable. A good scheme is to use a "hurdle" approach, which consists of combining two or more preserving treatments, on the assumption that their effects are additive (Huxsoll and Bolin 1989; Huxsoll *et al.* 1989). Potential preservative treatments that may be used are low temperature storage, pH modification, use of chemical additives, and controlled or modified atmosphere storage.

Color changes have been found to be one of the major problems in preserving cut fruits. Apples are an example of fruits that are susceptible to enzymatic browning. The browning reactions in apples appear to be a complex process involving several factors. Nature and levels of substrates, the enzymatic activity, and the presence of inhibitors or promoters influence the browning reactions. Polyphenoloxidase activity and the substrate concentration appear to be the two major factors involved. The extent that each will contribute to the browning reaction is dependent on the cultivar (Coseteng and Lee 1987).

Extensive research related to preserving the quality of fresh cut fruit has been performed with different well known varieties of apples. Ponting *et al.* (1972) compared the use of sulfite-containing and sulfite-free treatments on preserving the overall quality, especially color, of two varieties of apple, 'Golden Delicious' and 'Newtown Pippin'. They found that two-way combinations of either ascorbic acid (0.5 to 1.0%) or SO<sub>2</sub> (0.01 to 0.03%) with calcium (0.05 to 0.10%) were effective in preserving the color for several weeks. Santerre *et al.* (1988) tried to evaluate the feasibility, based on flavor, texture, and color, of different antioxidants to protect the color of apple slices. They suggested that 0.5% D-araboascorbic acid might be substituted for 1% L-ascorbic acid to treat 'Spy' and 'Jonathan' apple slices prior to freezing, because it maintained color and sensory properties as well, and is less expensive than L-ascorbic acid. Esselen *et al.* (1945) showed that, besides being effective in preventing undesirable color changes, small amounts of D-isoascorbic acid were also effective in preventing loss of natural L-ascorbic acid of tomato juice during storage, which may induce a "hurdle" effect on color preservation. Sapers *et al.* (1990) compared different browning inhibitors applied to the cut surface of apple through different

techniques aiming to achieve a more effective penetration into the fruit pieces. They found that apple plugs infiltrated with treatment solutions, in spite of increased shelf-life when compared with dipping, needed dewatering to prevent water logging. Kim *et al.* (1993b) tried to determine the most suitable among several major apple cultivars for minimal processing. They concluded that no single cultivar appeared to be most suitable for minimal processing. However 'NY 674', 'Cortland', 'Golden Delicious', 'Empire' and 'Delicious' showed more desirable attributes than 'Mutsu' and 'Rome'. However, all these studies dealt primarily with inhibition of browning in well known apple cultivars. Published information about the cultivars most suitable for minimal processing is limited. Scarce information is available on the effects of chemical additives on other quality parameters, including sensory attributes of apple cubes.

The objective of this research was to evaluate the shelf-life of apple cubes by detecting the limiting parameter and to test the influence of different chemical dips on cut apple quality. While sulfiting agents have been the standard for inhibiting browning reactions, concerns over possible sensitive consumers' allergic reactions have led to the use of alternatives (Brecht 1995). Three different chemical solutions were used.

## MATERIAL AND METHODS

### Plant Material

'Jonagored' apples grown at Estação Regional de Vitivinicultura e Fruticultura - Quinta de Sergude, Felgueiras, Portugal, were harvested on the 23rd of September, 1993 (normal harvest date every year). 'Jonagored' is a new variety, a mutant of 'Jonagold', which is a controlled cross of 'Jonathan' with 'Golden Delicious' (Trillot *et al.* 1993). 'Jonagold' has achieved wide popularity because of its high yield and excellent dessert quality. 'Jonagored' has potential to obtain even higher success among consumers, since its chemical characteristics are similar to 'Jonagold' and it has a more attractive red color. The fruits were stored in air at 4°C for 1 to 3 months until they were used in the experiments.

### Treatment and Storage Conditions

Apples stored under refrigeration were transported weekly to the laboratory in Porto. The experiments were performed on the same day as the transport. The apples for each experiment were initially washed in chlorinated water (0.75% active chlorine for 5 min) (Wardowski and Brown 1991) to prevent surface contamination. After peeling and coring, the remaining tissue of each apple was cut in cubes of approximately 1.5 cm. Apple cubes were then randomly selected for different experiments. Three replicates of 30 apple cubes were prepared for

each experimental series. Initially, the quality of the apple cubes was evaluated during 10 days of storage in air at 4C, and the critical quality parameter was determined by sensory analysis. In subsequent experiments, the apple cubes were dipped in chemical solutions for 5 min and drained in a plastic colander. The chemical solutions used were: 0.75% ascorbic acid; 0.75% ascorbic acid + 0.75% calcium chloride; and 0.75% ascorbic acid + 0.75% calcium chloride + 0.75% citric acid. The immersion time was determined in preliminary experiments. Three different periods of immersion time (1, 5 and 10 min) were tested and their influence on development of browning was evaluated. The relationship between browning and immersion time is related to a greater inhibitor diffusion into apple tissue over time, which has been reported to follow first order kinetics (Monsalve-Gonzalez *et al.* 1993). According to the preliminary results (data not shown), an immersion time of 5 min was selected and used as the most efficient to inhibit color changes.

The apple samples, both untreated and chemically treated, were stored in closed plastic boxes in air at 4C during 10 days in the dark. The boxes were not air tight and did not result in significant atmosphere modification (data not shown). Samples were evaluated in terms of several quality attributes, listed below, at different times of storage.

### Weight Loss

All the samples were weighed before and at different times of storage. The weight loss was calculated in terms of %.

### Color Assessment

One measurement was performed on each of 10 apple cubes from each of the three replicates. Cut fruit surface color was measured with a hand-held tristimulus reflectance colorimeter (Minolta CR-300, Minolta Corp., Ramsey, New Jersey, USA). Color was recorded using the CIE-L\*a\*b\* scale, where L\* indicates lightness, a\* indicates chromaticity on a green (-) to red (+) axis, and b\* chromaticity on a blue (-) to yellow (+) axis. Numerical values of a\* and b\* were converted into hue angle ( $H = \tan^{-1} b^*/a^*$ ) and chroma [ $\text{Chroma} = (a^{*2} + b^{*2})^{1/2}$ ] (Francis 1980).

### Firmness Measurements

One measurement was performed on each of 10 apple cubes (the same used for color assessment) from each of the three replicates. Fruit firmness was measured with an Instron Universal Testing Instrument (model 4501, Instron Corp., Canton, Massachusetts) using the compression mode (5 mm deformation). A 100 Newton load cell was used and the crosshead speed was 10 mm/min. A 5

cm diameter flat plate was used. This test measured apple firmness based on the resistance of the fruit flesh to deformation by the plate. Results were expressed in Newton (N) (Kader 1982).

### **Titrateable Acidity**

The 30 apple cubes from each of the three replicates were crushed, and 20–30 g of the expressed juice were diluted with 250 mL of recently boiled water. Twenty-five mL of the prepared juice were titrated with 0.1N NaOH, beyond pH=8.1, and data was interpolated to pH=8.1. This potentiometric titration was performed with a pH combined electrode Ingold U402-57/120 and a Crison MicroPH 2002 (Crison Instruments, S.A., Barcelona, Spain) potentiometer. The results were converted to percent malic acid [(mL NaOH\* 0.1N (NaOH)/weight of sample titrated) \* 0.067\*100].

### **pH**

The pH of the apple juice was measured using a pH meter (Crison model Micro pH 2002, Crison Instruments, S.A., Barcelona, Spain) with a xerolyte electrode Ingold Lot 406-MGDXX-57/25, which had been previously standardized to pH=4 and pH=7.

### **Sugars**

The sugars analyses (sucrose, D-glucose and D-fructose) were carried out using a high performance liquid chromatograph SP 8800 (Spectra Physics), using a NH<sub>2</sub> column, 5 $\mu$ /Spherisorb - Biochrom). Samples (10  $\mu$ L) were injected at a flow rate of 2.0 mL/ min using 80% acetonitrile + 20% water as eluent. The temperature of the column was 40C. The components were detected by a refractive index detector HP 1047 (Hewlett Packard). The peaks were quantified by an external calibration method.

### **Soluble Solids**

The soluble solids content of the nondiluted juice from the crushed apple cubes was determined at 20C with a hand held sugar refractometer model Atago-ATC1. Results were expressed in degrees Brix.

### **Sensory Analysis**

The aim of sensory analysis was to find out if the quality changes in minimally processed apple detected by objective measurements were perceived by sensory evaluation, and how those changes affected the product acceptability.

The screening and selection of the sensory panel was based on the ability for

recognition of basic tastes, to determine the intensity of basic tastes, odor recognition, and texture rating (Stevens and Albright 1980). Fifteen judges were selected and they were graduate students between 24 to 34 years old. Samples were evaluated by these 15 panelists and they were presented randomly to them at room temperature. Tasting was performed in a sensory testing room with individual booths and controlled lighting (white), with samples presented in plastic transparent boxes. Each panelist was asked to rate three main components of apple quality, color, firmness and flavor and also overall fruit quality, in terms of the degree of liking of each sample. A 5-point hedonic scale was used: 1 = dislike extremely; 3 = neither like or dislike; 5 = like extremely. The product was considered unacceptable if scored below 3. Each sample was evaluated twice.

### Statistical Analysis

In order to be able to compare experiments performed at different dates with apples stored for different periods of time, differences between the controls in those experiments were taken into account. The results from different treatments were corrected by those differences [corrected experimental result 2 = experimental result 2 + (control 1 - control 2)/ control 2 \* experimental result 2; corrected experimental result 2 was compared to experimental result 1].

The statistical analyses computer system package (SAS 1986) was used for analysis of the data. Statistical significance was assessed by two-way analysis of variance (sources of variation were chemical additives). Significant differences between chemical treatments and times of storage were detected using Duncan's multiple range test.

To study the eventual relationships between sensory attributes and objective quality measurements, correlation analysis was conducted between both sets of variables. R is the regression coefficient.

## RESULTS AND DISCUSSION

### Critical Parameter for Apple Quality Stored in Air at 4C

Color was found to be the critical objective quality parameter for untreated cut apple because significant changes occurred between the first and third day of storage ( $p < 0.05$ ). Those changes were considered quite severe showing that 'Jonagored' apple cubes underwent severe browning during the initial days of storage as expected (Kim *et al.* 1993a). The cut surfaces were significantly darker (lower  $L^*$  values) and less green (higher  $a^*$  and lower hue values) ( $p < 0.05$ ) (Fig. 1); the  $b^*$  value did not seem to be related to the extent of browning. Similar results were obtained by Sapers and Douglas (1987) with several other cut apple cultivars. They suggested that enzymatic browning at cut surfaces of apples could

be monitored by measuring changes in reflectance  $L^*$  and  $a^*$  values, and that  $b^*$  values seemed to be unrelated to the extent of browning. In agreement with objective data, color was found to be the limiting quality parameter also by sensory analysis. Significant differences ( $p < 0.05$ ) were found between the fresh samples and samples after three days of storage. It was the only sensory parameter that was rated below 3 (Table 1).

A significant decrease ( $p < 0.05$ ) of the resistance value for 5 mm deformation of the untreated cut apple was noticed after the 7th day of storage (Fig. 2). Kim *et al.* (1993b) also found increased loss of firmness in apple slices after the 7th day of storage at 2C in several cultivars. No significant change of firmness was detected by sensory analysis during storage (Table 1).

A decline in acidity (0.43 to 0.24 g malic acid/100g) of apple cubes was noticed with storage time ( $R = 0.61$ ). This decrease in acidity might be due to increased respiration following peeling and cutting. Acids are known to be used quickly during respiration compared with other compounds (Kim *et al.* 1993b).

The fructose content of untreated cut apple remained almost constant during the 10 days of storage (6.6 to 7.3%). No significant changes ( $p > 0.05$ ) were observed in the sucrose or glucose content (around 2% and 4%, respectively). No significant changes were observed either in the soluble solids content (around 13%).

Differences detected in flavor by sensory analysis were only significant at the 10th day of storage (Table 1).

The correlation between weight loss and storage time was found to be highly significant ( $R = 0.80$ ). Nevertheless, the weight loss after 10 days of storage was quite low (below 0.22%). The closed plastic boxes used for sample storage probably resulted in saturated or nearly saturated humidity, which probably minimized the water loss.

The shelf-life of apple cubes at 4C was, therefore, limited to less than three days by sensory analysis of color.

### **Influence of Chemical Treatments on Apple Quality**

Ascorbic acid was considered the best treatment by sensory analysis upon color evaluation in all experiments (Tables 2, 3, 4). Nevertheless, differences were only significant on the 7th day of storage. Ascorbic acid (0.75%) was also found to be the most effective treatment by objective measurements (highest  $L^*$  and hue values, and lowest  $a^*$  values) (Fig. 1). After three days of storage the decrease in  $L^*$  value was reduced from the 5.8% observed for untreated cut apple to 1.8% in cubes from the ascorbic acid dip, the decrease in hue from 5.3% to 3.2%, and the increase in  $a^*$  value was lowered from 57% to 14% (Table 5). Since the apple cubes still underwent surface browning in spite of the dip in an acid solution (pH lower than 3.7), it is probable that a 5-min dip in ascorbic acid

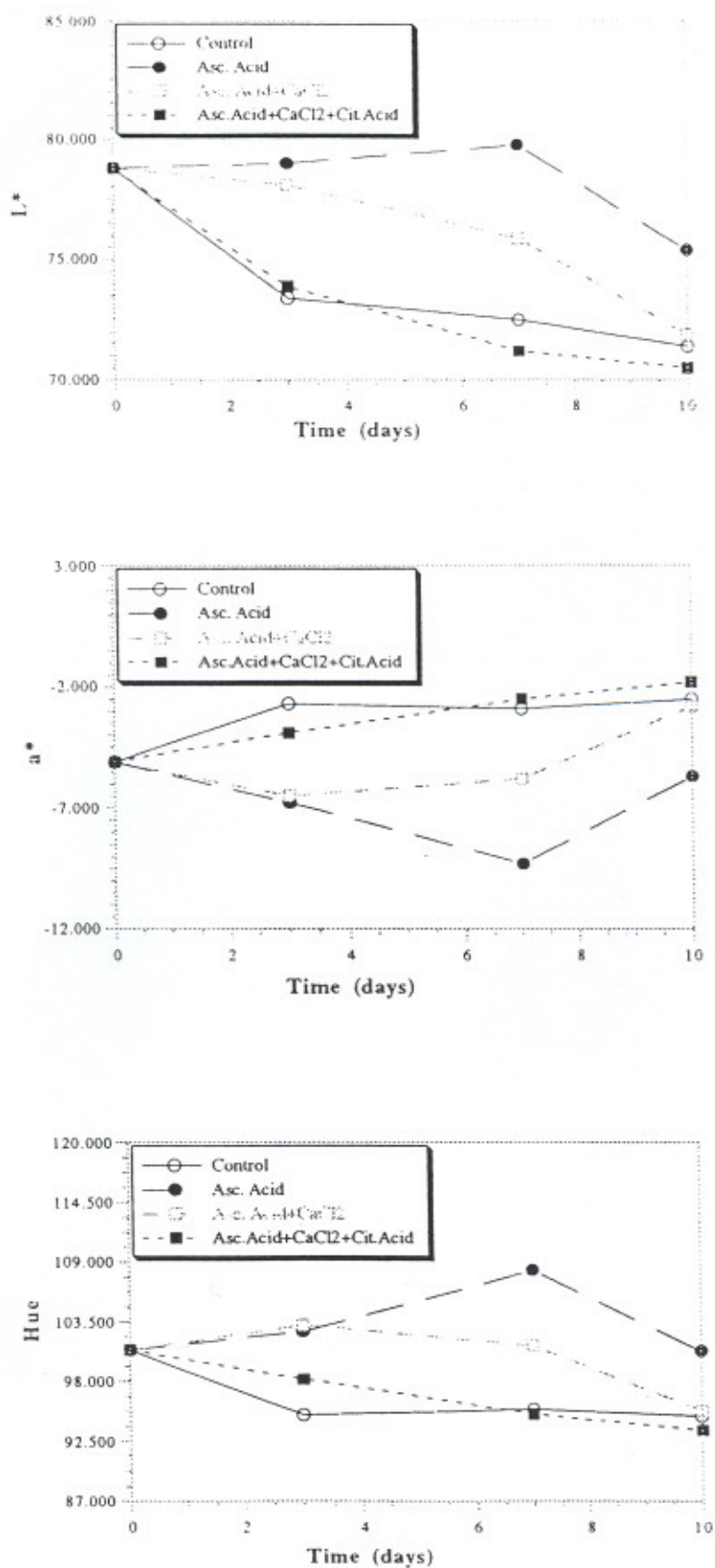


FIG. 1. COLOR PARAMETERS OF CUT APPLE (cv. Jonagored) DURING 10 DAYS AT 4°C

did not appreciably affect the pH of the apple cube. In fact, the effectiveness of ascorbic acid is considered quite low when compared with sulfite because of insufficient penetration into the cellular matrix. Furthermore, ascorbic acid is easily oxidized by endogenous enzymes or by iron or copper-catalyzed autoxidation. In that case, it may fall into a concentration range where it exerts prooxidant effects, allowing the browning reaction though at a lower rate and intensity (Ponting *et al.* 1972). The dip with ascorbic acid (0.75%) and calcium chloride (0.75%) was not as effective in preventing color changes as the ascorbic acid dip. However, the color parameters were improved in relation to the control (higher  $L^*$  and hue values, and lower  $a^*$  values)(Fig. 1). The color of 'Golden Delicious' slices was preserved for several weeks in refrigerated storage after dipping in ascorbic acid combined with calcium chloride (1% ascorbic acid + 0.1% calcium chloride) (Ponting *et al.* 1972). The treatment with ascorbic acid (0.75%) plus calcium chloride (0.75%) and citric acid (0.75%) did not seem to prevent color changes (Fig. 1). This was considered unexpected since several researchers such as Ponting *et al.* (1972) noted the beneficial influence of these chemicals on the color of apples. Santerre *et al.* (1988) used different concentrations and combinations of ascorbic acid (0.5 to 1%) with citric acid (0.25 to 0.5%) and calcium chloride (0.25%) with fairly good results on apple color (cv. Jonathan and cv. Spy). The chemical concentrations of citric acid and calcium chloride used in the present study were higher than the values reported by these authors and, therefore, they might not induce the expected color preservation.

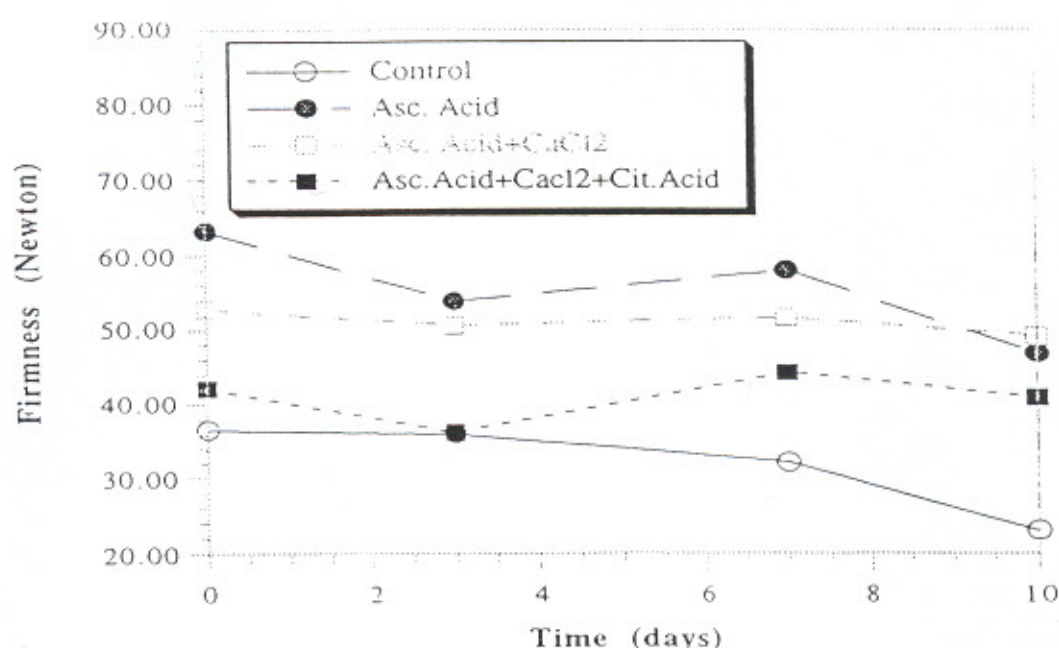


FIG. 2. FIRMNESS OF CUT APPLE (cv. Jonagored) DURING 10 DAYS AT 4°C

TABLE 1.  
OVERALL FRUIT QUALITY RATING (1-5) FOR UNTREATED CUT APPLE OVER 10  
DAYS OF STORAGE (\*)

Time (days)	Colour	Firmness	Flavour	Overall liking
0	4.60a (0.63)	4.67a (0.62)	4.27a (1.03)	4.67a (0.49)
3	1.36b (0.33)	4.36a (0.62)	4.29a (0.91)	4.14a (0.95)
7	1.36b (0.63)	4.36a (0.74)	4.00ab (1.18)	3.57ab (1.16)
10	1.14c (0.36)	4.00a (1.18)	3.29b (1.38)	3.00b (1.41)

(\*) Means separation in columns by Duncan's multiple range test ( $p=0.05$ ).  
Values in parenthesis are standard deviations.

TABLE 2.  
OVERALL FRUIT QUALITY RATING (1-5) FOR UNTREATED AND TREATED CUT  
APPLE AFTER 3 DAYS OF STORAGE (\*)

Time (days)	Colour	Firmness	Flavour	Overall liking
Control	1.36b (0.33)	4.36a (0.63)	4.29a (0.91)	4.14a (0.95)
Asc. Acid	2.20a (0.94)	3.60ab (1.12)	3.87ab (0.92)	3.47ab (0.74)
Asc. Acid +CaCl <sub>2</sub>	1.93a (1.16)	3.93ab (1.03)	3.40b (1.06)	3.27ab (1.03)
Asc. Acid + CaCl <sub>2</sub> + Cit. Acid	2.13a (0.99)	3.47b (1.25)	3.27b (1.39)	2.87b (1.13)

(\*) Means separation in columns by Duncan's multiple range test ( $p=0.05$ ).  
Values in parenthesis are standard deviations.

TABLE 3.  
OVERALL FRUIT QUALITY RATING (1-5) FOR UNTREATED AND TREATED CUT  
APPLE AFTER 7 DAYS OF STORAGE (\*)

Time (days)	Colour	Firmness	Flavour	Overall liking
Control	1.36b (0.63)	4.36a (0.74)	4.00a (1.18)	3.57a (1.16)
Asc. Acid	2.27a (0.88)	3.07b (1.28)	3.33ab (1.11)	3.00ab (1.07)
Asc. Acid +CaCl <sub>2</sub>	1.53b (0.52)	3.93ab (1.03)	3.80a (0.77)	3.33ab (0.89)
Asc. Acid + CaCl <sub>2</sub> + Cit. Acid	1.40b (0.51)	3.27b (1.39)	2.80b (1.42)	2.60b (1.18)

(\*) Means separation in columns by Duncan's multiple range test ( $p=0.05$ ).  
Values in parenthesis are standard deviations.

TABLE 4.  
OVERALL FRUIT QUALITY RATING (1-5) FOR UNTREATED AND TREATED CUT  
APPLE AFTER 10 DAYS OF STORAGE (\*)

Time (days)	Colour	Firmness	Flavour	Overall liking
Control	1.14b (0.36)	4.00a (1.18)	3.29a (1.38)	3.00a (1.41)
Asc. Acid	2.07a (0.88)	3.67a (1.23)	3.80a (1.01)	3.47a (0.83)
Asc. Acid + CaCl <sub>2</sub>	1.67ab (0.72)	3.80a (1.15)	2.87b (1.41)	2.67a (1.41)
Asc. Acid + CaCl <sub>2</sub> + Cit. Acid	1.53ab (0.83)	3.33a (1.45)	3.13ab (1.36)	2.87a (1.13)

(\*) Means separation in columns by Duncan's multiple range test ( $p=0.05$ ).  
Values in parenthesis are standard deviations.

Chemically treated apple cubes maintained greater firmness than the control cubes. Both 0.75% ascorbic acid and 0.75% ascorbic acid plus 0.75% calcium chloride were effective in avoiding loss of firmness during ten days of storage (Fig. 2). Several researchers have noted the beneficial influence of calcium on texture of apples. Drake and Fridlund (1986), Poovaiah (1986), and Floros (1993) explained the effectiveness of calcium chloride in reducing softening by the interaction with pectic acid in the cell walls to form calcium pectate. In fact, in 1941, Loconti and Kertesz already gave evidence of this view when treating tomatoes with calcium chloride. Powers and Esselen (1946) showed that calcium chloride solutions (0.1% during 1h, and 1% during 3h) were most effective with fresh sliced and frozen 'McIntosh' apples. Kertesz (1939) pointed out that calcium treatments were effective in retaining the firmness of plant products. The sensory panel rated the control samples as firm as those treated with 0.75% ascorbic acid plus 0.75% calcium chloride (Tables 2, 3, 4).

TABLE 5.  
COLOUR LOSS (%) AFTER THREE DAYS OF STORAGE

CIE values			
Treatment	L*	a*	Hue
Control	5.8	57.1	5.3
Asc. Acid	1.8	14.3	3.2
Asc. Acid + CaCl <sub>2</sub>	3.5	22.8	4.5
Asc. Acid + CaCl <sub>2</sub> + Cit. Acid	4.9	31.6	5.5

A decline in acidity was noticed with storage time in all experiments (R from 0.72 to 0.95). None of the treatments seemed to prevent the loss of acidity. The pH values (the pH of 'Jonagored' was between 3.2 and 3.7 in these experiments. In this range of pH the activity of polyphenoloxidases would not be expected to be very high (Coseteng and Lee 1987).

Overall, no significant differences ( $p > 0.05$ ) were noticed in fructose, sucrose and glucose contents of cut apple between treatments during storage.

Overall, in sensory analysis the untreated samples were found to have better flavor compared with apples after chemical treatment, although differences were not always significant (Tables 2, 3, 4). This was not unexpected since the use of chemical additives may affect the flavor of fresh cut fruits. Huxsoll *et al.* (1989) and Ponting *et al.* (1972) found that ascorbic acid adversely affected apple flavor. The weight loss increased significantly with the storage time in all experiments. None of the chemical treatments significantly affected weight loss.

### Relationship Between Sensory Analysis and Objective Measurements

Correlation between sensory and objective values would be useful in the sense that they would enable the defining of cut-off values for the objective parameters that correspond with the limits of sensory acceptability of the product. This is especially important for color, the critical parameter for quality.

Data from sensory analyses and objective measurements were considered well correlated with respect to color evaluation. The best correlation was obtained for the untreated cut apple (Table 6). With respect to this, the cut-off values (correspondent to a sensory score of 3) were 75.75 for L\* value, -3.95 for a\* value, and 100.55 for hue (calculated by linear regression).

TABLE 6.  
CORRELATION COEFFICIENT ( $R^2$ ) BETWEEN OBJECTIVE MEASUREMENTS AND  
SENSORY ATTRIBUTES OF COLOUR AND FIRMNESS OF CUT APPLE

Sensory attributes/treatment		Control	Asc. Acid	Asc. Acid + CaCl <sub>2</sub>	Asc Acid + CaCl <sub>2</sub> + Cit. Acid
<b>Color</b>	L* value	0.98	0.79	0.85	0.96
	a* value	0.99	0.85	0.77	0.93
	Hue	0.99	0.87	0.99	0.96
<b>Firmness</b>		0.90	0.91	0.84	--

$R^2$  at level  $P=0.05$

(--) no correlation found

Data from sensory and objective analyses of firmness were also found to be well correlated except for apple treated with ascorbic acid plus calcium chloride and citric acid for which no correlation was found.

Since sensory evaluation of firmness and flavor of untreated cut apple resulted in a score higher than 3, no cut-off values were defined for these quality parameters.

### Relationship Between Sensory Attributes

Sensory analysis of color and firmness of untreated cut apple were highly correlated with overall liking (Table 7). With respect to flavor, the correlation was not so high. When apples were chemically treated, the main component correlated with overall quality was firmness. Apples treated with ascorbic acid plus calcium chloride and citric acid showed very good correlation between every sensory attribute and overall fruit quality rating.

## CONCLUSIONS

Color was found to be the critical parameter for the quality of cut apple stored at 4C by both objective evaluation and sensory analysis. Color changes were noticed after three days of storage. The shelf-life was limited to less than three days by sensory analysis. Dipping in 0.75% ascorbic acid was found to be the most effective preservation treatment tested in order to avoid surface color changes. The combined use of 0.75% ascorbic acid and 0.75% calcium chloride inhibited the loss of firmness as well as ascorbic acid (0.75%). Addition of citric acid resulted in browning at the cut surface that was equal to the untreated control.

Good correlation ( $R > 0.77$ ) was found between sensory and objective evaluations of color of both untreated and chemically treated apple cubes.

TABLE 7.  
CORRELATION COEFFICIENT (R) BETWEEN OVERALL LIKING AND SENSORY  
ATTRIBUTES OF CUT APPLE

Sensory attributes / treatment	Control	Asc. Acid	Asc. Acid + CaCl <sub>2</sub>	Asc. Acid + CaCl <sub>2</sub> + Cit. Acid
Colour	0.96	0.93	0.93	0.98
Firmness	0.94	0.99	0.98	0.99
Flavour	0.90	0.94	0.93	0.98

In spite of the low concentrations used, the chemical treatments affected apple flavor. Since there is likely to be an increasing trend away from traditionally towards minimally processed fruits, considerable research will still be required to develop the most effective and safe processing and packaging systems (Floros 1993). A potential alternative is to evaluate the influence of controlled atmosphere storage on the quality of cut apple in order to replace or constitute a supplement to the chemical treatments in the extension of shelf-life. Minimally processed apple have higher respiration rates due to the increased surface area, but on the other hand they have fewer barriers to gas diffusion (Kader 1989). So it may be advisable to test extreme concentrations of the gases in the surrounding atmosphere of the product (higher CO<sub>2</sub> and lower O<sub>2</sub> than the ones usually recommended for whole apple).

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