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MINIMAL PROCESSING OF NEW YORK APPLES

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Consumer demand for fresh fruits and vegetables is increasing rapidly. During the last 10 years, per capita consumption of fresh produce has grown by more than 10% in the United States. Estimated sales in 1993 were over $62 billion (Rice, 1995). This increase has led to a relatively new market for minimally or lightly processed, fresh-like fruits and vegetables. Some of these products are conveniently sold as precut, prepared, and pre-packaged.

Much research has been done to find the optimum conditions for whole fruits and vegetables, but only limited information is available on fresh cut and other minimally processed products. Minimal processing includes grading, washing, sorting, peeling, slicing, chopping, and then packaging. Packaged products have a shelf life of 7 to 10 days when stored under conditions that retard respiration.

Forms of the products vary widely according to the characteristics of the raw materials and the methods of consumption. Usually, such products are raw so tissues remain alive after minimal processing. Raw fruits and vegetables are subject to mechanical injury or wounding that, in turn, induces complex physiological and metabolic changes, including: increased respiration at the injured site, stress ethylene production, accumulation of secondary metabolites, and softening. Tissues damaged by harvesting or processing also spoil faster than sound tissues because leakage of nutrients from damaged tissues allows microbial growth. In most cases, minimally processed products are more perishable than the unprocessed intact raw materials from which they originate.

The major obstacle to overcome in the production of minimally processed products is that of activated respiration of live tissues which results in reduced shelf life. To retard the respiration rate and to prevent the growth of aerobic spoilage microorganisms in minimally processed products, packaging is of paramount importance. Some packaging processes used for fresh produce are also used on minimally processed products. Since respiration continues in such processed products, considerations are similar in both whole and processed products. But the rate of change is significantly altered by processing, which, through slicing or cutting tissues, is responsible for wound respiration and wound ethylene production. Naturally, accelerated quality loss through senescence and enzymatic browning occur.

In order to retard or prevent these physiological changes, various treatments have been applied. Some of the treatments include the application of chemical compounds, usually by spraying or dipping the fruit and vegetable slices to prevent changes in firmness and color. Chemical preservatives may be useful. However, not only must they be effective in maintaining one or more quality factors but they must also not degrade another quality factor. For example, ascorbic acid, a chemical additive used to improve or maintain apple color, adversely affects the texture of aproduct, while sulfites, one of the most common anti-browning agents, adversely affects flavor.

Minimally processed apple slices are very unstable and more perishable than the unprocessed whole apples from which they are made. Peeled and sliced apples are prone to enzymatic browning which is aesthetically undesirable. The surface of the slice is an ideal environment for yeast fermentation, which is easily detected by a yeasty odor and the presence of surface bubbles. Mold spoilage can also occur on the surface if slices are held above freezing for an extended period of time. Therefore, extending shelf life of sliced apples is one of the major problems in the production of minimally processed apple slices.

The browning of freshly cut apple tissue is due to the oxidation of poly phenols by polyphenol oxidase. It occurs when the cell structure is damaged and will happen almost instantly at room temperature. The degree of browning varies among and within cultivars. Traditionally, commercial apple slices, processed mainly for commercial bakeries in refrigerated, frozen, or dehydrofrozen forms, are treated with sulfites (sulfur dioxide), a highly effective anti-browning agent. The use of a sulfur dioxide treatment is common practice on fresh sliced apples for the baking industry. Sulfur dioxide preserves the color of the slices and prevents microbial spoilage.

Unfortunately, the safety of sulfites in foods has been questioned because of alleged health hazards to asthmatics and because of the allergic reaction that sulfites cause in a certain segment of the population. Since 1986, the Food and Drug Administration has banned the use of sulfites on fresh fruits and vegetables and required a label declaration on any processed food containing more than 10 ppm of sulfur dioxide (FDA, 1987). Therefore, sulfur dioxide cannot be used in minimally processed apple products. New methods that maintain fresh apple slice-like quality for a certain period of storage time are needed.

Various alternatives including reducing agents, acidulants, chelating agents, inorganic salts, and enzymes have been evaluated for use on fresh cut apples (Macheix et al., 1990; Nicolas et al., 1994). Some agents were effective replacements for sulfur dioxide: acidulants, such as citric acid, retard browning reactions, but they show adverse softening effect on apple slices. Ideal chemicals, to be also considered useful nutrients for apple slices, are ascorbic acid and calcium chloride which have a synergistic effect. However, their efficacy in maintaining color and textural qualities is much less than that of sulfur dioxide in maintaining fresh-like quality for two to three weeks under refrigeration. Therefore, attempts were made to obtain optimal conditions for a method of minimal processing of New York State apple slices using various treatments, including modified atmosphere packaging systems.

SELECTION OF NEW YORK APPLE CULTIVARS

The chemical composition and physiological function of apples varies depending on cultivars. To determine the most suitable cultivars to use in this minimal processing study, various apple cultivars grown during the 1991 season in upstate New York were selected and harvested based on normal harvest dates established for the cultivar in the region. Selected apples were peeled, sliced longitudinally into 16 equal pieces, placed in unsealed polyethylene film bags, and then placed in a cold storage room at 2° to 3°C, 90% relative humidity for 12 days. Various physiological and chemical changes during storage were measured (Kim et al., 1993B): respiration rate (carbon dioxide evolution) was measured by a gas chromatograph (GOW-MAC gas chromatograph, Model 580) equipped with thermal conductivity detector using an Alltech CTR 1 column; firmness was measured by Lloyd Texturemeter (Model M5K) using a back extrusion cell; and color (lightness) was measured by a Hunter Colorimeter (Model D25-PC2A).

Table 1 shows data related to some physical and chemical attributes of apple slices during storage for 12 apple cultivars. We noticed a large variation in respiration rates among cultivars. Monroe apples had the highest initial respiration rate, followed by Rome, Mutsu, and RI Greening. Delicious apples had the lowest rate. The respiration rate of apple slices was expected to be higher than that of whole apples because of wound response (Laties, 1978). During storage, respiration rate decreased in all cultivars. A rapid decrease was observed in the first three days of storage. Thereafter, relatively small changes were observed. Some cultivars (for example, Delicious) showed a slight increase at the later stages of storage. In general, Delicious, Idared, Cortland, and NY 674 had low respiration rates, while Rome, Empire, Monroe, RI Greening, and McIntosh had high rates throughout storage. Since respiration rate of apple slices is important in the shelf life of minimally processed apple products, it should be an important criterion for cultivar selection.

Firmness of apple slices also showed a wide variation among cultivars. Monroe and Liberty apple slices were firmer then McIntosh, Mutsu, and NY 674 apples. The 12 cultivars could be separated into two groups according to firmness: Monroe, Liberty, Rome, Delicious, Empire, RI Greening, and Idared were firmer; Cortland, Golden Delicious, McIntosh, Mutsu, and NY 674 were less firm. A significant decrease in firmness during storage was observed. Initial firmness decrease ranged from 1.5-19% during seven days of storage, but after seven days there was a 15.5-52.9% decrease by 12 days. A fundamental problem in shelf life extension of minimally processed fruits is the loss of firmness during storage and distribution due to action of endogenous enzymes related to cell wall degradation and microorganisms (Huxsoll and Bolin, 1989).

In respect to the color of fresh apple slices, there was no significant difference among the 12 cultivars, except for Delicious which had the lowest "L" value (brownish). However, during storage, all 12 cultivars showed a rapid decrease in "L" value (darker) due to enzymatic browning during the first three days. Rome, Liberty, and McIntosh turned brown faster than NY 674, Golden Delicious, Cortland, Delicious, and Empire apples. NY 674 showed the least change in color among 12 cultivars. NY 674 apples were lower in polyphenol

Table 1. Changes in respiration rate, firmness, color, soluble solids, and acidity of apple slices during storage at 2 °C.

Storage day	Cortland	Delicious	Empire	G. Del.	Idared	Liberty	McIntosh	Monroe	Mutsu	NY674	RIGreen.	Rome
	Respiration rate (mL CO_2/Kg.hr)											
0	4.810	3.500	5.558	5.083	4.187	4.866	5.600	7.632	6.439	5.371	6.057	6.558
3	2.184	1.719	1.763	2.143	1.955	2.443	2.244	3.628	2.635	3.528	2.325	1.763
7	2.243	1.925	1.784	1.974	1.951	2.369	1.727	3.405	2.680	2.611	2.304	1.784
12	3.298	2.352	2.122	2.885	2.022	2.368	1.804	3.796	3.381	3.260	2.271	2.122
	Firmness (Newton)											
0	1793	2500	2430	1823	2386	2995	1550	3050	1590	1610	2447	2660
3	1710	2397	2353	1783	2373	2863	1490	2930	1533	1383	2360	2360
7	1560	2240	2300	1503	2350	2446	1483	2790	1493	1303	2280	2376
12	1338	2112	1983	1246	1880	2350	1170	2016	1140	958	1828	1813
	Color (lightness, "L" value)											
0	70.5	59.3	72.8	73.9	71.2	71.7	75.7	70.9	71.4	72.4	70.3	70.7
3	65.5	54.3	66.0	68.8	63.0	59.8	64.8	62.6	63.2	71.6	59.1	58.6
7	65.0	53.0	66.0	68.4	64.1	59.6	64.7	63.4	63.2	69.4	60.9	59.0
12	64.3	52.9	66.2	68.5	63.9	59.9	64.9	63.4	62.8	69.5	60.5	58.8
	Soluble solids (°Brix)											
0	15.3	14.0	13.9	15.2	12.5	14.6	13.3	18.4	16.0	16.2	14.6	14.1
3	15.3	14.0	13.8	15.0	12.4	14.4	13.3	18.3	15.7	15.7	14.6	14.1
7	15.3	13.9	13.9	15.0	12.2	14.4	13.2	18.3	15.6	15.3	14.3	14.1
12	15.3	14.0	13.8	15.0	12.3	14.3	13.1	18.0	15.4	15.1	14.2	14.0
	Titratable acid (%, as malic acid)											
0	0.452	0.226	0.480	0.319	0.569	0.644	0.607	0.768	0.408	0.699	0.731	0.381
3	0.425	0.213	0.480	0.308	0.535	0.570	0.576	0.713	0.370	0.624	0.665	0.370
7	0.418	0.206	0.473	0.295	0.528	0.569	0.569	0.699	0.363	0.596	0.641	0.370
12	0.398	0.199	0.452	0.295	0.507	0.569	0.569	0.686	0.350	0.576	0.650	0.350

Each value is a mean of triplicate measurements, except for color which is a mean of twenty measurements oxidase activity and polyphenol content compared to other cultivars which may explain this difference (Lee and McLellan, 1990). Based on the color change of apple slices, cultivars we studied could be divided into three groups: those that brown little (NY 674, Golden Delicious, and Empire); those that brown moderately (Mclntosh, Cortland, Idared, Monroe, and Mutsu); and those that brown severely (RI Greening, Liberty, Rome, and Delicious). Other attributes of apple slices, such as soluble solids, acids, pH, and weight loss also varied widely depending upon cultivar but their changes during storage were insignificant.

Based on the attributes we measured, no single cultivar appeared most suitable for minimal processing. One cultivar with an advantage in one parameter may have no advantage with respect to another parameter. For example, NY 674 was the best choice in terms of color but the worst choice in terms of firmness. Liberty was the best choice in terms of firmness but the worst choice in terms of color after minimal processing. Overall, based on color, firmness, and other quality parameters, Golden Delicious, Delicious, Cortland, NY 674, and Empire were better while Mutsu and Rome apples were less well suited for minimal processing. In addition, preliminary experiments on several of the early ripening New York State cultivars, such as Gala apples, showed promising results.

EFFECT OF HEAT TREATMENT ON THE QUALITY OF APPLE SLICES

Heat treatment is a method used to induce modification of physiological and phy sicochemical characteristics of plants after harvest (Brodl, 1989). Exposure of fresh fruits and vegetables to heat shock temperature (above 40°C) which is higher than normal ambient temperature, results in the synthesis of a set of heat shock proteins, modification of physiology, and, in many cases, interruption of normal cellular protein synthesis, including enzymes related to the quality of fruit and vegetable products. Heat can also inactivate enzymes which were already synthesized in fresh produces. Several scientists have reported that the ripening of fruits was inhibited during storage by exposure to high temperatures (38-40°C) for several days (Liu, 1978; Porritt and Lidster, 1978) prior to storage. Some apple cultivars showed desirable responses toward retardation of ripening (Klein and Lurie, 1990). Therefore, it is expected that the shelf life of intact and minimally processed fruits may be extended further through interruption of enzyme synthesis and/or inactivation of enzymes that cause changes in color and texture of products when fruits are properly treated with heat at optimum conditions of temperature and time.

In order to determine and compare the effect of heat treatment on flesh color and firmness of apple slices among various apple cultivars, 11 selected apple cultivars were exposed to various temperatures for various time using a water bath and then stored in a cold room (2-3°C). Effects of heat treatments on color and firmness of apples were measured within 24 hours of the treatment (Kim et al., 1993A). Heat-treated apples were peeled, cored, sliced, and placed in unsealed polyethylene film bags and stored at 2-3°C for eight days. Changes in the respiration rate, color, and firmness of apple slices were measured during storage and several quality indices were analyzed.

A typical physiological response of apples to the heat treatment at 40, 45, and 50°C was the development of flesh browning. Table 2 shows heat treatment response on browning initiation. The percent of initial browning varied greatly by cultivar and temperature. Rome, Monroe, Liberty, and RI Greening apples were very susceptible to browning while Idared, Cortland, Empire, NY 674, and Mclntosh showed relatively moderate browning. Delicious and Golden Delicious apples showed the strongest tolerance to heat treatment. Only light browning of the entire flesh was observed in both varieties after four hours at 40°C, two hours at 45°C and one hour at 50°C. Browning in apple flesh during heat treatment

Table 2. Heat Treatment Response on Browning Initiation

Cultivar	Temp (°C)	Time of Browning Initiation (min)	Incidence of Browning (%)*
Rome	40	60	92.5
	45	30	90.0
	50	15	85.0
Monroe	40	60	75.5
	45	30	52.5
	50	15	67.5
Liberty	40	60	32.5
	45	60	32.5
	50	30	55.0
RI Greening	40	120	42.5
	45	30 30	50.0
	50		35.0
Idared	40	180	45.0
	45	105	67.5
	50	30	52.5
Cortland	40	180	25.0
	45	90 30	52.5
	50		32.5
Empire	40	180	17.5
	45	105	12.5
	50	45	20.0
NY674	40	180	52.5
	45	105	20.0
	50	30	15.0
Mclntosh	40	180	12.5
	45	105	25.0
	50	30	60.0
Delicious	40	240	20.0
	45	120	15.0
	50	60	52.5
G Delicious	40	240	17.5
	45	120	15.0
	50	60	12.5

Observed in 40 apples

might be caused by accelerated respiration (Porritt and Lidster, 1978) or altered apple metabolism induced by undesirable environmental conditions. Browning of slices from heat treated apples showed some positive effect of heat treatment: most apples treated for two hours at 40°C showed less browning than non-treated apples, except for Cortland. Most apples (except for Cortland and Idared) heated at 45°C exhibited less browning on slices. The greatest resistance to browning was observed in Golden Delicious, Delicious, and NY 674. At 50°C, all treated cultivars showed relatively less browning compared to non-treated apples, but it appeared that the temperature was too high for most apple cultivars and adversely affected browning with increased time. The observed intensity of browning in apple slices was less in apples treated at 45°C than those treated at 40 and 50°C.

The beneficial result of the moderate heat treatment may be due to inhibition of polyphenol oxidase, the enzyme involved in browning reactions. In normal *in vitro* condition, inhibition of the enzyme would not be expected between 40 and 50°C. However, the kinetic characteristics of the enzyme in whole apples heated at such conditions might differ from that of *in vitro* conditions because the internal microenvironment of apples, such as oxygen and carbon dioxide concentrations, might be changed by the treatment. The response in firmness of apples to heat treatment also varied widely depending upon cultivar and conditions. Delicious, Golden Delicious, and Empire heat treated for one hour at 40°C were firmer than non-treated apples. Note that the firmness of these apples increased although there was development of browning by the heat treatment at 40°C for over three hours. The beneficial effect of heat treatment in firmness of apples was reported previously (Liu, 1978; Lurie and Klein, 1990). Among cultivars heated at 45°C, only slices of Golden Delicious and Delicious were firmer than non-treated slices. At 50°C, only Golden Delicious and Delicious treated for up to 45 minutes were firmer and the other nine cultivars decreased in firmness. An increase in firmness of fruits and vegetables subjected to heat treatment was explained by the fact that the precooking heat treatment activates pectin demethylation by pectin methylesterase and endogenous calcium ion complexes with pectic substances that increases tissue firmness (Van Buren, 1979;Leeetal., 1979; Moledina et al., 1981).

Five apple cultivars (Empire, Golden Delicious, Mclntosh, NY 674, and Delicious) which showed relatively low incidence of browning and relatively firmer texture by heat treatment, were selected for the heat treatment at 45°C for 105 minutes and the quality of the slices during storage was measured. We found that the respiration rates of the slices from heat treated apples were lower than those of the non-heated apples. Respiration rates of both heated and non-heated apple slices decreased rapidly after one day storage at 2°C, which indicated that the respiration rate of injured tissue stabilized after the initial stress response. All five cultivars had higher "L" values in slices of heated apples after eight days storage than those of control (non-heated) apples, as shown in Figure 1. Significant differences were observed in Golden Delicious, Mclntosh, NY 674, and Delicious apples. Heat-treated apple slices were also firmer than non-treated samples after eight days storage in all five cultivars (Figure 2). Apple slices of Delicious had the highest firmness and NY 674

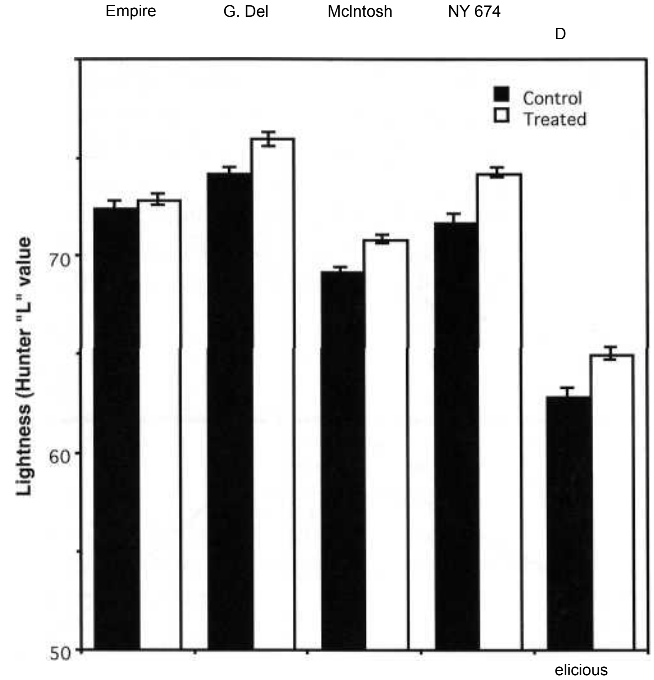


Figure 1. Lightness (Hunter "L" values) of apple slices after eight days storage prepared from heat treated (45°C/105 min) and non-treated apples. Bars on graph represent standard deviation.

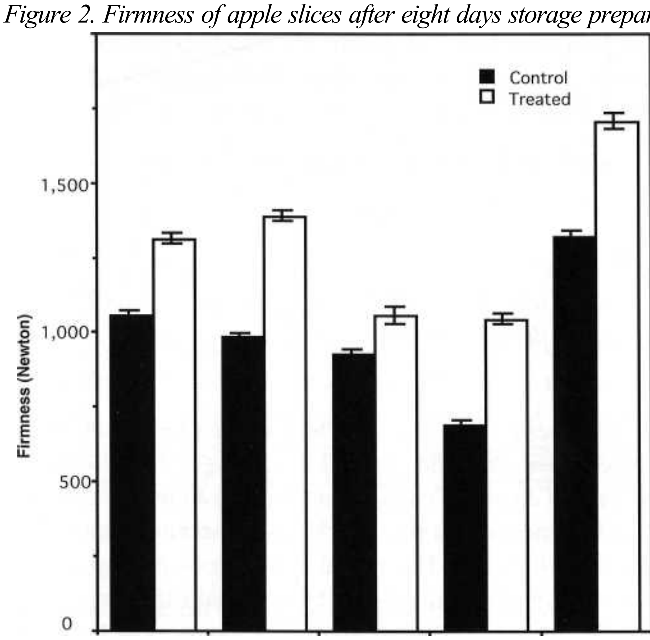


Figure 2. Firmness of apple slices after eight days storage prepared from heat treated (45°C/105 min) and non-treated apples. Bars on graph represent standard deviation.

the lowest. Increased firmness was a notable benefit of the heat treatment and may be very useful for improving the texture of minimally processed fruits.

Figure 3 shows changes in firmness of heat-treated and non-treated Golden Delicious and Delicious apples slices during three weeks storage. Firmness of slices prepared from heated apples first increased during storage and then decreased, while firmness of slices prepared with non-treated apples exhibited a steady decrease over time. Firmness increased in heated Golden Delicious and Delicious apple slices up to seven and 14 days storage, respectively. Firmness of slices prepared from heated Golden Delicious apples was approximately 34% higher at seven days storage and that of Delicious apples was 48% higher at 14 days storage than the initial values.

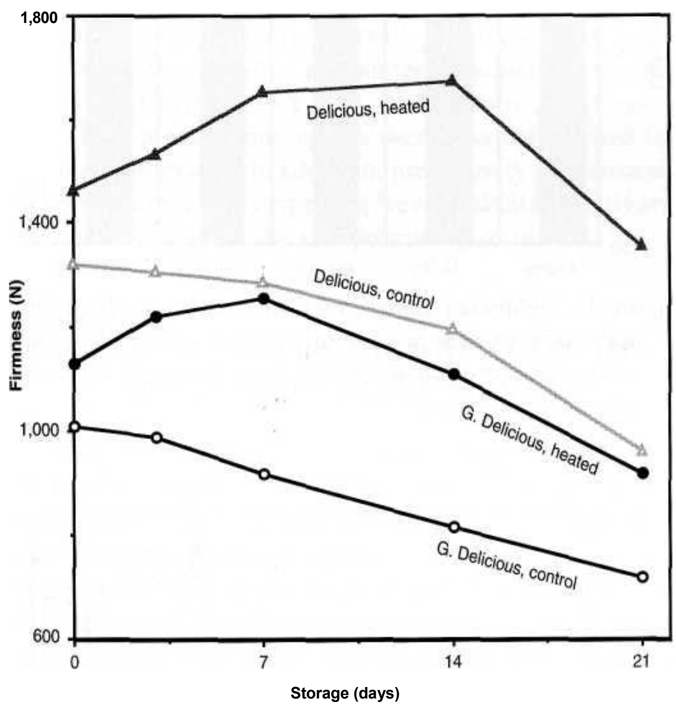


Figure 3. Changes in firmness of slices prepared from heat treated and non-treated Delicious and Golden Delicious apples during storage at 2 °C.

In general, fruit tissue softened when heated at higher temperatures partly due to the loss of turgor, but also due to a variety of chemical changes in the cell wall matrix polysaccharide, especially in pectin. This polysaccharide modification can be influenced by a number of factors, principally pH, enzymes, and the amounts and types of salts that are present (Van Buren, 1979). In this study, the firmness of the apple slices prepared from apples heated at 45 °C for 105 minutes improved and increased during storage. A possible explanation is that such heating activates pectin methylestrase, which then demethylates pectic substances that allow cross-linking of the freed carboxyl groups by internal calcium ions. A similar trend was also observed in low temperature blanching of canned carrots (Lee et al., 1979).

It is concluded from this heat treat experiment that apple slices prepared from apples heat treated at 45°C were better in color and in firmness compared to nontreated apples. Among apple cultivars, Golden Delicious and Delicious apples were the most stable to browning and produced firmer slices. However, commercial application of the heat treatment on apples on a large scale may require additional equipment and modification in the processing operation.

MINIMALLY PROCESSED APPLE SLICES USING VACUUM PACKAGING

Application of Commercial Browning Inhibitors

In order to compare the relative efficacy of various commercial enzymatic browning inhibitors, Snow Fresh^M (Monsanto Co.), Sporix-C™ (Seo-Do Chemical Co.), and Keep 'M Fresh^M (Agra Research, Inc.) were prepared to 1% solution as dipping solutions. Since honey showed a certain antibrowning activity (Oszmianski and Lee, 1990), 10% solution was prepared for a comparison. Golden Delicious apples were peeled, cored, and sliced into 16 pieces each by using a Pease machine and then immediately dipped into the dipping solution for three minutes. The excess liquid was drained off and the treated slices (100 g) were placed in high oxygen barrier plastic bags (Cryovac P640B, oxygen permeability, 10 cc/m^/24hrs) and then sealed under vacuum (-0.8 bar) using a Multivac sealing machine. Packaged apple slices were stored at 3-5°C for 21 days. Various quality parameters were measured during storage.

Figure 4 shows the discoloration rate of vacuum packaged Golden Delicious apple slices treated with various inhibitors. Relative color changes among dipping solution showed that Snow Fresh and Keep 'M Fresh as the least, followed by Sporix-C, honey and the control (non-treated). Since the composition of the commercial products is not fully known, it is difficult to explain the chemistry of their inhibitory effects. However, we noticed that all three products contained certain amounts of ascorbic acid and that Keep 'M Fresh had the highest concentration. Although the 10% honey solution was found to be less potent compared to the commercial inhibitors, it still was very effective when compared to the control. Slices dipped in the Snow Fresh and Keep 'M Fresh solutions showed a higher initial "L" value (lightness) than Sporix-C and also showed less color change during the 21 -day storage period. The initial lightness of apple slices dipped in honey solution was low because there was no bleaching effect of ascorbic acid as with the commercial inhibitors. No visible discoloration was noted up to 14 days storage. A slight brownish color was observed at the end of the 21 days storage.

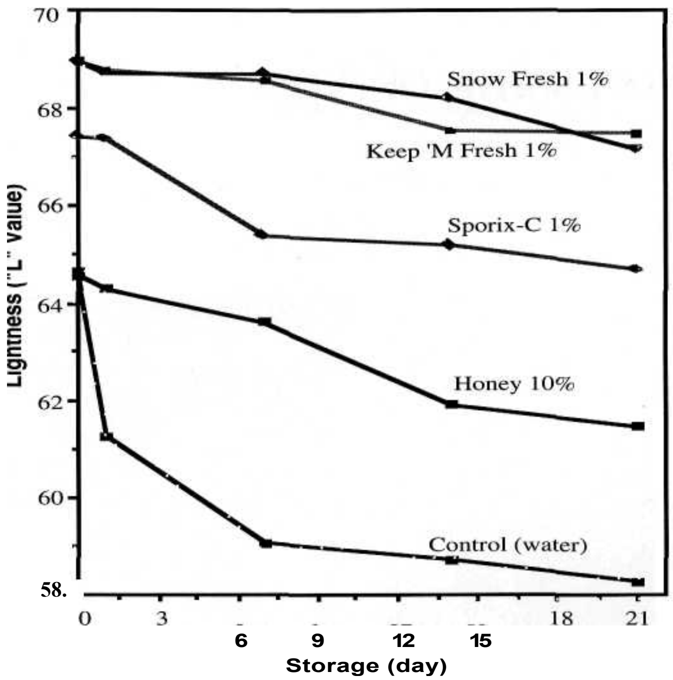


Figure 4. Change in lightness of vacuum packaged Golden Delicious apple slices treated with browning inhibitors during storage.

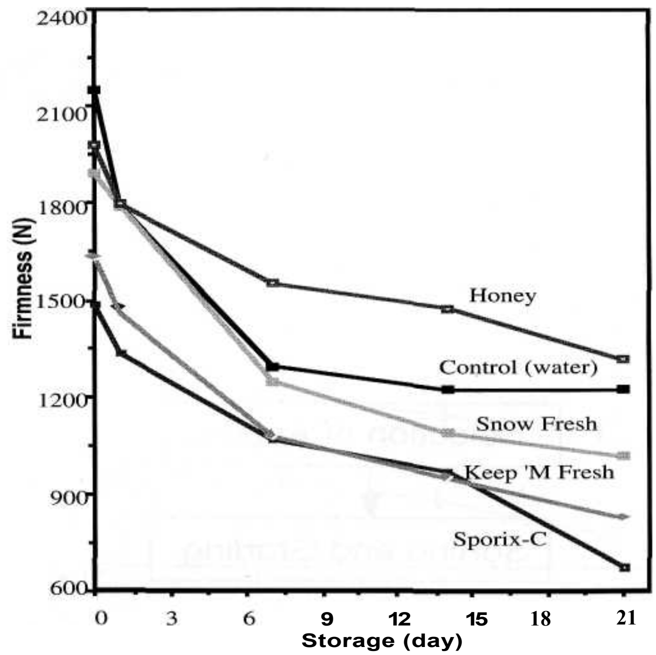


Figure 5. Change in firmness of vacuum packaged Golden Delicious apple slices treated with browning inhibitors during storage.

Firmness changes of vacuum packaged apple slices during storage varied significantly among the dipping solutions (Figure 5). Apple slices dipped in Sporix-C and Keep 'M Fresh solution softened faster than those dipped in the Snow Fresh solution and the control. An interesting observation was that the honey dip yielded firmer apple slices compared to the other commercial browning inhibitors and control. The loss of firmness produced by the commercial dips appeared to be related to pH of the solutions. Apple slices that lost firmness rapidly during storage had lower pH values. This softening of apple slices due to acidic effects was also observed by Ponting et al. (1971). In experiments with various acidulants, such as citric acid, ascorbic acid and erythorbic acid, which inhibit browning reactions, we observed that the higher the concentration of acidulants in dipping solutions, the higher the softening effect on apple slices.

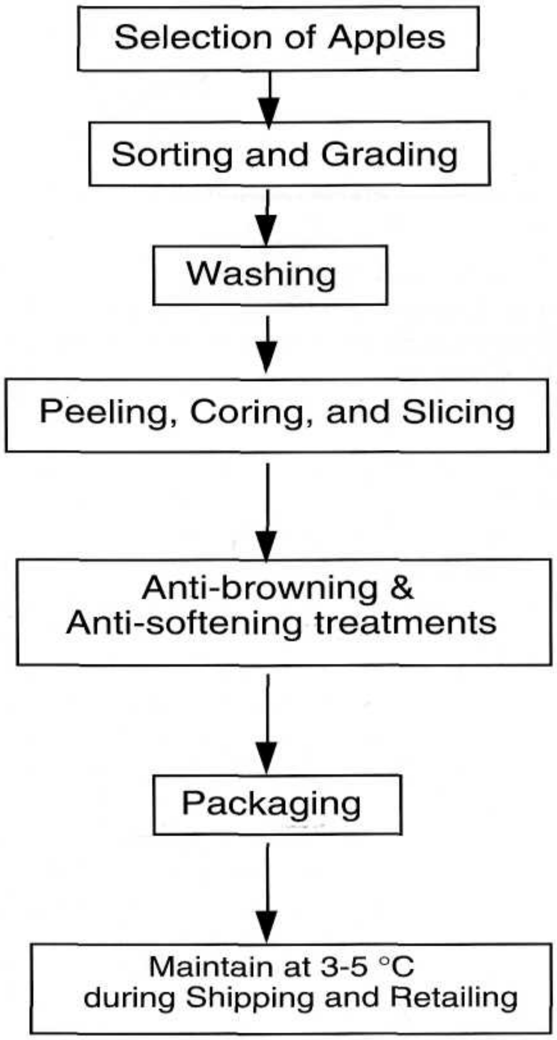
Addition of Calcium to Prevent Softening of Slices

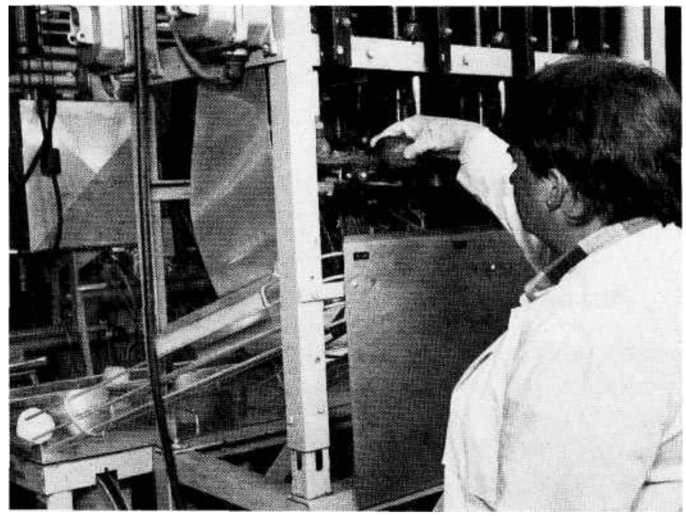
The addition of calcium chloride to an acidic dipping solution in order to minimize the softening of apple slices has been suggested for some time (Ponting et al., 1971). In our experiment, apple slices were treated in different solutions of 0.5% erythorbic acid (Pfizer Inc.) containing 0, 0.25 and 0.5% calcium chloride, vacuum packaged as previously described, and then stored at 3-5°C for 21 days. Figure 6 shows the effect of different concentrations of calcium chloride on the firmness of Golden Delicious apple slices. Apple slices (prepared from apples stored for six months) treated with erythorbic acid with no added calcium chloride were the softest among samples. They were softer than the control water dipped sample (data not shown). Addition of calcium chloride to the erythorbic acid solution increased the firmness of apple slices significantly, but their firmness decreased slowly with the time of storage. The firmness of apple slices dipped in 0.5% erythorbic acid and 0.5% calcium chloride solution showed a slight increase at seven-day storage and maintained the same level of firmness throughout 21 days of storage. With Cortland apples (data not shown), the same initial increase in firmness of apple slices by added calcium chloride was observed, but the rate of softening during storage was much faster due to varietal characteristics. In addition, calcium chloride added to erythorbic acid showed some synergi stic effects (data not shown) on the color of apple slices by increasing "L" value (lightness). Therefore, addition of calcium chloride at the level of 0.25 to 0.5% to anti-browning acidulants such as citric acid, ascorbic acid and erythorbic acid provided beneficial effects on both color and firmness of minimally processed apple slices.

Effect of Vacuum Packaging on Firmness of Apple Slices

Vacuum packaging removes oxygen and modifies the atmosphere inside the package. This process prevents enzymatic browning reactions on the surface of apple slices. However, the beneficial effect of vacuum on apple slice

Flow Sheet of Minimal Processing of Apple Slices





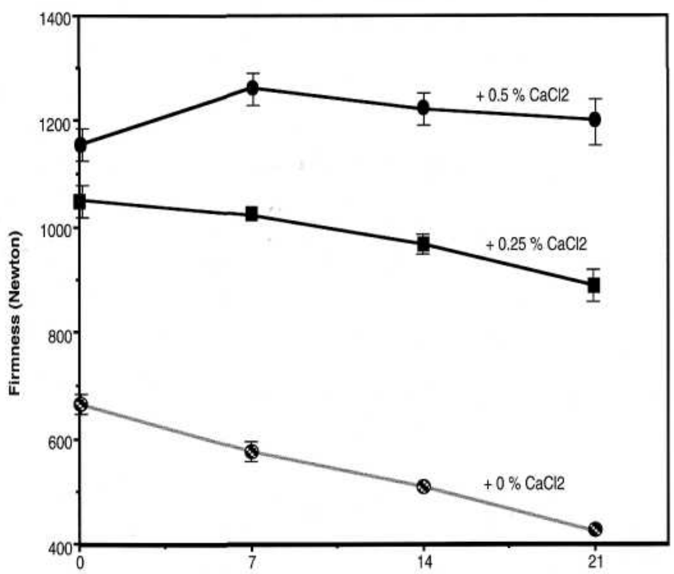
Peeling and coring process.

The sealing process of modified atmosphere packaging.

color appears to be offset by a negative effect on firmness. In order to investigate the effect of vacuum on firmness of apples, Golden Delicious apple slices prepared as in the previously described experiment were packaged (using the same Cryovac bags) with a vacuum (at -0.8 bar) using a Multivac sealing machine, and without vacuum using Pac Bag Sealer (Model 16VB, Packaging Aids Corp.). As shown on Figure 7, the results of both the calcium treated and the calcium + erythorbic acid treated samples showed that apple slices packaged under vacuum were softer than those packaged without vacuum. The rate of softening was also faster than the samples packaged without vacuum. In another experiment, Jonagold apple slices were packaged under the vacuum of two different levels: the lower one at -0.5 5 bar and the higher one at -0.98 bar. We observed that (data not shown) apple slices packaged at low vacuum were significantly firmer than apple slices packaged at high vacuum after three weeks storage. Therefore, we conclude that vacuum packaging helps prevent discoloration but contributes to softening.

Storage (day)

Figure 6. Effect of different concentration of calcium



chloride added to 0.5% erythorbic acid solution on firmness of Golden Delicious apple slices during storage at 3-5 °C.

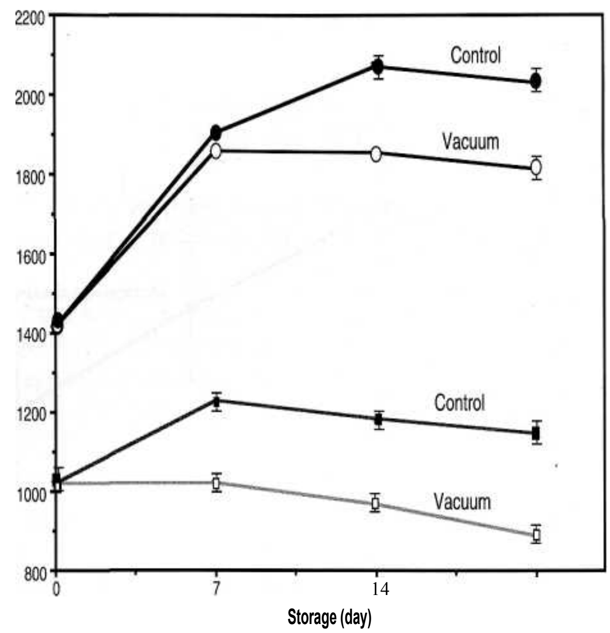


Figure 7. Firmness of minimally processed Golden Delicious apple slices packaged with vacuum and without vacuum (control): 0&9 treated in 0.5% calcium chloride solution and □<& I *treated in 0.5% erythorbic acid + 0.25% calcium chloride solution.*

MINIMALLY PROCESSED APPLE SLICES USING NITROGEN ATMOSPHERE

Since vacuum packaging has a somewhat unsatisfactory effect on the firmness of apple slices, another attempt was made for modified atmosphere packaging using nitrogen with no vacuum. Apple slices (prepared from Golden Delicious stored for six months) packed in plastic bags were flushed with nitrogen and sealed using the same Multivac sealing machine connected to a nitrogen gas tank. The packaged apple slices were stored at 3-5°C for 22 days. All three treatments prior to packaging—calcium dipping, ascorbic acid dipping, and dipping using a combination of calcium chloride and ascorbic acid—as well as a control (water dipped), showed that apple slices packaged under the nitrogen atmosphere were firmer than those packaged under vacuum. Figures 8 and 9 show the effect of nitrogen atmosphere packaging on the firmness of apple slices compared with vacuum packaging during storage. Nitrogen atmosphere packaging produced firmer slices with both treatments compared to vacuum packaging. We also noticed that apple slices packaged under the vacuum rapidly turned brown after the package was opened. However, apple slices packaged with the nitrogen atmosphere did not brown quickly after the package was opened and a desirable, stable color was maintained for hours.

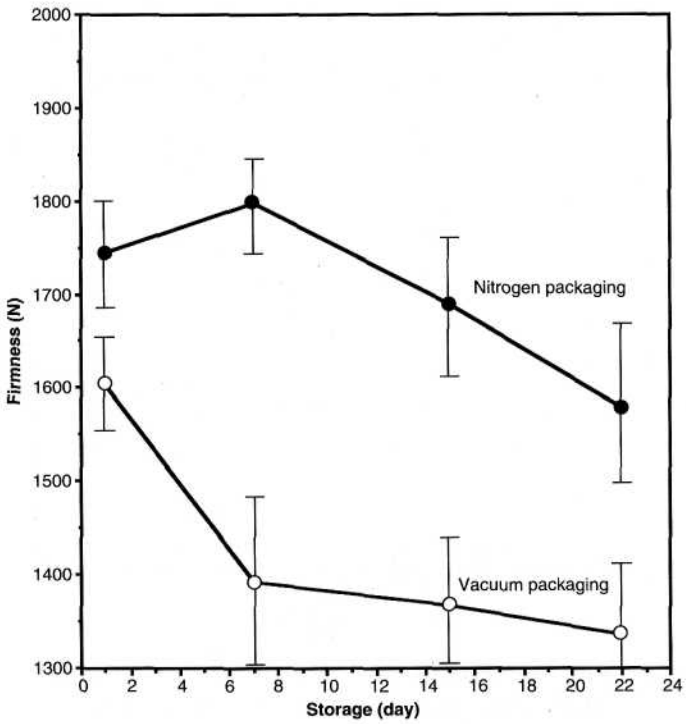


Figure 8. Effect of nitrogen on packaging on firmness of apple slices.

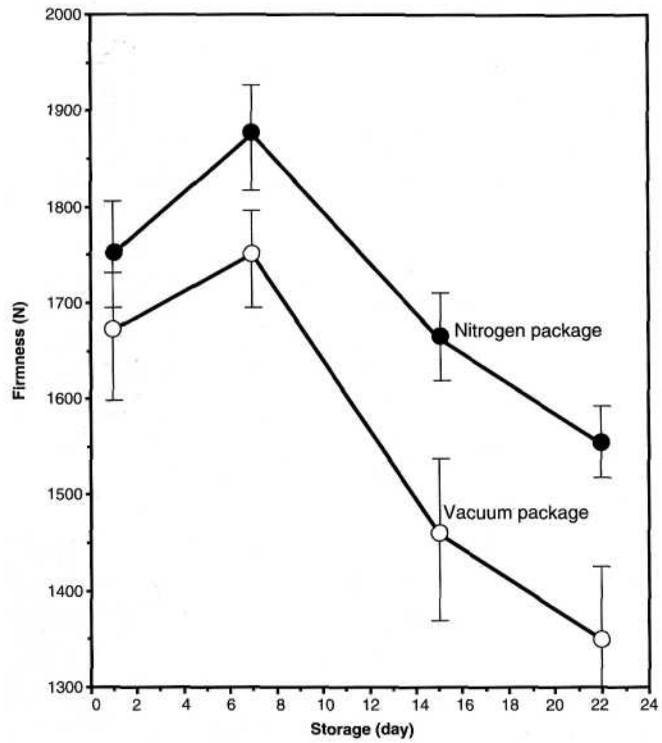


*Figure 9. Effect of nitrogen atmosphere packaging onfirmess of apple slices treated with 0.2% ascorbic acid and 0.2% CaCl^*

CONCLUSION

In order to meet consumer demand for convenient and fresh-like quality of minimally processed fruits and to provide additional technical information to New York apple growers and processors for value added product, we have been working on minimal processing of apple slices for several years. Progress has been made. Based on our research, several local apple growers are producing commercial apple slices made from New York apples and are distributing them to the upstate New York market. Proper cultivar selection is the first step in producing high quality minimally processed apple slices. Apple cultivars such as Golden Delicious, Delicious, Cortland, and Empire are recommended for minimal processing. The proper combination of a dipping treatment and nitrogen modified atmosphere packaging maintained color and texture of apple slices for a period of three weeks at 3-5°C. Additional work on new anti-browning and anti-softening agents is being carried out.

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