Tropical Agricultural Research Vol. 15: 166- 176 (2003)

Quality of Avocado Slices as Affected by Stage of Ripeness, Anti-browning Agents and Packaging

C. Nikapitiya and C.K. Illeperuma[1]

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka

ABSTRACT. *A suitable stage of ripeness based on flesh firmness was identified for minimal processing of avocado. Suitability of low-density polyethylene (LDPE), linear low density polyethylene (LLDPE) and LLDPE laminated with nylon as packaging materials and effectiveness of ascorbic and citric acids as anti-browning agents were tested based on visual quality rating, browning inhibitor and off-odour development in avocado slices. In-package oxygen and carbon dioxide concentrations and ethanol and acetaldehyde contents of avocado slices were determined during storage at 8 °C and 90 ±2% RH. Mature avocado fruit partially ripened to a firmness of 1.5±0.05 kg cm⁻² was found to be suitable for minimal processing. Carbon dioxide concentrations were 3.7 and 5.3% and oxygen concentrations were 8.4 and 5.5% in LDPE 0.050 mm and 0.075 mm packages, respectively, on day 7 in storage at 8°C. Under similar conditions, ethanol contents were 21 and 28 ppm and acetaldehyde contents were 4.2 and 5.3 ppm, respectively. Immersion of avocado slices in 1000 ppm citric and 200 ppm ascorbic acid at 4-6°C for 2 minutes followed by packaging in LDPE (0.050 and 0.075 mm) maintained the quality during storage for 7 days at 8 °C and 90±2% RH.*

INTRODUCTION

Enhanced respiration, browning of cut surface and tissue softening due to the action of endogenous enzymes are the major problems of minimal processing of fruit and vegetables (Rolle and Chism, 1987). Rate of enzymatic browning could be minimized by reducing the activity of polyphenol oxidase (PPO) and, thereby improving the appearance of cut fruit and vegetables (Romig, 1995). This is generally achieved by heat inactivation of PPO (McCord and Kilara, 1983; Ma *et al.*, 1992), exclusion of oxygen (Langdon, 1987) and, or application of anti-browning chemicals (Sapers *et al.*, 1994; Castner *et al.*, 1996; Sapers and Miller, 1998). Several anti-browning agents such as ascorbic acid, citric acid, sulphite, L-cystein and their combinations have been used to prevent the enzymatic browning of many processed products. However, due to several negative attributes associated with sulphites, their use is limited (Tong and Hicks. 1991) and ascorbic and citric acids have been shown to be good alternatives to sulphites (Laurila *et al.*, 1998).

Packaging of fresh-cut produce under an equilibrium modified atmosphere condition (1-5% oxygen, 5-10% carbon dioxide) offers a prolonged shelf-life for respiring products by suppressing the respiration rate and by inhibiting the enzymatic browning reactions of the cut surfaces (Kader, 1980; Day, 1997). Moreover, modified atmosphere packaging preserves the pigments by reducing browning and discolouration (Zagory and Kader, 1988). However, as film permeability plays an important role in

[1] Department of Food Science and Technology, Faculty of Agriculture, University of Peradeniya, Sri Lanka

atmosphere modification within such packages, selection of a suitable packaging material to suit the respiration rate of cut tissues is a major task (Chu and Wang, 2001). An experiment was conducted using different packaging materials with ascorbic and citric acids as anti-browing agents to investigate their effect of on fresh-cut avacado quality. The optimum stage of ripeness of avocado for minimal processing was also identified.

MATERIALS AND METHODS

'Booth 7' avocado fruit, obtained from the Horticultural Research Farm, Gannoruwa, were washed with 200 ppm commercial Chlorox and stored at room temperature (27±2°C) for 4-5 days for ripening. Ripening stage of the fruit was determined at the initial unripe, at initiation of ripening and post ripening, by assessing the fruit flesh firmness using a fruit firmness tester (AST Everwell Co.). Based on the results, fruit were divided into three firmness stages, 1.8 ± 0.2 kg cm^{-2}, 1.5 ± 0.05 kg cm^{-2} and 1.0 ± 0.25 kg cm^{-2}.

Determination of a suitable ripening stage for processing

Each fruit was cut into 16 slices of 10 mm thickness (approx. 5 g) with a sharp stainless steel knife. and slice firmness was determined in triplicate. The slices were dipped in a 200 ppm Chlorox solution at 4-6°C for 2 minutes, surface dried with tissue paper and packaged in 5 different materials *viz.* 0.050, 0.075 and 0.100 mm low-density polyethylene (LDPE), 0.015 mm linear low density polyethylene (LLDPE), and 0.060 mm LLDPE laminated with nylon (LLDPE/nylon). The experimental treatment structure was a two-factor factorial (5 x 3) with packaging materials and firmness as the factors laid out in a completely randomised design. Five packaging materials, 0.050, 0.075, 0.100 mm LDPE, 0.015 mm LLDPE, 0.060 mm LLDPE/nylon and three firmness stages, 1.8 ± 0.2 kg cm^{-2}, 1.5 ± 0.05 kg cm^{-2}, and 1.0 ± 0.25 kg cm^{-2} were used as the levels of the factors. From each packaging material 42 packages were made. Fourteen perforated packages containing 3 slices (approx. 15 g) per package were used as a control. Packages were heat sealed and stored at 8°C and 90±2% RH. Two packages from each treatment combination were opened at a time, and fruit slice firmness was measured daily for 7 days and the data were subjected to variance analysis using the SAS package (SAS Institute, 1994). The means were compared at $p<0.05$ according to the Fisher's protected Least Significant Difference test.

Selection of a packaging material and an anti-browning treatment

Fruit (firmness: 1.5 ± 0.05 kg cm^{-2}) were cut into halves along the stem axis, and each half was cut into eight pieces using a sharp stainless steel knife. From each avocado fruit, 16 slices of 10 mm in thickness were obtained. Three experiments were performed to establish the best anti-browning treatment. Experiment 1: Citric acid at 100, 500, 1000, 1500, 2000 and 2500 ppm concentrations. Experiment 2: Ascorbic acid at 100, 150, 200, 500 and 1000 ppm concentrations. Experiment 3: Solutions containing citric acid and ascorbic acids of 1000 and 150 ppm, 1000 and 200 ppm, 1500 and 150 ppm, and 1500 and 200 ppm, respectively. The control slices were dipped in distilled water.

Fruit slices were dipped either in water, citric acid, ascorbic acid or their combinations at 4-6°C for 2 minutes, surface dried with tissue paper and packaged in

0.050, 0.075, and 0.100 mm LDPE, 0.015 mm LLDPE and 0.060 mm LLDPE/nylon. Perforated packages were used as a control. The experimental treatment structure was a two-factor factorial in a completely randomised design, where the packaging materials and anti-browning agents with different concentrations were the two factors. Three packages from each packaging material were made for each treatment. The avocado slices were stored at 8 °C for 10 minutes before heat sealing. The sealed packages were stored at 8°C and 90±2% RH for 7 days, and subjective measurements on visual quality rating (VQR:1-poor, 3-fair, 5-good, 7-very good and 9-excellent.), browning index (BI:1-brown, 2-moderate brown, 3-slight brown, 4-neither yellow nor brown, 5-slight yellow, 6-moderate yellow and 7-yellow normal.) and off odour development (1-none, 2- slight, 3- moderate, and 4- severe) were made using 10 panellists. Data were analysed by MINITAB statistical package, using Friedman's non-parametric test, and a suitable treatment combinations was selected.

Gaseous composition, ethanol and acetaldehyde contents

Selection, preparation and storage of fruit slices were same as above. Five different packaging materials were used in a completely randomised design with triplicate. Fruit slices were dipped in 1000 ppm citric and 200 ppm ascorbic acid and packaged in 0.050, 0.075, and 0.100 mm LDPE, 0.015 mm LLDPE and 0.060 mm LLDPE/nylon. Perforated packages were used as the control. Self-sealing septa were fixed onto the packages to facilitate gas measurements. In-package concentrations of oxygen and carbon dioxide, and ethanol and acetaldehyde contents of the slices were measured (Jayathunge and Illeperuma, 2001) in triplicate after 1, 4 and 7 days of storage using a gas chromatograph (Shimadzu, model GC-14B). The data were subjected to variance analysis using the SAS package (SAS Institute, 1994), and the means were compared at $p<0.05$ according to the Fisher's protected Least Significant Difference test.

RESULTS AND DISCISSION

The initial (unripe) flesh firmness of avocado fruit was 1.8±0.2 kg cm^{-2}. When the fruit were allowed to ripen at room temperature without packaging, flesh firmness reduced to 1.5±0.05 kg cm^{-2} at the initiation of ripening, and further reduced to 1.0±0.25 kg cm^{-2} when partially ripe. The firmness at the table ripe stage varied between 0.70 and 0.75 kg cm^{-2}. When avocado slices with an initial firmness of 1.8±0.2 kg cm^{-2} were packaged in LDPE and stored at 8 °C and 90±2% RH, ripening was not initiated and slice firmness did not change during storage (Figure 1). Under similar conditions, the quality of slices with an initial firmness of 1.2 kg cm^{-2} was poor due to excessive softening and watery texture. Initial firmness of 1.5±0.2 kg cm^{-2} was found to be the best as indicated by a slices firmness of 0.75 kg cm^{-2} within three days of storage, which reduced further to 0.73 kg cm^{-2} on day 7 in storage (Figure 1). A similar pattern of tissue softening was observed during storage of slices in the other packaging materials such as 0.075 and 0.100 mm LDPE, 0.015 mm LLDPE and 0.060 mm LLDPE laminated with nylon (data are not shown).

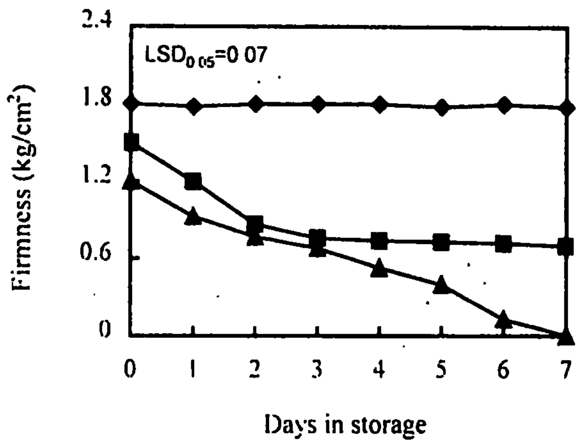

Fig. 1. **Firmness of 'Booth 7' avocado slices packaged in 0.05 mm LDPE and stored at 8 °C and 90 ± 2% RH.**

(Fruits of three ripening stages, with an initial firmness of 1.8 (♦), 1.5 (■) and 1.2 (▲) kg cm^{-2}, were used)

The interaction effect between packaging material x anti-browning treatment was significant ($p<0.05$) on VQR, BI, and off odour of the avocado slices. Significantly higher ($p<0.05$) VQR and BI values were observed for slices treated with 1000 ppm or 1500 ppm citric acid than those treated with other citric acid concentrations after 7 days of storage in 0.050 mm and 0.075 mm LDPE (Table 1). Similar results were obtained for slices treated with 150 ppm or 200 ppm ascorbic acid after 7 days of storage in 0.050 mm and 0.075 mm LDPE (Table 2). Fruit slices treated with 1000 ppm citric and 200 ppm ascorbic acid and packaged in 0.050 mm and 0.075 mm LDPE showed significantly higher values ($p<0.05$) for VQR and BI than those treated with other combinations of citric and ascorbic acids (Table 3). The slices in 0.060 mm LLDPE/nylon and 0.1 mm LDPE showed significantly higher off odour development than those packaged in other materials (Tables 1, 2 and 3). No off odour development was observed for slices in 0.050 mm LDPE, 0.075 mm LDPE, 0.015 mm LLDPE or perforated packages regardless of the anti-browning treatment.

The effect of packaging material was significant ($p<0.05$) on in-package concentrations of oxygen and carbon dioxide, and ethanol and acetaldehyde contents of avocado slices. The highest in-package oxygen and lowest carbon dioxide concentrations were recorded in 0.015 mm LLDPE on day 7 in storage (Table 4). The lowest oxygen and highest carbon dioxide concentrations were observed in 0.06 mm LLDPE/nylon packages (Table 4).

Fruit firmness is used as an indicator of stage of ripening in many fruits such as pear (Dong *et al.*, 2000; Gorney *et al.*, 2000) and avocado (Flitsanov *et al.*, 2000). Mature green fruit are not suitable for minimal processing as eating quality may be compromised due to lack of juiciness and fruity aroma and firm texture. Moreover, significantly less cut-surface darkening was observed in partially ripe and mature green than ripe pear fruit (Gorney *et al.*, 2000). The optimum ripeness stage, based on flesh firmness, for fresh cut processing of pear was reported to be between 44-58 N (Gorney *et al.*, 2000). It was revealed that ripening stage of avocado plays an important role in

Table1. **Effect of citric acid treatment and packaging material onvisual quality rating (VQR), browning index (BI) and off odour of 'Booth 7' avocado slices stored at 8 °C and 90±2 % RH for 7 days.**

Packaging Material	Citric acid (ppm)	VQR	BI	Odour
LDPE (0.050 mm)	100	3.37	4.15	1.00
	500	3.21	4.10	1.00
	1000	5.26	5.29	1.00
	1500	5.46	5.00	1.00
	2000	4.07	3.79	1.00
	Control (Water)	2.07	2.30	1.00
LDPE (0.075 mm)	100	3.06	2.93	1.00
	500	3.38	3.71	1.00
	1000	5.14	4.65	1.00
	1500	5.10	4.76	1.00
	2000	3.07	3.49	1.00
	Control (Water)	2.07	1.90	1.00
LDPE (0.100 mm)	100	3.04	3.51	1.40
	500	3.13	3.71	1.50
	1000	3.46	3.85	1.70
	1500	3.04	3.88	1.94
	2000	2.93	3.80	1.96
	Control (Water)	2.07	2.38	1.40
LLDPE (0.015 mm)	100	2.93	2.15	1.00
	500	3.07	2.71	1.00
	1000	3.07	2.57	1.00
	1500	3.07	2.38	1.00
	2000	2.93	2.71	1.00
	Control (Water)	2.15	2.46	1.00
LLDPE/ nylon (0.060 mm)	100	3.63	3.96	3.40
	500	4.21	4.57	3.50
	1000	5.18	4.99	3.60
	1500	5.07	5.00	3.80
	2000	3.21	4.43	4.00
	Control (Water)	2.07	3.24	3.40
Control.	100	2.26	1.71	1.00
	500	2.07	1.20	1.00
	1000	2.07	1.93	1.00
	1500	2.07	1.43	1.00
	2000	2.21	1.90	1.00
	Control (Water)	2.07	1.01	1.00

Each value represents the mean of triplicate judged by ten panellists.
VQR : 1-poor, 3-fair, 5-good, 7-very good and 9-excellent.
BI: 1-brown, 2-moderate brown, 3-slight brown, 4-neither yellow nor brown, 5-slight yellow, 6-moderate yellow and 7-yellow normal.

the quality of fruit slices. Avocado fruits with firmness of 1.8±0.2 kg cm^{-2} or above and of 1.0±0.25 kg cm^{-2} or below were found to be unsuitable for minimal processing as the former resulted in a firm texture and the latter resulted in a soggy texture during storage of the slices. Moreover, ripening was not initiated in the slices with firm texture and thus did not reach the table ripe stage even after termination of storage as revealed by firmness of higher than 0.70-0.75 kg cm^{-2}. Therefore, mature avocado fruit partially ripened to a firmness of 1.5±0.05 kg cm^{-2} should be used for minimal processing.

Table 2. Effect of ascorbic acid treatment and packaging material on Visual quality rating (VQR), browning index (BI) and off odour of 'Booth 7' avocado slices stored at 8 °C and 90 ± 2% RH for 7 days.

Packaging Material	Citric acid (ppm)	VQR	BI	Odour
LDPE (0.050 mm)	100	3.58	2.65	1.00
	150	5.44	5.00	1.00
	200	5.44	5.19	1.00
	500	3.56	4.65	1.00
	1000	3.77	4.38	1.00
	Control (Water)	1.78	1.54	1.00
LDPE (0.075 mm)	100	3.44	2.74	1.00
	150	5.11	4.98	1.00
	200	5.24	5.20	1.00
	500	3.56	3.51	1.00
	1000	4.00	3.57	1.00
	Control (Water))	1.72	1.65	1.00
LDPE (0.100 mm)	100	2.89	2.51	1.03
	150	4.00	3.29	1.08
	200	3.72	3.43	1.12
	500	2.72	3.38	1.20
	1000	3.58	3.51	1.27
	Control (Water)	1.53	1.51	1.04
LLDPE (0.015 mm)	100	2.72	2.29	1.00
	150	3.44	2.65	1.00
	200	2.58	2.65	1.00
	500	2.89	2.76	1.00
	1000	3.00	2.51	1.00
	Control (Water)	1.61	1.61	1.00
LLDPE/ nylon (0.060 mm)	100	3.81	3.68	3.40
	150	4.75	4.85	3.50
	200	4.81	4.65	3.52
	500	4.56	4.38	3.70
	1000	4.88	4.54	3.97
	Control (Water)	2.42	2.26	1.90
Control.	100	2.25	1.57	1.00
	150	2.00	1.57	1.00
	200	1.64	1.24	1.00
	500	1.58	1.61	1.00
	1000	1.52	1.74	1.00
	Control (Water)	1.53	1.51	1.00

Each value represents the mean of triplicate judged by ten panellists.
VQR : 1-poor, 3-fair, 5-good, 7-very good and 9-excellent.
BI: 1-brown, 2-moderate brown, 3-slight brown, 4-neither yellow nor brown, 5-slight yellow, 6-moderate yellow and 7-yellow normal.
Off odour: 1-none, 2- slight, 3- moderate, and 4- severe.

Table 3. Effect of citric and ascorbic acids, and packaging materials on Visual quality rating (VQR), browning index (BI) and off odour of 'Booth 7' avocado slices stored at 8 °C and 90 ± 2 % RH for 7 days.

Packaging Material	Citric (ppm) + ascorbic acids (ppm)	VQR	BI	Odour
LDPE (0.050 mm)	1000+150	5.65	5.80	1.00
	1000–200	7.60	6.77	1.00
	1000–150	7.20	6.54	1.00
	1500–200	6.41	5.63	1.00
	Water	1.75	1.97	1.00
LDPE (0.075 mm)	1000–150	5.48	5.30	1.00
	1000–200	7.40	5.50	1.00
	1000+150	7.50	5.30	1.00
	1500+200	5.88	4.87	1.00
	Water	1.98	1.77	1.00
LDPE (0.100 mm)	1000+150	5.01	5.20	1.40
	1000+200	5.68	5.53	1.37
	1000+150	5.88	5.47	1.70
	1500+200	5.31	4.63	1.96
	Water	1.31	1.87	1.39
LLDPE (0.015 mm)	1000+150	3.38	4.07	1.00
	1000+200	3.81	3.80	1.00
	1000+150	3.35	3.67	1.00
	1500+200	3.31	3.47	1.00
	Water	1.72	1.80	1.00
LLDPE/ nylon (0.060 mm)	1000+150	7.31	6.13	3.30
	1000+200	7.78	6.87	3.50
	1000+150	7.82	6.57	3.97
	1500+200	6.65	5.87	4.00
	Water	3.18	4.63	3.10
Control.	1000+150	1.01	1.00	1.00
	1000+200	1.01	1.07	1.00
	1000+150	1.10	1.07	1.00
	1500+200	1.01	1.03	1.00
	Water	1.20	2.20	1.00

Each value represents the mean of triplicate judged by ten panelists. VQR : 1-poor, 3-fair, 5-good, 7-very good and 9-excellent.
BI: 1-brown, 2-moderate brown, 3-slight brown, 4-neither yellow nor brown, 5-slight yellow, 6-moderate yellow and 7-yellow normal.
Off odour: 1-none, 2- slight, 3- moderate. and 4- severe.

Short shelf life of minimally processed fruits and vegetables is mainly caused by enzymatic browning during storage (Rolle and Chism, 1987; Sapers) and Hicks, 1989; McEvily *et al.*, 1992). As the Food and Drug Administration (FDA) banned use of sulphites as anti-browning agents on fresh commodities (Wiley, 1994), alternatives such as different formulations of ascorbic acid, erythorbic acid or their sodium salts with citric acid have been used to control enzymatic browning (Langdon, 1987). Immersion of avocado slices in either citric acid or ascorbic acid solutions was not effective in controlling enzymatic browning. However, a combination of 1000 ppm citric acid and 150 ppm ascorbic acid was found to be the most effective anti-browning treatment for avocado slices. This is probably due to the cumulative effects of citric acid and ascorbic acid, where the former lowers the pH below the optimum pH and chelates the copper prosthetic group of polyphenol oxidase (Langdon, 1987) and the latter reduces o-quinones to o-dehydroxy phenolic compounds, thereby preventing browning. Furthermore, ascorbic acid acts as an oxygen scavenger limiting molecular oxygen for enzymatic browning (Langdon, 1987).

Table 4. Effect of packaging material on in-package concentrations carbon dioxide, and ethanol and acetaldehyde contents of avocado slices during storage at 8 °C and 90 ± 2 % RH.

Packaging Material	Days in storage	Oxygen %	Carbon dioxide %	Ethanol (ppm)	Acetaldehyde (ppm)
LDPE (0.050 mm)	1	12.5	4.4	7	2.1
	4	9.6	3.4	17	2.3
	7	8.4	3.7	21	4.2
LDPE (0.075 mm)	1	11.2	6.0	13	2.3
	4	7.9	5.5	18	3.5
	7	5.5	5.3	28	5.3
LDPE (0.100 mm)	1	12.1	4.9	36	5.6
	4	5.0	7.3	179	9.6
	7	3.9	9.1	360	23.0
LLDPE (0.015 mm)	1	14.0	2.3	nd	nd
	4	13.7	2.5	nd	1.9
	7	12.2	1.9	7	2.2
LLDPE/ nylon (0.060 mm)	1	4.9	16.6	81	6.8
	4	2.4	34.1	483	44.8
	7	1.6	24.4	1260	140.5
Control	1	20.4	nd	nd	nd
	4	20.1	nd	nd	nd
	7	20.1	nd	nd	nd
$LSD_{0.05}$		1.2	0.9	17	4.9

Each value represents the average of triplicates. nd-not detectable

However, as low oxygen causes anaerobic respiration, concentration of ascorbic acid and the permeability of the packaging films are equally important to prevent off-odour development. A combination of 1000 ppm citric with 200 ppm ascorbic acid was found to be effective in preventing off-odour development when the slices were packaged in 0.050 mm LDPE and 0.075 mm LDPE, probably due to high oxygen and carbon dioxide permeability properties of these packaging films (Zagory and Kader, 1988). Low VQR and BI observed in slices packaged after treating with 1000 ppm citric acid and 150 ppm ascorbic in 0.015 mm LLDPE may be due to high in-package oxygen levels, which was also reflected by the low levels of ethanol and acetaldehydes, the major anaerobic plant fermentative metabolic products of fruits (Kader *et al.*, 1989; Gorny *et al.*, 1999). Thus, 0.015 mm LLDPE is not a suitable material for packaging avocado slices. LLDPE laminated with nylon is also not a suitable packaging material as in-package concentrations of oxygen was lower and carbon dioxide was higher than the injury levels of 2-3% oxygen and 8% carbon dioxide for most commodities (Day, 1997). Under similar conditions, the slices contained high acetaldehyde and ethanol levels, which is a result of low in-package oxygen concentrations (Carlin *et al.*, 1990). Similar results were observed for slices packaged in 0.1 mm LDPE. LDPE, 0.05 mm and 0.075 mm, was found to be suitable for packaging avocado slices after treating with 1000 ppm citric and 200 ppm ascorbic acid as the anti-browning agent.

CONCLUSIONS

Mature avocado fruit partially ripened to a firmness of close to 1.5±0.05 kg cm^{-2} was found to be suitable for minimal processing. A combination of 1000 ppm citric acid and 200 ppm ascorbic was more effective than when applied individually in minimizing browning. Immersion of avocado slices in 1000 ppm citric acid and 200 ppm ascorbic acid at 4-6 °C for 2 minutes followed by packaging in LDPE (0.05 and 0.075 mm) maintained the visual quality during storage for 7 days at 8 °C and 90±2% RH.

ACKNOWLEDGEMENTS

The authors are thankful to Mr. P.K. Liyanage and Mr. L. Wawegama, Technical Officers, Department of Food Science & Technology, Faculty of Agriculture, University of Peradeniya for their help with gas chromatography.

REFERENCES

Carlin, F., Nguyen, C., Hilbert, G. and Chambroy, Y. (1990). Modified atmosphere packaging of fresh, 'ready to-use' grated carrots in polymeric films. J. Food Sci. 55: 1033-1038.

Castner, M., Gill, M.L., Artes, F. and Tomas-Barberan, F.A. (1996). Inhibition of browning of harvested head lettuce. J. Food Sci. 61(2): 314-321.

Chu C.L. and Wang S.L. (2001). Effect of cutting style, low-oxygen atmosphere and cold temperature on the respiration rate of minimally processed vegetables. Acta Hort. 553 (2): 691-692.

Dong, X., Wrolstard R.E. and Sugar, D. (2000). Extending shelf life of fresh cut pears. J. Food Sci. 65 (1): 181-186.

Day B.P.F. (1997). Effective packaging for fresh produce. pp. 89-100. In: Ackermann P., Jagerstad M. and Ohlsson T. (Eds). Foods and packaging Materials: Chemical Interactions. The Royal Society of Chemistry, Cambridge, UK.

Flitsanov, U., Mizrach, A., Liberzon A., Akerman, M. and Zauberman, G. (2000). Measurements of avocado sofetening at various temperature using ultrasound. Postharv. Biol. Technol. 20: 279-286.

Gorny, J.R., Cifuentes R.A., Hess-Pierce, B. and Kader, A.A. (2000). Quality changes in fresh-cut pear slices as affected by cultivar, ripeness stage, fruit size and storage regime. J. Food Sci. 65 (3): 541-544.

Gorny, J.R., Hess-Pierce, B. and Kader, A.A. (1999). Quality changes in fresh-cut peach and nectarine slices as effected by cultivar, storage atmosphere and chemical treatments. J. Food Sci. 64 (3): 429-432.

Jayathunge K.G.L.R. and Illeperuma C.K (2001). Extension of postharvest life of oyster mushroom under ambient conditions. Tropical Agric. Res. 13:78-89.

Kader, A.A. (1980). Prevention of ripening in fruits by use of controlled atmospheres. Food Technol. 34 (3): 50-54.

Kader, A., Zagory, D. and Kerbal, E.L. (1989). Modified atmosphere packaging of fruits and vegetables. CRC-Critical Rev. Food Sci. Nutr. 28: 1-30.

Langdon, T.T. (1987). Preventing of browning in fresh prepared potatoes without the use of sulphitic agents. Food Technol. 41(5): 64-67.

Laurila E.K., Hurme E.U. and Ahvenainen R.T. (1998). Shelf life of sliced raw potatoes of various cultivar varieties – Substitution of bisulphites. J. Food Prot. 61: 1363-1371.

Ma, S., Silva, J.L., Hearnsberger, J.O. and Garner, J.O..Jr. (1992). Prevention of enzymatic darkening in frozen sweet potatoes by water blanching: Relationship among darkening, phenols, and polyphenol oxidase activity. J. Agric. Food Chem. 40: 864-867.

McCord, J.D. and Kilara, A. (1983). Control of enzymatic browning in processed mushrooms (*Agaricus bisporus*). J. Food Sci. 48: 1479-1481.

McEvily, A.J., Iyengar R. and Otwell, W.S. (1992). Inhibition of enzymatic browning in foods and beverages. CRC-Crit. Rev. Food Sci. Nutr. 32: 253-273.

Rolle, R.S. and Chism, G.W. (1987). Physiological consequences of minimally processed fruits and vegetables. J. Food Quality 10: 157-177.

Romig, W.R. (1995). Selection of cultivars for lightly processed fruits and vegetables. Hortscience 30:38-40.

Sapers, G.M and Hicks, K.B. (1989). Inhibition of Enzymatic browning in fruits and vegetables. pp. 29-43. In: Jen J.J. (Ed) Quality Factors of Fruits and Vegetables: Chemistry and Technology. ACS symp. Series 405, Am. Chem. Soc., Washinton D.C.

Sapers, G.M. and Miller, R.L. (1998). Browning inhibition in fresh-cut pears. J. Food Sci. 63: 342-346.

Sapers, G..M., Miller. R.L., Miller, F.C., Cocke, P.H. and Chai, S.W. (1994). Enzymatic browning control in minimally processed mushrooms. J. Food Sci. 59: 1042 –1047.

SAS Institute, SAS/STAT User's Guide, Version 6. 4th Edition. (1994). SAS Institute Inc., Cary, North Carolina, USA. pp 229-234.

Tong, C.B.S. and Hiks K.B. (1991). Sulphated polysaccharides inhibit browning of apple juice and diced apples. J. Agric. Food Chem. 39: 1719-1722.

Wiley, R.C. (1994). Preservation methods for minimally processed refrigerated fruits and vegetables. pp. 66-134. In: Wiley R.C. (Ed). Processed Refrigerated Fruits and Vegetable. Chapman and Hall, New York.

Zagory, D. and Kader, A. (1988). Modified atmosphere packaging of fresh produce. Food Technol. 42:70-77.