Fresh Produce ©2009 Global Science Books

Effect of Immersion Solution and Packaging on Quality of Fresh-cut 'Red Fire' Lettuce

Supranee Manurakchinakorn* • Sirikorn Thirawut

School of Agricultural Technology, Walailak University, Nakhon Si Thammarat, 80160, Thailand

Corresponding author: * **msuprane@wu.ac.th**

ABSTRACT

Shelf-life extension of fresh-cut 'Red Fire' lettuce by immersion in a solution consisting of 2 g/L citric acid and 1 g/L calcium chloride prior to modified atmosphere packaging (MAP) during 24 days of storage at 4°C was investigated. Polyethylene bag was used as a container for 3 packaging treatments including non-perforation, 2-hole perforation and 4-hole perforation. Visual quality (overall visual quality (OVQ), leaf edge browning (LEB) and russet spotting (RS)), weight loss and ascorbic acid content of the product were evaluated at 4-day intervals. Immersing fresh-cut lettuce in the mixed solution tended to retard loss of ascorbic acid and OVQ. Non-perforation MAP seemed to be superior for maintaining OVQ and delaying weight loss, compared with other MAP treatments. On the other hand, changes in LEB and ascorbic acid content were not apparently affected by different packaging treatments. Using immersion solution in combination with non-perforation MAP effectively maintained visual and nutritional qualities of fresh-cut lettuce, as a consequence of retaining fresh weight, ascorbic acid content, OVQ and delaying LEB. During 24 days of storage, discolouration of RS was not detected in all treatments, indicating that 'Red Fire' lettuce is not a RS sensitive cultivar.

Keywords: calcium chloride, citric acid, *Lactuca sativa* L., minimal processing, modified atmosphere packaging, perforation

Abbreviations: **CO_2**, carbon dioxide; **LEB**, leaf edge browning; **MAP**, modified atmosphere packaging; **OVQ**, overall visual quality; **O_2**, oxygen; **PAL**, phenylalanine ammonia lyase; **PE**, polyethylene; **PPO**, polyphenol oxidase; **RS**, russet spotting

INTRODUCTION

Consumption of fresh-cut lettuce has a high increase in the market due to consumer demand for freshness and convenience. As minimal processing of lettuce satisfies a need of consumer, a detrimental effect on the shorter shelf-life of minimally processed lettuce, compared with the unprocessed raw material, has to be concerned. Fresh-cut processing affects quality factors such as appearance, flavour and colour, and product deterioration may proceed rapidly. The inherent quality deterioration of fresh-cut produce is largely due to cutting, because it initiates the physiological and biochemical changes at a faster rate than in intact raw vegetable (Watada and Qi 1999). Quality and shelf-life of cut lettuce are decreased by the development of tissue browning. Discolouration of surface and edge is the main defect of fresh-cut lettuce (López-Gálvez *et al.* 1996; Saltveit 2000; Degl'Innocenti *et al.* 2007). Overall visual quality of 5 different types of cut lettuce (iceberg, romaine, butter, green leaf and red leaf) was reported to be below the limit of salability after 12 days of storage in air at 5°C (López-Gálvez *et al.* 1996). Maintaining an appearance appealing to the consumer results in the prolonged shelf-life of cut lettuce (Zhou *et al.* 2004). Furthermore nutritional loss, emphasising ascorbic acid content, is also evaluated during storage of fresh-cut lettuce because ascorbic acid is highly susceptible to degradation during processing and storage (Barry-Ryan and O'Beirne 1999).

Many techniques have been used to delay quality deterioration of fresh-cut lettuce. Shelf-life extension of fresh-cut iceberg lettuce by using chemical treatment was reported (Ihl *et al.* 2003). Citric acid and calcium chloride comprising in the immersion solution resulted in maintaining colour and texture of the cut lettuce, respectively. On the other hand, modified atmosphere packaging (MAP) is effective in prolonging the shelf-life of fresh-cut iceberg lettuce (Heimdal *et al.* 1995; Smyth *et al.* 1998; Fan *et al.* 2003), in addition to retaining ascorbic acid content of the product (Barry-Ryan and O'Beirne 1999). Generally, the beneficial effect of MAP is obtained by the low level of oxygen (O_2) and high level of carbon dioxide (CO_2) inside a package (Kader *et al.* 1989). However, a lack of O_2 could induce the development of off-flavour due to the change from aerobic to anaerobic metabolism (Beaudry 2000). To reduce anaerobic respiration, perforation-mediated MAP may be a suitable alternative to providing high O_2 transmission rate because the O_2 transmits through hole 6 times faster than film (Zagory 1997). Moreover, MAP using perforation is a flexible system which can be adapted easily to any plastic films.

Aside from iceberg lettuce, one of the most demanded types of lettuce to be incorporated in mixed salads is 'Red Fire' lettuce. This is a red leaf lettuce that does not form a head but produces crisp leaves loosely arranged on the stalk. This lettuce has a good flavour with a sweet aftertaste, but is more perishable than head lettuce. However, there has been little information about quality preservation of fresh-cut 'Red Fire' lettuce during storage. Therefore the objective of this study was to investigate the quality retention of fresh-cut 'Red Fire' lettuce by using chemical treatment and perforation-mediated MAP. Polyethylene (PE) bag, which is cheap and easily available, was used as a container to create the desired MAP in the study.

MATERIALS AND METHODS

Sample preparation

'Red Fire' lettuce (*Lactuca sativa* L.), hydroponically grown in laboratory greenhouse, was used in this study. Lettuce, harvested at optimal maturity, was processed immediately by discarding outer and core leaves. The selected lettuce leaves were then cut

Received: 22 December, 2008. Accepted: 10 June, 2009.

Original Research Paper

with a sharp knife in transversal long narrow strips of 4 cm, dipped for 40 s in immersion solution containing 2 g/L citric acid and 1 g/L calcium chloride (Ihl *et al.* 2003) and manually centrifuged to remove excess moisture before packing. Cut lettuce dipped in distilled water was used as control. About 30 g of cut lettuce was packaged in 19 cm × 25 cm bag of 80 µm PE film and heat sealed with an electric sealing machine. The O_2, CO_2 and water vapour transmission rates of the PE film were 3,938 cm^3/m^2 day, 14,173 cm^3/m^2 day and 9.2 g/m^2 day, respectively, at 25°C. Three packaging treatments including non-perforation, 2-hole perforation and 4-hole perforation (0, 2 and 4 holes of 0.6 mm diameter per bag, respectively) were used in this study.

Quality evaluations

Quality assessment of fresh-cut lettuce was conducted for visual quality, weight loss and ascorbic acid content at 4-day intervals during 24 days of storage at 4°C and 85% RH. Visual quality was evaluated using the following parameters and scoring systems: (1) overall visual quality (OVQ) was rated on a scale from 5 to 1, where 5 = excellent and 1 = unusable, (2) leaf edge browning (LEB) was scored on a scale from 1 to 5, where 1 = no browning and 5 = severe browning, (3) russet spotting (RS) was scored on a scale from 1 to 5, where 1 = none and 5 = severe. For each of these defects, an index was calculated by multiplying the scores for severity by the percentage of pieces affected (López-Gálvez *et al.* 1996). Ascorbic acid was measured by titrimetric assay (James 1995).

Statistical analysis

The experiment was repeated twice with similar results; the paper reports the results from a representative experiment. Three replicates were used per treatment. Statistical analysis was conducted using SPSS version 10.0. An analysis of the variance was processed using the general linear model procedure. Mean comparisons were performed using Duncan's New Multiple Range Test.

RESULTS

Weight loss

No significant difference ($P>0.05$) in weight loss was detected between fresh-cut lettuce immersed in distilled water and immersion solution throughout the storage period, considering the same packaging treatment (**Fig. 1**). On the other hand, packaging treatments resulted in significant difference ($P<0.05$) of weight loss between non-perforation MAP and 4-hole perforation MAP from day 16 till the end of storage, whereas significant difference ($P<0.05$) of weight loss between 2-hole perforation MAP and 4-hole perforation MAP was detected from day 20. At the end of storage, the highest weight loss ($P<0.05$) was found in the product stored in 4-hole perforated bag, due to the highest extent of gas and water vapour transfer through the holes.

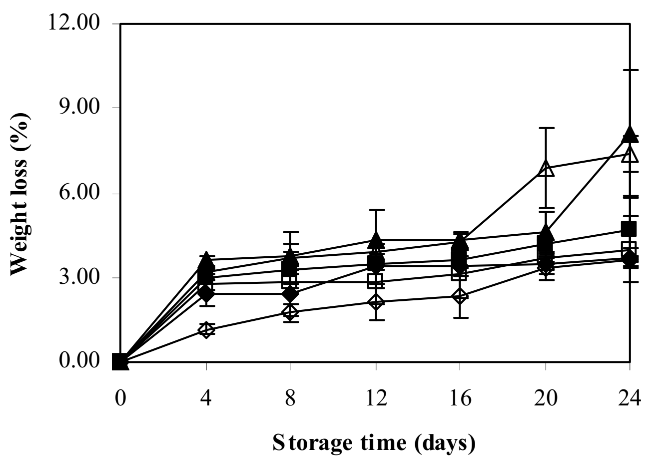

Fig. 1 Weight loss of fresh-cut lettuce during 24 days of storage at 4°C as affected by different treatments. (♦) Dipping cut lettuce in distilled water prior to packing in imperforated bag, (■) dipping cut lettuce in distilled water prior to packing in 2-hole perforated bag, (▲) dipping cut lettuce in distilled water prior to packing in 4-hole perforated bag, (◊) dipping cut lettuce in immersion solution prior to packing in imperforated bag, (□) dipping cut lettuce in immersion solution prior to packing in 2-hole perforated bag, (Δ) dipping cut lettuce in immersion solution prior to packing in 4-hole perforated bag. The vertical line at each data point represents the standard deviation about that mean ($n = 3$).

Visual quality

Immersion solution used in this study tended to delay browning of cut surface of the minimally processed lettuce, though there was no significant difference ($P>0.05$) of LEB between the immersion solution treatment and distilled water treatment (**Fig. 2A**). In addition, the discolouration of leaf edge of the cut lettuce was not apparently affected ($P>0.05$) by MAP treatment. However, LEB indices of all lettuce treatments were small (score<2) at the end of storage, indicating the acceptable extent of browning at the cut surface during 24 days of storage. Furthermore RS was not detected in all treatments (score<1.05) throughout the storage period (**Fig. 2B**).

Dipping cut lettuce in immersion solution resulted in maintaining high OVQ scores for fresh-cut lettuce stored under all MAP treatments (**Fig. 2C**). OVQ of fresh-cut lettuce dipped in immersion solution differed evidently ($P<0.05$) from distilled water-dipped lettuce from day 12 of storage. The decline in OVQ of fresh-cut lettuce dipped in immersion solution appeared after 16 days of storage. On the other hand, OVQ scores of fresh-cut lettuce differed ($P<0.05$) among MAP treatments at the end of storage. Fresh-cut lettuce dipped in immersion solution before packaging in imperforated bag obtained the highest OVQ score ($P<0.05$) and was still salable (score>3) at the end of storage. It seemed that LEB index partially contributed to the OVQ index of fresh-cut 'Red Fire' lettuce, in addition to the main contribution by weight loss of the cut lettuce.

Ascorbic acid

Ascorbic acid of fresh-cut lettuce in all treatments decreased drastically during storage (**Fig. 3**). It was found that dipping cut lettuce in immersion solution was beneficial to delaying loss ($P<0.05$) of ascorbic acid, whereas there was no significant difference ($P>0.05$) among various MAP treatments. The retention of ascorbic acid in fresh-cut lettuce ranged from 16-30% at the end of storage.

DISCUSSION

Weight loss is a natural process of catabolism of horticultural products, catalysed by enzymes and is accelerated by cutting. The decrease in weight may be attributed to respiration and other senescence-related metabolic processes during storage (Watada and Qi 1999). Perforation of PE bag facilitated transmission of water vapour and other volatile products from the package of fresh-cut lettuce, resulting in the highest weight loss of cut lettuce kept in 4-hole perforated bag (**Fig. 1**).

Browning in fresh-cut lettuce is a major defect and extensively affects marketability of the product. Quality loss due to browning of surface and edge of fresh-cut lettuce depends on cultivars of lettuce (López-Gálvez *et al.* 1996). Wounds incurred during processing of fresh-cut lettuce induce accumulation of phenolic compounds by phenylalanine ammonia lyase (PAL) (Peiser *et al.* 1998) and subsequent development of browning by polyphenol oxidase (PPO) (Brecht 1995). Immersion solution used in this study had a tendency to delay discolouration of fresh-cut lettuce (**Fig. 2**). Citric acid containing in the immersion solution shifts pH from the optimum range for PPO and chelates copper of active site of the enzyme (Martinez and Whitaker 1995; Castañer *et al.* 1996). PPO in head lettuce has opti-

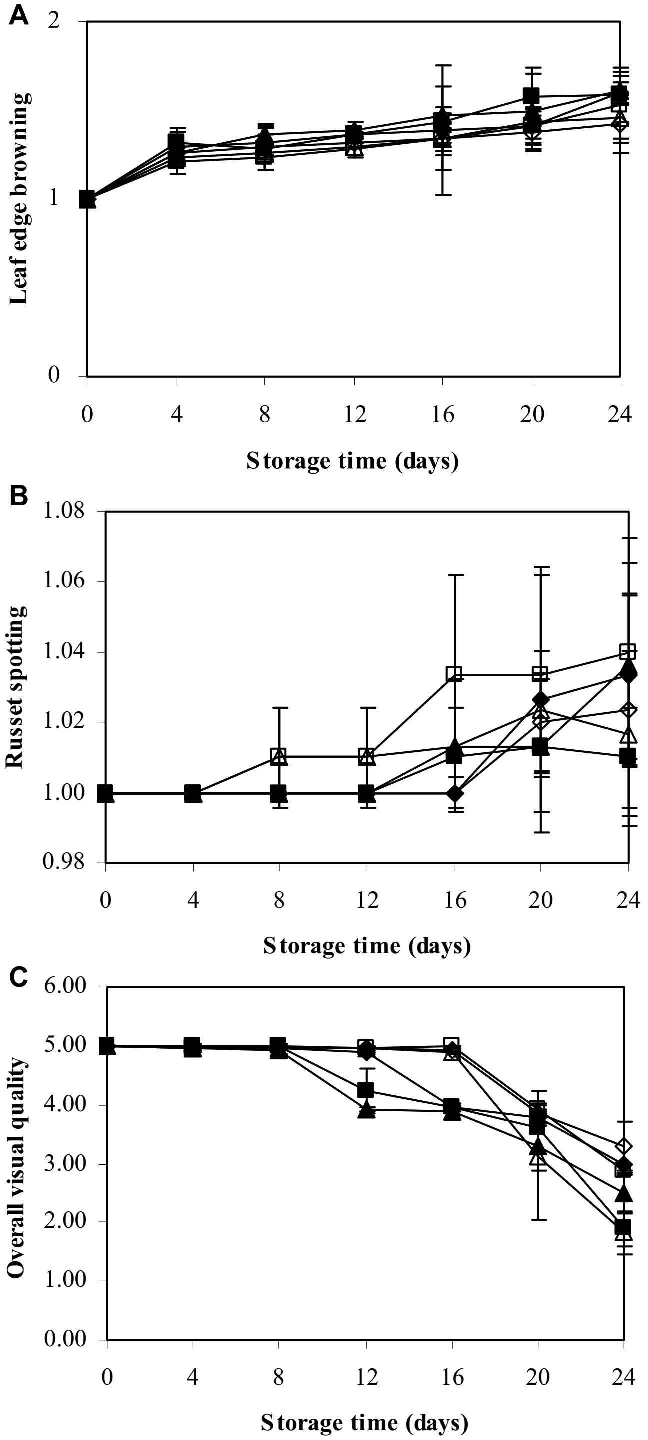

Fig. 2 Leaf edge browning (A), russet spotting (B) and overall visual quality (C) of fresh-cut lettuce during 24 days of storage at 4°C as affected by different treatments. (♦) Dipping cut lettuce in distilled water prior to packing in imperforated bag, (■) dipping cut lettuce in distilled water prior to packing in 2-hole perforated bag, (▲) dipping cut lettuce in distilled water prior to packing in 4-hole perforated bag, (◊) dipping cut lettuce in immersion solution prior to packing in imperforated bag, (□) dipping cut lettuce in immersion solution prior to packing in 2-hole perforated bag, (Δ) dipping cut lettuce in immersion solution prior to packing in 4-hole perforated bag. The vertical line at each data point represents the standard deviation about that mean (n = 3).

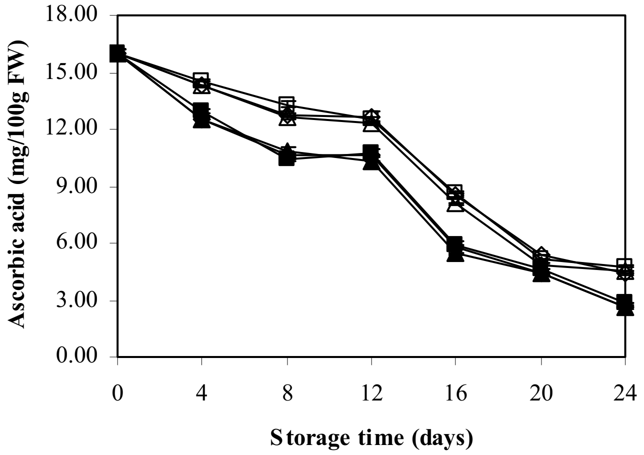

Fig. 3 Ascorbic acid content of fresh-cut lettuce during 24 days of storage at 4°C as affected by different treatments. (♦) Dipping cut lettuce in distilled water prior to packing in imperforated bag, (■) dipping cut lettuce in distilled water prior to packing in 2-hole perforated bag, (▲) dipping cut lettuce in distilled water prior to packing in 4-hole perforated bag, (◊) dipping cut lettuce in immersion solution prior to packing in imperforated bag, (□) dipping cut lettuce in immersion solution prior to packing in 2-hole perforated bag, (Δ) dipping cut lettuce in immersion solution prior to packing in 4-hole perforated bag. The vertical line at each data point represents the standard deviation about that mean (n = 3).

mum pH between 5 and 8 (Fujita *et al.* 1991) and has different conformations and native molecular weights in photosynthetic and vascular lettuce tissues (Heimdal *et al.* 1994). In addition to function of textural enhancer (Luna-Guzman and Barrett 2000), calcium chloride containing in the immersion solution might act as browning inhibitor by interaction of chloride ion with copper at the PPO active site (McEvily *et al.* 1992). Synergistic effect of citric acid in combination with calcium chloride on browning prevention of minimally processed lettuce was also reported (Ihl *et al.* 2003). The firming action of calcium ion could contribute to a reduced leakage of PPO and its substrates at the exposed cut surfaces (Sapers and Miller 1992). Furthermore, calcium ion is reported to inhibit stress-induced senescence by maintaining membrane integrity (Picchioni and Watada 1998). Ihl *et al.* (2003) suggested that calcium chloride component of immersion solution might be beneficial in reducing ethylene emanation corresponding to wounding stress of fresh-cut lettuce.

Though 2-hole and 4-hole perforation might facilitate the development of higher O_2 and lower CO_2 levels inside the bags and enhance enzymatic browning of cut lettuce, compared with imperforated bag, dipping cut lettuce in immersion solution tended to retard browning of the cut surface (**Fig. 2A**). López-Gálvez *et al.* (1996) found that LEB of red leaf-type cut lettuce stored in air was more severe than that of the cut lettuce stored in a controlled atmosphere (3% O_2 and 10% CO_2) from day 8 until day 12 of storage. On the other hand, visual quality of immersion solution-dipped lettuce stored in imperforated bag appeared highly acceptable (highest OVQ score at the end of storage) (**Fig. 2C**), without brown stain symptom caused by CO_2 injury (data not shown). High O_2 and low CO_2 enhanced enzymatic browning, while low O_2 and, more significantly, high CO_2 enhanced CO_2 injury (brown stain) of fresh-cut butterhead lettuce (Varoquaux *et al.* 1996). Fresh-cut products generally are more tolerant to higher CO_2 levels than intact products because the resistance to diffusion is smaller (Kader *et al.* 1989). Varoquaux and Wiley (1994) found that shredded crisphead lettuce tolerated higher levels of CO_2 than its intact counterpart. Allende *et al.* (2004) reported that general appearance of shredded 'Lollo Rosso' lettuce was still acceptable and LEB of the cut lettuce was assessed as modulate by panelists, after 7 days of storage in sealed polypropylene bag (initial atmosphere containing 3% O_2 and 5% CO_2) at 5°C.

RS is a common disorder due to exposure to low concentrations of ethylene which stimulates the production of phenolic compounds which lead to brown pigments. A relationship between the activity of PAL in iceberg lettuce leaf tissue and the development of RS symptom has been reported (Ritenour *et al.* 1996). Low level of O_2 and high level of CO_2, as a result of respiration of cut lettuce, inside imperforated bag might prevent ethylene production, resulting in delaying RS disorder of the product during storage (**Fig. 2B**). In addition, no RS symptom was detected in cut lettuce stored in 2-hole and 4-hole perforated bags throughout the storage. These results indicated that 'Red Fire' lettuce is not a RS sensitive cultivar.

Ascorbic acid degraded very quickly when 'Red Fire' lettuce was minimally processed (**Fig. 3**). Heimdal *et al.* (1995) reported that ascorbic acid in shredded lettuce degraded drastically during storage at 5°C. Seven days after processing, ascorbic acid was no longer detectable. Similar effect of slicing on loss of ascorbic acid in shredded iceberg lettuce was reported by Barry-Ryan and O'Beirne (1999). Albrecht (1993) also found that the retention of ascorbic acid in intact heads of 8 lettuce cultivars ranged from 40-74% after 7 days of refrigerated storage. Ascorbic acid is labile and readily affected by light, O_2, heat, enzymes and metals (Albrecht *et al.* 1991). In present study, citric acid containing in the immersion solution might have beneficial effect on preventing degradation of ascorbic acid by chelating contaminated metal ions in the system. Consequently, catalytic action of metal ions on the oxidation of ascorbic acid in the cut lettuce was inhibited.

CONCLUSION

Visual and nutritional qualities of fresh-cut 'Red Fire' lettuce could be preserved by using immersion solution in combination with imperforated PE bag. PE bag was appropriate for packaging of fresh-cut 'Red Fire' lettuce, considering the expense of using MAP technology, both on the basis of film cost and on the need for modifications to packing line systems.

ACKNOWLEDGEMENTS

We are grateful to Walailak University for financial support and providing research facilities throughout this work.

REFERENCES

Albrecht JA (1993) Ascorbic acid content and retention in lettuce. *Journal of Food Quality* **16**, 311-316

Albrecht JA, Schafer HW, Zoltola EA (1991) Sulfhydryl and ascorbic acid relationship in selected vegetables and fruits. *Journal of Food Science* **56**, 427-430

Allende A, Aguayo E, Artés F (2004) Microbial and sensory quality of commercial fresh processed red lettuce throughout the production chain and shelf life. *International Journal of Food Microbiology* **91**, 109-117

Barry-Ryan C, O'Beirne D (1999) Ascorbic acid retention in shredded iceberg lettuce as affected by minimal processing. *Journal of Food Science* **64**, 498-500

Beaudry R (2000) Responses of horticultural commodities to low oxygen: Limits to the expanded use of modified atmosphere packaging. *HortTechnology* **10**, 491-500

Brecht JK (1995) Physiology of lightly processed fruits and vegetables. *Hort Science* **30**, 18-21

Castaňer M, Gil MI, Artes F, Tomas-Barberan FA (1996) Inhibition of browning of harvested head lettuce. *Journal of Food Science* **61**, 314-316

Degl'Innocenti E, Pardossi A, Tognoni F, Guidi L (2007) Physiological basis of sensitivity to enzymatic browning in 'lettuce', 'escarole' and 'rocket salad' when stored as fresh-cut products. *Food Chemistry* **104**, 209-215

Fan X, Toivonen PMA, Rajkowski KT, Sokorai KJB (2003) Warm water treatment in combination with modified atmosphere packaging reduces undesirable effects of irradiation on the quality of fresh-cut iceberg lettuce. *Journal of Agricultural and Food Chemistry* **51**, 1231-1236

Fujita S, Tono T, Kawahara H (1991) Purification and properties of polyphenol oxidase in head lettuce (*Lactuca sativa*). *Journal of the Science of Food and Agriculture* **55**, 643-651

Heimdal H, Kűhn BF, Poll L, Larsen LM (1995) Biochemical changes and sensory quality of shredded and MA-packaged iceberg lettuce. *Journal of Food Science* **60**, 1265-1268, 1276

Heimdal H, Larsen LM, Poll L (1994) Characterization of polyphenol oxidase from photosynthetic and vascular lettuce tissues (*Lactuca sativa*). *Journal of Agricultural and Food Chemistry* **42**, 1428-1433

Ihl M, Aravena L, Scheuermann E, Uquiche E, Bifani V (2003) Effect of immersion solutions on shelf-life of minimally processed lettuce. *Lebensmittel, Wissenschaft undTechnologie* **36**, 591-599

James CS (1995) *Analytical Chemistry of Foods*, Blackie Academic and Professional, Glasgow, UK, 178 pp

Kader AA, Zagory D, Kerbel EL (1989) Modified atmosphere packaging of fruits and vegetables. *CRC Critical Reviews in Food Science and Nutrition* **28**, 1-30

López-Gálvez G, Saltveit M, Cantwell M (1996) The visual quality of minimally processed lettuces stored in air or controlled atmosphere with emphasis on romaine and iceberg types. *Postharvest Biology and Technology* **8**, 179-190

Luna-Guzman I, Barrett DM (2000) Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. *Postharvest Biology and Technology* **19**, 61-72

Martinez MV, Whitaker JR (1995) The biochemistry and control of enzymatic browning. *Trends in Food Science and Technology* **6**, 195-200

McEvily AJ, Iyengar R, Otwell WS (1992) Inhibition of enzymatic browning in foods and beverages. *CRC Critical Reviews in Food Science and Nutrition* **32**, 253-273

Peiser G, López-Gálvez G, Cantwell M, Saltveit ME (1998) Phenylalanine ammonia lyase inhibitors control browning of cut lettuce. *Postharvest Biology and Technology* **14**, 171-177

Picchioni GA, Watada AE (1998) Membrane structural lipid changes in fresh-cut carrots; Revisiting the "wounding and aging" phenomenon. *Acta Horticulturae* **464**, 237-242

Ritenour M, Sutter EG, Williams DM, Saltveit ME (1996) Indole-3-acetic acid (IAA) content and auxiliary bud development in relation to russet spotting in harvested iceberg lettuce. *Journal of the American Society for Horticultural Science* **121**, 543-547

Saltveit ME (2000) Wound induced changes in phenolic metabolism and tissue browning are altered by heat shock. *Postharvest Biology and Technology* **21**, 61-69

Sapers GM, Miller RL (1992) Enzymatic browning control in potato with ascorbic acid-2-phosphates. *Journal of Food Science* **57**, 1132-1135

Smyth AB, Song J, Cameron AC (1998) Modified atmosphere packaged cut iceberg lettuce: effect of temperature and O_2 partial pressure on respiration and quality. *Journal of Agricultural and Food Chemistry* **46**, 4556-4562

Varoquaux P, Mazollier J, Albagnac G (1996) The influence of raw material characteristics on the storage life of fresh-cut butterhead lettuce. *Postharvest Biology and Technology* **9**, 127-139

Varoquaux P, Wiley RC (1994) Biological and biochemical changes in minimally processed refrigerated fruits and vegetables. In: Wiley RC (Ed) *Minimally Processed Refrigerated Fruits and Vegetables*, Chapman and Hall, New York, USA, pp 226-268

Watada AE, Qi L (1999) Quality of fresh-cut produce. *Postharvest Biology and Technology* **15**, 201-205

Zagory D (1997) Advances in modified atmosphere packaging (MAP) of fresh produce. *Perishables Handling Newsletter* **90**, 2-4

Zhou T, Harrison AD, McKellar R, Young JC, Odumeru J, Piyasena P, Lu X, Mercer DG, Karr S (2004) Determination of acceptability and shelf life of ready-to-use lettuce by digital image analysis. *Food Research International* **37**, 875-881