Tropical Agricultural Research & Extension 16(2): 2014

QUALITY OF MINIMALLY PROCESSED, MODIFIED ATMOSPHERE STORED BELL PEPPER, AS AFFECTED BY PRE-TREATMENTS

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Accepted: 06 February 2014

ABSTRACT

Minimally processed bell pepper strips stored at 8-10^{0}C for seven days were evaluated for variation in color, in package gases, firmness, physicochemical sensory and microbiological quality. Bell pepper strips were treated with sodium chloride, calcium chloride, sodium chloride+calcium chloride or distilled water (control) and packed in polystyrene packages before storage. Pretreatments did not drastically affect the physicochemical properties (titratable acidity (TA), total soluble solids (TSS) and pH) when compared to the control. A slight discoloration of bell pepper was evident, indicated by decreasing L*, a* and b* values. Variations in firmness were observed. Fairly high level of CO_2 accumulation was evident inside packages where O_2 concentration displayed a declining trend. Sensory attributes generally declined with time but were within acceptable limits. Microbial counts were within safe-to-consume limits for all samples within the storage period. All pretreatments tested had no drastic effect on sensory properties and maintained low microbial counts, however 1% sodium chloride pretreatment was more successful in retaining higher sensory properties and maintaining lower microbial counts by the end of storage period than the other pretreatments.

Key words: Bell Pepper, Minimal Processing, Modified Atmosphere Packaging, Pretreatments

INTRODUCTION

Minimally processed products are defined as any perishable commodity submitted to a process of physical alteration (cutting, trimming, slicing) but ensuring that they remain in the fresh state after processing (Moretti *et al*. 2000). The growing concern towards healthy living has increased the demand for minimally processed products during past few years (Botelho *et al*. 2008). Physical, chemical and biochemical changes in such products occur at faster rates than in intact raw commodities due to tissue damages, especially in color and firmness (Botelho *et al*. 2008). Development of off-flavors as well as microbial spoilage is also frequent causes of quality loss of minimally processed products (Rojas-Guru *et al*. 2009).

To minimize deleterious effects of minimal processing, low temperature and modified atmosphere packaging (MAP) can be employed effectively (Latifah *et al*. 1999). MAP or controlled atmosphere suppress ethylene effects as indicated by inhibition of color change, fruit softening and prolongation of the pre-climacteric phase (Oz *et al*. 2010). Apart from that, pretreatments could be also employed to extend shelf life of such products since they rinse enzymes and substrates released by disrupted cells reducing microbial spoilage (Hui *et al*. 2006). Peppers are one of the popular vegetables because of the combination of color, taste and nutritional value. Peppers contain a wide array of phytochemicals and are a good source of vitamin C and carotenoids that are important nutritional antioxidants found in human diet (Zhang and Hamauzu 2003). Off shaped but high quality bell pepper are available in the local market, which are non-marketable due to their appearance. This type of commodities could be subjected to minimal processing and be sold at local supermarkets as a value added products.

The objectives of the present study were to investigate the quality of minimally processed bell pepper subjected to selected pretreatments, and stored at 8-10^{0}C with respect to physico-

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chemical, sensory, in package gas and microbiological properties.

MATERIALS AND METHODS

Preparation of bell pepper samples: Off shaped, fresh *Capsicum annuum* (green bell pepper) at full maturity (5-6 weeks) was purchased from Pasar Borong market in Serdang, Malaysia and transported to the Postharvest laboratory at Malaysian Agricultural Research and Development Institute (MARDI), Serdang to determine the physicochemical, variation in color, firmness, in package gases and sensory properties. Green bell peppers at full maturity (5 to 6 weeks) purchased from supermarkets in Mount Lavinia, Sri Lanka were transported to the laboratory at the Department of Botany, University of Kelaniya, Sri Lanka to determine microbiological properties. Fruits were washed in distilled water and dipped in chilled water for 2 minutes. Bell pepper was cut into long strips (5 mm × 5 mm × 5-8 cm) using a sharp stainless steel knife under aseptic conditions. Bell pepper strips were dipped in pretreatment solutions of T_1 - 1% (w/v) sodium chloride, T_2 - 1% (w/v) calcium chloride, T_3 - 1% (w/v) sodium chloride + 1% (w/v) calcium chloride or T_4 - distilled water /control for 2-3 minutes separately. Samples were drained and air dried for 10 minutes and 12-15 strips were packed separately in polystyrene packages of 150 g capacity on top of water absorbent sachets (Supersorb) and fastened with clip-on lids. Packages were over wrapped with polyvinylchloride (PVC) stretch film (0.001 mm) (Latifah *et al.* 1999). All packages were placed on plastic trays of 30×40 cm in size (8 packages per tray) and stored in a cold room at 8-10^{0}C and 80-85% relative humidity.

Physicochemical properties: Samples were removed on day 0, 2, 4 and 7 and subjected to physicochemical analysis.

Total soluble solids (TSS): 50-60 g sample of bell pepper from each treatment was blended (National MX 7986 blender, Japan) for 2 minutes. Approximately 5 g of pulp was weighed using a digital balance (Scaltec, Germany). TSS in the pulp was measured using a Digital Refractometer (Atago, DBX-55, Japan) (Latifah *et al*. 2000; Rashidi *et al*. 2010). Three replicate samples were used per treatment.

pH of filtrates: Samples of pulp prepared for TSS analysis (each having approximately 5 g) were diluted with 20 ml distilled water and pH was recorded using a Microprocessor pH meter (WTW, Germany) (Latifah *et al*. 2008). Three replicate samples were used per treatment.

Titratable acidity (TA): Sample pulps prepared for pH determination were titrated against 0.1 N NaOH to an end point of 8.1 using a Digital Burette. The burette readings were converted to % TA using the malic acid factor (0.67) and sample weight. Three samples were used for each treatment (Latifah *et al.* 2008).

In-package atmosphere changes: In- package atmosphere (O_2, CO_2 and C_2H_4) changes were measured on n day 1, 2, 3, 4 and 7 during cold storage by withdrawing air samples (1 ml) from headspace of the packages through a septum using a hypodermic syringe. Three replicate injections were made per treatment package. Concentrations of CO_2, was analyzed using a thermal conductivity detector of a gas chromatograph (Perkin Elmer, auto XL, USA) fitted with a stainless steel column packed with Porapak R of size 80-100 mesh. Carrier gas purified nitrogen was at a flow rate of 30 ml/min and the injector temperature was at 100^{0}C (Latifah *et al.* 2000). Oxygen concentration in-packages were determined using a thermal conductivity detector of a gas chromatograph (Perkin Elmer, Clarus 500, USA) fitted with a 60-80 Molecular Sieve SA column. Carrier gas was purified nitrogen at a flow rate of 5 ml/min and the injector temperature was at 60^{0}C (Latifah *et al.* 2000). Ethylene measurements were recorded by injecting headspace samples into a flame ionization detector of a Perkin Elmer, Clarus 500 gas chromatograph (USA) equipped with a carboxen 1006 plot capillary column. Carrier gas was purified helium at a flow rate of 10 ml/min and the injector temperature was at 100^{0}C (Latifah *et al*. 2000).

Color of flesh: The surface color of the bell pepper samples were recorded on day 0, 2, 4 and 7 using a Chromameter (Minolta, CR 300, Japan) (Hasmah *et al.* 2007). Three replicate samples were used for each treatment.

Firmness: The firmness of bell pepper strips were determined on day 0, 2, 4 and 7 using the Quality Testing System (QTS) Controller Texturemeter (United Kingdom) fitted with a flat round tip probe with a capacity of 5N at a penetration speed of 10 mm/s (Abdullah *et al.* 2007). Three replicate samples were used for each treatment.

Sensory properties: Samples of bell pepper were removed on day 0 and 7 and subjected to sensory properties. The treated samples were provided to a trained, 6 member taste panel along with a questionnaire. Sensory evaluation was conducted using a 7 point ranking system (Dharmabandu *et al*. 2007).

Microbiological properties: Samples were removed on day 0 and 7 and subjected to microbiological assessment.

Total aerobic plate count: Twenty (20.0) g of bell pepper was homogenized with sterile 0.9% NaCl (180.00 ml) in a blender for 2 minutes and a dilution series was prepared up to 10^{-5}. From 10^{-3}, 10^{-4} and 10^{-5} dilutions 1.00 ml was plated to which 12 ml of molten plate count agar (PCA) was poured. Plating was done in duplicate. Plates were incubated at 28 ± 2^0C for 72 hours and bacterial colonies were counted. The colony forming units (CFU) were determined using the equation described by SLS Part 1 (1991). Eight replicate samples were used per each treatment.

Yeast and mould count: One (1.00) ml from 10^{-3}, 10^{-4} and 10^{-5} dilutions prepared under total aerobic plate count, were separately plated along with 12 ml molten yeast and mould agar (YMA). Plating was done in duplicate. Plates were incubated at 28 ± 2^0C for 72 hours and CFU were determined (Nur Aida *et al*. 2007). Eight replicate samples were used per treatment.

Salmonella: A 2 g sample of bell pepper from each treatment was separately added to flasks containing 20 ml Selenite broth and incubated at 37^0C for 24 hours. A loopful from each treatment was sub cultured onto MacConkey agar medium. Plating was done in duplicate. Plates were incubated at 37^0C and examined for the presence of colorless colonies after 24 hours (Dharmabandu *et al*. 2007). Four replicate samples were used per treatment.

Statistical analysis: The experimental arrangement was a completely randomized design (CRD). Data obtained for sensory properties were subjected to Kruskal Wallis nonparametric statistical test whereas data with respect to physicochemical properties, gas analysis and microbial content were subjected to one-way ANOVA and the means were compared using Tukey's multiple comparison test. Statistical analysis was done using the MINITAB statistical package.

RESULTS AND DISCUSSION

The pH is dependent on the total quantity of acids as well as the strength of the acids present (Schmidl and Labuza 2000). A slight increase in pH values were observed in the present study (Table 1). According to Latifah *et al*. (2007) the pH of *Citrus reticulata* packed in polyethylene bags and stored at 10^0C indicated a slight increase by the end of the three week storage period. Even though statistical analysis indicated a significant ($p<0.05$) difference in TSS and TA during the 7 day storage between treatments and control when considering their variations within the same day the values were not very different to each other (Table 1). TSS reflects the sugar concentration of a fruit (Latifah *et al*. 2008). A gradual variation in TSS was observed in all treatments and control. Notably TSS from day 4 to 7 decreased for all treatments and control (Table 1). The decreasing trend is often relat-

ed to the components used as energy partly to carry on respiration and other metabolic functions (Latifah *et al*. 2008). According to Moretti *et al*. (2000) pH and TSS were not significantly affected in minimal processed bell pepper which were sanitized by NaClO (150mg/kg) and stored at 12±2^{0}C.

TA value, which is a quantitative measure of organic acids, decreases with senescence process (Latifah *et al*. 2008). Organic acids are used in respiration as a respiratory substrate with time after harvest (Mostofi *et al*. 2008). As in the present study the TA values decreased with increasing storage period in 'Shaif Abadi' apple which were maintained under modified atmospheres, packed in polyethylene and polypropylene containers (Mostofi *et al*. 2008).

Due to the physiological activity of the fresh-cut vegetables, an equilibrium atmosphere is generated within packages with low O_2 and moderately high CO_2 levels, the values of which will depend on the produce (Conesa *et al*. 2007). Similarly in the present research fairly high level of CO_2 accumulated in packages with bell pepper while O_2 level depleted (Table 2). There was no statistically significant change in O_2 level within all treatments and control or with time. Mechanical injuries such as cuts, impacts, compression and abrasion are associated with increase in CO_2 evolution in different vegetables (Moretti *et al*. 2000). However, CO_2 level decreased within packages with increasing storage time. Similarly according to Moretti *et al*. (2000) low temperature was able to reduce CO_2 evolution in both intact and minimally processed bell pepper. When comparing day 1 and 7, an increase in C_2H_4 level was observable with time in all treatments indicating a stress response (Table 2). Similarly the C_2H_4 level increased upto 7 days and subsequently decreased at 10^{0}C in minimally processed bell pepper according to Gonzalez-Aguilar *et al*. (2007).

Physical changes in relation to skin color which was recorded in numerical notation system as L*, a* and b*, where L* indicates lightness or darkness (0, black; 100, white),

Table 1: ANOVA results for effects of different pretreatments on physico-chemical characteristics of minimally

Storage time (days)			pH	
	T_1	T_2	T_3	T_4
0	$5.58^{a} \pm 0.03$	$5.63^{a} \pm 0.01$	$5.73^{a} \pm 0.06$	$5.72^{a} \pm 0.08$
2	$5.78^{a} \pm 0.18$	$5.58^{a} \pm 0.06$	$5.56^{a} \pm 0.04$	$5.84^{a} \pm 0.01$
4	$5.73^{a} \pm 0.05$	$5.75^{a} \pm 0.06$	$5.74^{a} \pm 0.05$	$5.94^{a} \pm 0.04$
7	$6.24^{a} \pm 0.05$	$6.14^{a} \pm 0.05$	$6.03^{a} \pm 0.06$	$6.15^{a} \pm 0.08$
			TSS (^{0} Brix)	
	T_1	T_2	T_3	T_4
0	$5.17^{ac} \pm 0.03$	$5.37^{a} \pm 0.12$	$3.97^{b} \pm 0.12$	$4.80^{c} \pm 0.12$
2	$5.00^{a} \pm 0.17$	$4.43^{ab} \pm 0.09$	$4.87^{ab} \pm 0.13$	$4.07^{b} \pm 0.29$
4	$5.80^{a} \pm 0.31$	$6.43^{a} \pm 0.56$	$5.63^{a} \pm 0.29$	$5.17^{a} \pm 0.26$
7	$4.30^{a} \pm 0.17$	$4.46^{a} \pm 0.33$	$4.43^{a} \pm 0.09$	$4.33^{a} \pm 0.33$
			TA (% Malic acid)	
	T_1	T_2	T_3	T_4
0	$0.14^{a} \pm 0.01$	$0.12^{ab} \pm 0.00$	$0.13^{ab} \pm 0.01$	$0.11^{b} \pm 0.01$
2	$0.13^{a} \pm 0.01$	$0.11^{ab} \pm 0.01$	$0.12^{ab} \pm 0.01$	$0.10^{b} \pm 0.00$
4	$0.12^{a} \pm 0.01$	$0.11^{a} \pm 0.01$	$0.12^{a} \pm 0.01$	$0.11^{a} \pm 0.01$
7	$0.09^{a} \pm 0.01$	$0.09^{a} \pm 0.01$	$0.09^{a} \pm 0.01$	$0.09^{a} \pm 0.01$

T_1 - 1% Sodium chloride, T_2 - 1% Calcium chloride, T_3 - 1% Sodium chloride + 1% Calcium chloride, T_4 - Distilled water

Each data point represents the mean of three replicates ± standard error.

Means sharing a common letter (s) within the same row are not significantly different by Tukey's multiple comparison test.

Table 2: Variation of gases within packages containing minimally processed bell pepper during storage at 8-10^{0}C

Storage time	Pre-treatment	O_2 %	CO_2 %	C_2H_4 µL/L
Day 1	NaCl	14.55^a	2.12^b	0.17^{ab}
	$CaCl_2$	14.68^a	1.79^{ab}	0.09^a
	NaCl + $CaCl_2$	14.18^a	1.64^{ab}	0.44^{ab}
	Control	13.53^a	0.95^{ab}	0.12^a
Day 2	NaCl	13.71^a	0.74^{ab}	0.23^{ab}
	$CaCl_2$	14.11^a	0.65^a	0.09^a
	NaCl + $CaCl_2$	12.96^a	1.11^{ab}	0.53^{ab}
	Control	14.33^a	0.84^{ab}	0.09^a
Day 3	NaCl	13.64^a	0.82^{ab}	0.36^{ab}
	$CaCl_2$	14.50^a	0.65^a	0.18^{ab}
	NaCl + $CaCl_2$	13.55^a	0.84^{ab}	0.50^{ab}
	Control	14.40^a	0.68^a	0.34^{ab}
Day 4	NaCl	13.50^a	0.83^{ab}	0.27^{ab}
	$CaCl_2$	14.79^a	0.64^a	0.16^{ab}
	NaCl + $CaCl_2$	14.56^a	0.61^a	0.36^{ab}
	Control	14.47^a	0.67^a	0.13^a
Day 7	NaCl	14.89^a	0.98^{ab}	0.85^{bc}
	$CaCl_2$	14.72^a	0.66^a	0.31^{ab}
	NaCl + $CaCl_2$	14.56^a	0.87^{ab}	1.54^c
	Control	15.13^a	0.70^a	0.87^{bc}

Each data point represents the mean of three replicates. Means sharing a common letter (s) within the same column are not significantly different by Tukey's multiple comparison test.

a* indicates the hue on a green to red axis (negative value, greenness; positive value, redness), and b* indicates hue on blue to yellow axis (negative value, blueness; positive value, yellowness) (Latifah *et al*. 2007). In the present research the L* values showed a declining trend indicating darkening (Table 3). Lowering of a* values indicated a slight loss of bright green color and lowering b* values indicated a slight decrease in yellowness.

Significant changes in firmness of bell pepper were observed with storage time in the present study but when considering the variation of values within the same day, they were quite similar to each other (Table 3). According to Dharmabandu *et al*. (2007) firmness of minimally processed *Solunum surattense* remained unchanged regardless of pre-treatments for

Table 3: Variation in Color and force of minimally processed bell pepper during storage at 8-10^{0}C.

Storage time	Pre-treatment	Color			Force (N)
		L	a	b	
Day 0	NaCl	36.75^{ab}	-16.14^{ab}	18.08^{ab}	1.28^{ac}
	$CaCl_2$	37.51^{ac}	-16.99^{ab}	20.50^{ab}	1.25^{ac}
	NaCl + $CaCl_2$	35.52^{ab}	-16.30^{ab}	19.05^{ab}	1.39^{abc}
	Control	36.97^{ab}	-16.72^{ab}	19.37^{ab}	1.37^{abc}
Day 2	NaCl	36.76^{ab}	-17.00^{ab}	19.05^{ab}	1.11^c
	$CaCl_2$	35.30^{ab}	-16.44^{ab}	18.85^{ab}	1.13^c
	NaCl + $CaCl_2$	36.40^{ab}	-17.51^{ab}	20.84^{ab}	1.16^{cd}
	Control	36.52^{ab}	-17.49^{ab}	20.91^{ab}	1.13^a
Day 4	NaCl	33.86^{bc}	-15.87^{ab}	17.98^{ab}	1.25^{ac}
	$CaCl_2$	36.19^{ab}	-17.31^{ab}	20.71^{ab}	1.42^{abc}
	NaCl + $CaCl_2$	32.97^b	-13.93^b	15.86^b	1.56^{abd}
	Control	38.32^a	-18.46^a	22.86^a	1.41^{abc}
Day 7	NaCl	34.47^{ab}	-15.53^{ab}	18.08^{ab}	1.60^{ab}
	$CaCl_2$	34.26^{ab}	-15.41^{ab}	18.18^{ab}	1.63^{ab}
	NaCl + $CaCl_2$	34.55^{ab}	-16.00^{ab}	18.55^{ab}	1.75^b
	Control	35.76^{ab}	-15.79^{ab}	18.38^{ab}	1.72^b

Each data point represents the mean of three replicates.
Means sharing a common letter (s) within the same column are not significantly different by Tukey's multiple comparison test.

the storage period of 7 days at 8^0C.

The decrease in sensory attributes for all commodities (Table 4) is quite unavoidable as they are living tissues. Similar results were obtained by Conesa *et al*. (2007) where the sensory attributes (visual appearance, color, aroma, flavor) evaluated during a storage period of 10 days decreased in minimally processed bell pepper, stored at 5^0C. However, in the present study overall acceptability was fairly acceptable (4.75-4.92) even after 7 days (Table 4), indicating the suitability of this commodity for processing minimally. According to the results sodium chloride treated samples were more successful in retaining their sensory properties by the end of the 7 day storage period than the other pretreated samples.

Table 4: Sensory properties of minimally processed bell pepper stored at 8-10^{0}C

Storage time	Pre-treatment	Appearance	Color	Odor	Flavor	Taste	Overall acceptability
Day 0	NaCl	6.83[a]	6.83[a]	6.83[a]	6.50[a]	6.50[a]	6.83[a]
	$CaCl_2$	6.83[a]	6.83[a]	6.67[a]	6.50[a]	6.50[a]	6.67[a]
	NaCl + $CaCl_2$	6.83[a]	6.83[a]	6.67[a]	6.67[a]	6.50[a]	6.67[a]
	Control	6.83[a]	6.83[a]	6.50[a]	6.17[a]	6.33[a]	6.50[a]
Day 7	NaCl	4.50[b]	4.58[b]	4.83[b]	4.83[b]	5.00[b]	4.92[b]
	$CaCl_2$	4.17[b]	4.42[b]	5.00[b]	4.67[b]	4.83[b]	4.75[b]
	NaCl + $CaCl_2$	4.33[b]	4.42[b]	4.50[b]	4.67[b]	4.50[b]	4.75[b]
	Control	4.33[b]	4.58[b]	4.83[b]	4.67[b]	4.67[b]	4.75[b]

(7 – Excellent, 6 – Very good, 5 – Good, 4 – Neither good nor bad, 3 – Bad, 2 – Very bad, 1 – Completely spoilt)
Each data point represents the mean of six replicates
Means sharing a common letter (s) within the same column are not significantly different by Kruskal Wallis non-parametric test.

Principally good sanitation and temperature management controls microbial growth on minimally processed products, whereas low temperature during and after processing generally retards microbial growth (Dharmabandu *et al*. 2007). According to Kang and Lee (1997), total microbial growth increased from 4.6-7.2 $\log_{10}$ CFU/g during the 6 day storage period for minimally processed green pepper stored at 5^0C. The legal regulations on minimally processed fresh vegetables establish a maximum total limit for TPC of 7.7 $\log_{10}$ CFU/g (Francis *et al*. 1999) and the recommended limit for TYM of fresh cut produce is 5 $\log_{10}$ CFU/g (Nur Aida *et al*. 2007). Since the microbial counts in the present study did not exceed these recommended values by day 7 (Table 5), bell pepper can be considered as safe to consume. The absence of *Salmonella* in pretreated bell pepper samples also indicates the suitability of this commodity for minimal processing and the processing conditions adopted. Similar results were obtained by Dharmabandu *et al*. (2007) for minimally processed *Solunum surattense* for a storage period of 7 days at 8^0C.

In the present research, sodium chloride treated samples recorded the lowest total plate count and yeast and mould count by day 7 (Table 5). Previous research has shown that washing with 0.5% - 1% $CaCl_2$ reduced microbial growth on various commodities (Hui *et al*. 2006). Sodium chloride and calcium chloride concentrations between 1% - 4% are commonly used as pretreatments. When sodium chloride and calcium chloride is incorporated as a pretreatment, high osmotic pressure results in plasmolysis of microbial cells which dehydrate and inhibit growth. Moreover, the chloride ion is toxic to microbes (Hui *et al*. 2006). Calcium was also found to be effective in quality retention of fresh-cut fruit. Wounding that occur during preparation of fresh cut fruit, among others cause disassembly of the pectin matrix, which is also mediated by the action of pectic enzymes. This wounding may increase the level of pectic enzymes. Due to possible role of Ca in protecting the pectic backbone from the enzymes, it was found to

maintain the freshness of various types of cut fruits e.g., cantaloupe, honeydew, mango and strawberries (Chuni *et al*. 2010).

Table 5: Microbiological properties of minimally processed bell pepper during storage at 8-10^{0}C.

Treatment	Day 0		Day 7	
	Total plate count (Log_{10} CFU/g)	Yeast and mould count (Log_{10} CFU/g)	Total plate count (Log_{10} CFU/g)	Yeast and mould count (Log_{10} CFU/g)
NaCl	$4.94^a \pm 0.13$	$2.66^a \pm 0.00$	$4.99^a \pm 0.13$	$0.00^a \pm 0.00$
$CaCl_2$	$5.02^a \pm 0.06$	$1.81^a \pm 1.81$	$5.08^a \pm 0.01$	$1.33^a \pm 1.33$
NaCl + $CaCl_2$	$4.90^a \pm 0.07$	$1.33^a \pm 1.33$	$5.16^a \pm 0.07$	$1.33^a \pm 1.33$
Control	$5.62^a \pm 0.51$	$0.00^a \pm 0.00$	$5.36^a \pm 0.07$	$1.48^a \pm 1.48$

Each data point represents the mean of eight replicates ± standard error.
Means sharing a common letter (s) within the same column are not significantly different by Tukey's multiple comparison test

CONCLUSION

Any drastic effects of pretreatments on the physicochemical or sensory properties of bell pepper were not evident during the survey. The pretreatments in combination with MAP and cold temperature maintained the microbial content within the packages under safe to consume level. Therefore these products could be recommended for the local market to be sold at supermarket chains where cold storage facility is available. Sodium chloride (1% w/v) can be suggested as a more suitable pretreatment due to its ability to maintain lower microbial counts and high sensory properties compared to the other treatments and control.

ACKNOWLEDGMENTS

We acknowledge the financial assistance by University of Kelaniya, Sri Lanka and research support provided by Zainab, Kamal, Khairul, Arzlie at MARDI, Malaysia.

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