

Effect of different post-harvest treatments on quality of minimally processed long bean (*Vigna unguiculata* var. *Sesquipedalis*)

[Kesan pelbagai perlakuan lepas tuai terhadap kualiti kacang panjang (*Vigna unguiculata* var. *Sesquipedalis*) yang diproses secara minimum]

M. Razali* and M. Habsah*

Key words: minimally processed, long bean (*Vigna unguiculata* var. *Sesquipedalis*), post-harvest treatments, physical and chemical changes, carbon dioxide concentration, ethylene production

Abstrak

Kacang panjang (*Vigna unguiculata* var. *Sesquipedalis*) yang diproses secara minimum telah diberi perlakuan lepas tuai iaitu kawalan (tanpa perlakuan), 1% kalsium klorida (CaCl_2), 1% asid askorbik (AA; $\text{C}_6\text{H}_8\text{O}_6$), 1% kalsium laktat (CaLac; $\text{C}_3\text{H}_6\text{O}_3 \cdot 1/2\text{Ca}$), 1% $\text{CaCl}_2 + 1\%$ AA dan 1% $\text{CaCl}_2 + 1\%$ CaLac. Terdapat beberapa perubahan fisiologi pada kacang panjang yang diproses secara minimum yang disimpan pada suhu 2 °C. Hasil dinilai setiap 3 hari penyimpanan. Penilaian mutu merangkumi perubahan fizikal, kimia, kepekatan CO_2 dan pengeluaran etilena. Apabila suhu persekitaran dikekalkan pada suhu rendah (0 °C), mutu kacang panjang yang diproses secara minimum masih dalam keadaan baik selepas disimpan dalam tempoh penyimpanan yang tertentu (2 minggu).

Pemrosesan minimum kacang panjang yang telah diberi perlakuan 1% AA menunjukkan nilai yang terendah bagi kehilangan berat (0.037%), jumlah asid tertitrat (JAT–0.156%) dan kadar pengeluaran etilena (C_2H_4 -0.116 $\mu\text{L C}_2\text{H}_4/\text{kg}/\text{jam}$) berbanding dengan perlakuan lain. Walau bagaimanapun, kandungan AA menunjukkan nilai yang tinggi (7.263 mg/100 g), manakala pH dan kepekatan CO_2 adalah sedikit tinggi, masing-masing 5.16 dan 0.572% berbanding dengan perlakuan lain. Terdapat perbezaan ketara ($p < 0.05$) bagi pH, JAT dan kepekatan CO_2 bagi kacang panjang yang diberi perlakuan lepas tuai yang berbeza semasa tempoh penyimpanan. Pemrosesan minimum kacang panjang yang diberi perlakuan 1% AA merupakan perlakuan lepas tuai yang tidak melibatkan pemerangan enzimatik dan juga baik dari segi kualitinya. Terdapat juga perbezaan bererti ($p < 0.05$) terhadap semua parameter bagi kacang panjang yang diproses secara minimum semasa tempoh penyimpanan.

Abstract

Different post-harvest treatments were evaluated on the minimally processed (MP) long bean (*Vigna unguiculata* var. *Sesquipedalis*) i.e. control (without treatment), 1% calcium chloride (CaCl_2), 1% ascorbic acid (AA; $\text{C}_6\text{H}_8\text{O}_6$), 1% calcium lactate (CaLac; $\text{C}_3\text{H}_6\text{O}_3 \cdot 1/2\text{Ca}$), 1% $\text{CaCl}_2 + 1\%$ AA, and 1% $\text{CaCl}_2 + 1\%$ CaLac. Some physiological changes occurred on MP long bean during

*Horticulture Research Centre, MARDI Headquarters, Serdang, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia
Authors' full names: Razali Mustaffa and Habsah Mohamad

E-mail: razally@mardi.my

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storage at 2 °C. The product was evaluated at 3 days storage interval. Quality observation was based on physical and chemical changes, rate of respiration and ethylene production. When the storage temperature (2 °C) was maintained at lower level (0 °C), the quality of MP long bean still remained good after being stored at certain storage period (2 weeks). The MP long bean treated with 1% AA showed lowest in percentage weight loss (0.037%), total titratable acidity (TTA; 0.156%) and ethylene (C₂H₄) production rate (0.116 µL C₂H₄/kg/h), compared to other treatments. However, the ascorbic acid (AA) content was highest (7.263 mg/100 g) and the pH and CO₂ concentration were slightly higher, 5.16 and 0.572%, respectively for the MP long bean treated with 1%AA compared to other treatments. There were significant differences ($p < 0.05$) observed in pH, TTA, AA and CO₂ concentration of MP long bean with different post-harvest treatments during storage period. Minimally processed long bean treated with 1% AA was not affected by enzymatic browning and showed better quality. There were also significant differences ($p < 0.05$) in all parameters of MP long bean with duration of storage.

Introduction

Consumers are increasingly asking for convenient, ready-to-use and ready-to-eat fruits and vegetables with fresh-like quality, containing only natural ingredients (Lund 1989). Control of browning in minimally processed (MP) vegetables and fruits has drawn a great deal of researchers' attention because of its importance to the food processing industry. Browning reactions in vegetables and fruits become evident when, for instance, food material is subjected to processing or to mechanical injury (Laurila et al. 1998). A combination of controlled atmosphere packaging and/or firming agents like calcium salts has been reported to successfully retard texture softening (Ponting et al. 1972; Poovaiah 1986; Rosen and Kader 1989; Gorny et al. 1998). Minimal processing usually increases the degree of perishability, causes disruption of cell tissue and breakdown of cell membranes; increases the respiratory rate (Wong et al. 1994), ethylene production (Gordon 1992), surface dehydration and total moisture loss (Barry-Ryan and O'Beirne 1998) and limits their shelf life (Lownds et al. 1994). Suitable storage temperature and types of packaging are important factors in maintaining the quality

and extending shelf life of MP vegetables (Osornio and Chaves 1998).

A long-standing goal of food technology has been to find effective substitutes to prevent cut surface browning in order to extend the shelf life of fresh produce (Dong et al. 2000). Numerous potential browning inhibitors have been tested on fresh-cut fruits and vegetables. Ascorbic acid (AA) and its isomer, erythorbic acid (Ponting et al. 1972; Sapers and Ziolkowski 1987) have been reported to be effective browning inhibitors for fresh-cut apples. Minimally processed fruits and vegetables are vulnerable to discoloration because of damaged cells and tissues, and lack of protective skin. These exposed tissues have the potential of becoming dehydrated and/or discoloured (Watada and Ling 1999). Before carving a sustained niche in the market place, fresh produce processors must solve a series of challenging problems. One of the foremost is shelf life. Because of the minimal processing treatment, quality factors such as appearance, texture, and flavour are not stabilized and product deterioration may proceed rapidly (Huxsoll et al. 1989). Shelf life is minimal even with refrigeration.

The objective of this study was to evaluate the effect of different post-harvest

treatments on quality of minimally processed long bean during storage period at 2 °C. Quality evaluations were based on the physical and chemical changes, the rate of respiration and ethylene production. Physiological behaviour was also monitored during the storage study. Temperature surrounding the products was also monitored to relate with quality.

Materials and methods

Handling operations

Long bean (*Vigna unguiculata* var. *Sesquipedalis*) harvested at commercial maturity used in this study were bought at the wholesale market in Selangor. Samples were brought to the Minimal Processing Laboratory (MPL) at MARDI, Serdang. Upon arrival at the MPL, samples were sprayed and washed with chlorinated water to remove dirt, fungicide residue and also to reduce microbial populations before cutting. Samples were sorted and selected to remove the physiological defects and/or off-cut pieces. Only samples that were free from mechanical injuries were used in this study. Samples were cut into 3–4 cm trimmed form and then immersed in chilled water containing different post-harvest treatments, i.e. control (without treatment), 1% calcium chloride (CaCl₂), 1% ascorbic acid (AA; C₆H₈O₆), 1% calcium lactate (CaLac; C₃H₆O₃·1/2Ca), 1% CaCl₂ + 1% AA, and 1% CaCl₂ + 1% CaLac for about 1–2 minutes. Samples were dip-dried to free the excess water before packing. The cut samples were packed in 500 mL round-shaped polypropylene (PP) container and then stored at chill condition (2 °C). Sample was evaluated every 3 days and three containers from each treatment were used for triplicates.

Physical and chemical analyses

Physical appearances (colour, texture, taste and odour) were observed visually. The percentage weight loss of the cut long bean sample was obtained by measuring the difference in weight before and after storage.

Analyses of the chemical parameters were carried out on the same day after taking the weight loss. Samples for the chemical analyses were blended. The pH value was measured using an Orion digital pH meter (model SA 520) and total titratable acidity (TTA) was determined by titrating the known volume of homogenates solution with 0.1N NaOH to an end point of pH 8.1 using digital burette (Shaw et al. 1987). The AA content was determined by titrating with 2,6-dichlorophenolindophenol (Ranganna 1977). Experiments were performed in triplicates.

Gases in the package

Measurement of the gases (CO₂ and C₂H₄) was taken at every 3 days interval. The gas samples were measured using a closed system. A syringe through a septum in the package drew the gases. One milliliter of the C₂H₄ gas sample was injected into a Perkin Elmer Auto System_XL gas chromatography fitted with flame ionization detector (FID) and a stainless steel column packed with Porapak T of 100/120-mesh size. Simultaneously, CO₂ was detected using a different detector (thermal conductivity detector; TCD) with a stainless steel column packed with Porapak R of 80/100-mesh size. The flow rate of the purified helium gas was 30 mL/min and the column oven was operated at 50 °C and 100 °C for CO₂ and C₂H₄ gases, respectively. Helium was also used as a carrier gas at the same flow rate and the injector temperature was 35 °C. Three replications were used for each experiment.

Statistical analysis

Experiment was designed by using split-plot design. For data analyses, the Statistical Analysis System programme was used (SAS Institute 1985). The values obtained were subjected to analyses of variance and tested using the Least Significant Difference (Gomez and Gomez 1984).

Results and discussion

Minimally processed long bean started to turn brown at the cutting surface, change in colour, become soft and soggy, off-odour and off-flavour after 15 days (2 weeks) of storage for all samples. The reduction in quality started from the seed that was higher in nutrients and humidity as compared to the pod of long bean. There were significant differences ($p < 0.05$) among the post-harvest treatments on pH, TTA, AA, and CO₂ concentration of MP long bean stored at 2 °C. According to Krahn (1977) and Bolin and Huxsoll (1991), when products are stored at low temperatures, browning can be controlled successfully. However, there was no significant difference ($p > 0.05$) among the post-harvest treatments on percentage weight loss and C₂H₄ production rate of MP long bean stored at 2 °C (Table 1).

There was a significant difference ($p < 0.05$) in percentage weight loss of MP long bean with different post-harvest treatments during storage period at 2 °C (Figure 1a). The percentage weight loss of MP long bean treated with 1% AA was lower (0.037%) and similar to the 1% CaLac (Table 1), however, there was no significant difference ($p > 0.05$) among all the treatments. The percentage weight loss of

MP long bean without treatment (control) showed an increasing trend with duration of storage at 2 °C compared to other treatments where it decreased at the early storage until day 6 (0.037%) and started to increase until the end of storage period (Figure 1).

According to Luna-Guzman and Barret (2000), weight loss tends to decrease when sample is dipped in CaCl₂. A similar trend was reported on MP long bean with different forms of cutting stored at 2, 5, 10, 15 and 25 °C (Razali et al. 2000), on MP cabbage stored at 2, 5, 7, 10, 15 and 25 °C (Razali et al. 2001), and on carrot shreds stored at 0, 5 and 10 °C (Izumi and Watada 1994). According to Grierson and Wardowski (1978), water loss reduces the saleable weight and also can reduce senescence of the product.

The result from Figure 1 showed that at the early storage, the percentage weight loss was lower (-0.077 to -0.013%) at day 3, and then slightly decreased (-0.073 to -0.100%) at day 6. The negative values may be due to several factors such as absorption of water by using ‘supersorb’ in packaging; CaCl₂ treatment after cutting which is hygroscopic; and condensation of water after storage at low temperature. The percentage started to increase at day 9

Table 1. Changes in the percentage weight loss, pH, total titratable acidity, ascorbic acid content, and C₂H₄ production rate and CO₂ concentration of minimally processed long bean from different post-harvest treatments after 2 weeks storage at 2 °C

Post-harvest treatments	Weight loss (%)	pH	Total titratable acidity (%)	Ascorbic acid (mg/100 g)	Ethylene production rate (µL C ₂ H ₄ /kg/h)	CO ₂ concentration (%)
Control (No treatment)	0.059a	5.11a	0.158c	3.033c	0.436a	0.563a
1% CaCl ₂	0.056a	5.06b	0.167ab	5.536b	0.353a	0.585a
1% Ascorbic acid	0.037a	5.16a	0.156c	7.263a	0.116a	0.572ab
1% Calcium lactate	0.037a	5.16a	0.159c	4.712b	0.174a	0.476ab
1% CaCl ₂ + 1% Ascorbic acid	0.131a	5.05b	0.173a	6.443a	0.206a	0.399b
1% CaCl ₂ + 1% Calcium lactate	0.126a	5.19a	0.164bc	5.554b	0.149a	0.402ab
LSD _{0.05}	ns	0.03	0.01	0.87	ns	0.184

Each value was the mean of three replicates. Means with the same letter are not significantly different ($p < 0.05$) according to Least Significant Difference (LSD)

ns = not significant

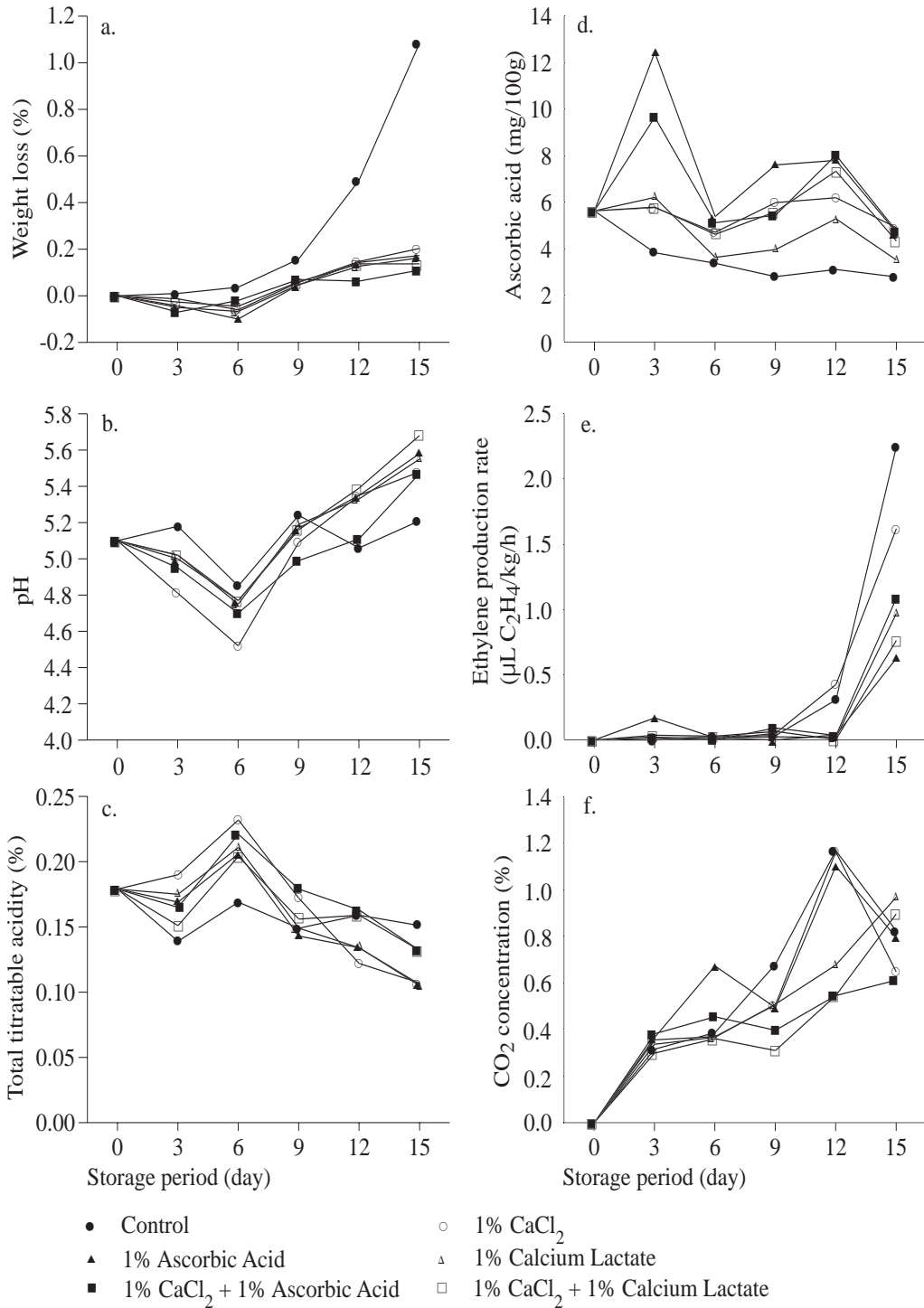


Figure 1. Effects of different post-harvest treatments on the physical and chemical changes of minimally processed long bean stored at 2 °C during storage period

(0.047 to 0.07%) until the end of storage period (0.063 to 0.203%). Lownds et al. (1994) reported that water loss of nine chili cultivars reduces with the reduction of storage temperature. They also mentioned that the packaging could also reduce water loss rate 20 times or more at each storage temperature.

The pH value of MP long bean with different post-harvest treatments was significantly different ($p < 0.05$) during storage period at 2 °C (*Figure 1b*). However, the pH value among the 1% AA, 1% CaLac, 1% CaCl₂ + 1% CaLac, 1% AA + 1% CaLac treatments and control was not significantly different ($p > 0.05$) compared to 1% CaCl₂ + 1% AA (*Table 1*). The pH of MP long bean treated with 1% AA was slightly higher (5.16) compared to control (5.11), 1% CaCl₂ (5.06) and 1% CaCl₂ + 1% AA (5.05). During the storage period, the pH changed slightly (*Figure 1b*) and the trend was similarly reported by Carlin et al. (1989) on grated carrot, and cut lettuce (King et al. 1991) and salad-cut lettuce (Bolin and Huxsoll 1991). The pH value of MP long bean treated with 1% AA was decreasing at the early storage until day 6 (4.77) and started to increase gradually until the end of storage period, day 15 (5.58). The increment rate was not predicted.

At low temperature storage (2 °C), pH is not negatively correlated with titratable acidity (Mohamed and Ahmad Khir 1993). A similar result was also observed in other treatments (*Figure 1b*). According to Izumi and Watada (1994), pH value of carrot shreds shows gradual decreasing trend during storage at 0, 5 and 10 °C. The decreasing of pH value has contributed to reduce bacterial spoilage (Izumi and Watada 1994).

The TTA of MP long bean with different post-harvest treatments also showed significant difference ($p < 0.05$) during storage period (*Figure 1c*). The TTA was lowest (0.156%) for MP long bean treated with 1% AA compared to control (0.158%) and other post-harvest treatments

(*Table 1*). However, the TTA of 1% CaCl₂ + 1% AA was highest (0.173%) compared to other treatments. The TTA of 1% AA has increased at the early storage until day 6 (0.206%), and then started to decrease until the end of storage period, day 15 (0.106%). A similar result was also observed on MP long bean treated with other treatments. In most cases, the concentration of TTA tends to decline during post-harvest storage (Wills et al. 1981; Kays 1991).

The ascorbic acid (AA) content showed significant difference ($p < 0.05$) on MP long bean with different post-harvest treatments during storage period at 2 °C (*Figure 1d*). There was significant difference ($p < 0.05$) among the post-harvest treatments of MP long bean stored at 2 °C (*Table 1*). The AA content of MP long bean treated with 1% AA was highest (7.263 mg/100 g) compared to other treatments (*Table 1*). However, the content changed slightly (*Figure 1d*) where it increased at the early storage, day 3 (12.436 mg/100 g) and decreased at day 6 (5.391 mg/100 g). Then it increased to 7.800 mg/100 g at day 12 and decreased to 4.712 mg/100 g at the end of storage period. The trend fluctuated until the end of storage. The loss of AA depends on storage temperature rather than on the length of storage period (Adisa 1986). Reduction in ascorbic acid content is always associated with the increase in surface browning (Wong et al. 1994).

The ethylene (C₂H₄) production rate (*Figure 1e*) and CO₂ concentration (*Figure 1f*) of MP long bean showed an irregular pattern with duration of storage at 2 °C for all post-harvest treatments. There was a significant difference ($p < 0.05$) in ethylene production rate of MP long bean with different post-harvest treatments during storage period at 2 °C (*Figure 5*). However, among the treatments, the C₂H₄ rate was not significantly different ($p > 0.05$) (*Table 1*). The C₂H₄ rate of 1% AA of MP long bean stored at 2 °C increased at day 3 (0.019 µL C₂H₄/kg/h) and decreased at day 9 (0.001 µL C₂H₄/kg/h). However, the rate started to

increase (0.038 $\mu\text{L C}_2\text{H}_4/\text{kg/h}$) at day 12 until the end of storage period, day 15 (0.625 $\mu\text{L C}_2\text{H}_4/\text{kg/h}$). The increase in ethylene rate was due to the stimulation of CO_2 through the induction of 1-aminocyclopropane-1-carboxylate (ACC) synthase and ACC oxidase activities.

This result was supported by Mathooko et al. (1998). Similar trend was also observed in other treatments where there was an irregular pattern during storage period (*Figure 1e*). The increases in ethylene production rate, as well as other reactions associated with wounding are common when fresh product is processed at low temperature (Bretcht 1996). The ethylene can also accumulate in seal packaging and cause undesirable quality of products (Abe and Watada 1991). The sample treated with 1% AA was lowest (0.116 $\mu\text{L C}_2\text{H}_4/\text{kg/h}$) compared to other treatments (*Table 1*).

During the storage period at 2 °C, the CO_2 concentration of MP long bean with different post-harvest treatments was significantly different ($p < 0.05$). The CO_2 concentration of MP long bean treated with 1% AA was increased until day 6 (0.673%) and then decreased at day 9 (0.494%). The rate started to increase at day 12 (1.101%) and decreased at the end of storage period, day 15 (0.796%). According to Bretcht (1996), the increases in CO_2 concentration, as well as other reactions associated with wounding, are therefore minimized when the fresh product is processed at low temperature. The production of CO_2 of MP long bean with ring form shows an irregular pattern with duration of storage at 2, 5, 10, 15 and 25 °C (Razali et al. 2000). The increase in the respiration rate reflects the defence mechanism being triggered by the wounding tissue of the minimally processed product (Rolle and Chism 1987). The CO_2 concentration of MP long bean treated with 1% AA was slightly higher (0.572%) and not significantly different ($p > 0.05$) with control (0.563%) (*Table 1*).

The increase in the respiration rate of minimally processed product is thought to

be a consequence of elevated ethylene, which stimulates respiration (Bretcht 1996). However, the CO_2 concentration of 1% $\text{CaCl}_2 + 1\%$ AA was lowest (0.399%) compared to other treatments. Storage under refrigeration helps to maintain the quality and reduces respiration rate and decay (Gil et al. 1998). According to Brorenstein (1987) and Sapers and Ziolkowski (1987), AA and its isomer, erythorbic acid, inhibit browning in various fruits and vegetables. Sapers et al. (1987) reported that AA derivatives are effective against product browning.

Conclusion

Maintaining the quality of minimally processed (MP) long bean with different post-harvest treatments at proper temperature (2 °C) is considered as primary goal for the success of the food processing industry. The quality of MP long bean treated with different post-harvest treatments were significantly different ($p < 0.05$) in the percentage weight loss, pH, total titratable acidity (TTA), ascorbic acid (AA) content, rates of ethylene production and respiration during storage period at 2 °C. There were significant differences ($p < 0.05$) among the post-harvest treatments on pH, TTA, AA content and CO_2 concentration of MP long bean. Minimally processed long bean treated with 1% ascorbic acid (AA) was a suitable treatment to reduce browning and prolong storage life with better quality in appearances (colour, texture, taste and odour) until the end of storage period (day 15). In this treatment, the percentage weight loss, TTA and ethylene production rate were lower but AA content was highest compared to other treatments. The changes in the physiological behaviour and the physical and chemical characteristics were due to the limitation for prolonged storage life.

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