

The Quality Maintenance and Extending Storage Life of Mango Fruit after Postharvest Treatments

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Abstract—The quality attributes and storage life of ‘Jinhwang’ mango fruit can be effectively maintained with 1-methylcyclopropene (1-MCP) application and/or chitosan coating. ‘Jinhwang’ mango fruit was treated with $5 \mu\text{l l}^{-1}$ 1-MCP for 12 h, dipped with 0.5 % chitosan, $5 \mu\text{l l}^{-1}$ 1-MCP combine with 0.5 % chitosan and untreated (control) then stored at 10°C . Mango treated with 1-MCP maintained firmness, sucrose and starch content. Chitosan coating delayed firmness loss, sucrose content and the fruit decay when compare with control. Application of 1-MCP combine with chitosan also delayed firmness loss, sucrose content and starch content during storage. Furthermore, chitosan coating and combine treatment prolonged storage life of mango up to 29 days after storage while 1-MCP extended to 28 days after storage. Therefore, using all application of chitosan coating or 1-MCP combine with chitosan or 1-MCP in mango at 10°C is a feasible technology for maintains quality and prolongs storage life in order to expand marketability and export options.

Keywords—1-Methylcyclopropene (1-MCP), chitosan, quality, storage life

I. INTRODUCTION

MANGO (*Mangifera indica* L.) is tropical fruit and contains vitamins, minerals and fiber which is essential to human health and export market [1].

‘Jinhwang’ mango is classifies as climacteric fruit and show rapidly deterioration after harvest due to ripening and senescence [2]. Additionally, desiccation of mango during transportation, storage and the shelf life period causes its shriveling and reduces the market value of the fruit [3]. In this regard, development of postharvest technology related to quality maintenance and extending the postharvest life are an important to consumer acceptability and marketing consideration for export options [4, 5]. Application of 1-MCP or C_4H_6 is an ethylene action inhibitor, a non-toxic mode of action, with negligible residue [6], colourless and a volatile, odorless gas [7]. Consequently, It is safe to use on humans, animals, the environment including ornamentals and edible horticultural products [6, 7]. 1-MCP has reported to prolong the storage life of apricots [8] and banana [9], and delayed firmness, TSS and TA of sapodilla [4].

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Furthermore, chitosan is a cationic polysaccharide derives from chitin [10] and it is use in preservative coating for fresh fruit due to its excellent film-forming and biochemical properties [11]. The coating is also safe and has prolonged storage life and controlled the decay of many fruits such as litchi [12], strawberry [13] and mango [14]. Therefore, the application of 1-MCP, chitosan coating and combine treatment are crucial to maximize profit for agricultural businesses and provide a quality consumer product for export including reduce postharvest loss, increase value-added crop and crop quality improvement leading to better life of farmers and entrepreneurs. The objective of this study was to evaluate the effects of 1-MCP, chitosan coating and 1-MCP combine with chitosan treatment on ripening inhibition, and increasing the storage life and quality of ‘Jinhwang’ mango fruit during storage under an optimum temperature condition at 10°C , however holding at this temperature, mango did not sensitive to chilling injury (CI) symptoms during storage under low temperature.

II. MATERIALS AND METHODS

A. Plant material

Mango fruit cv. Jinhwang (*M. indica* L.) was harvested as the commercial maturity about 130 days after anthesis (DAA) from an orchard in Pintung, Taiwan. The fruit were then transported to NPUST. After grading for uniform size and shape, the fruit were treated with $5 \mu\text{l l}^{-1}$ 1-MCP, 0.5% chitosan, $5 \mu\text{l l}^{-1}$ 1-MCP combine with 0.5 % chitosan and untreated (control). Fruit qualities were evaluated at 5 day intervals during storage.

B. 1-MCP treatment

Mango was placed in a 137.2 L plastic container and fumigated with $5 \mu\text{l l}^{-1}$ 1-MCP (Ansip, Lytone Enterprise, Inc, Taiwan) for 12 h at 25°C . The 1-MCP powder was placed inside the flask with a rubber septum. Then distilled water was added into the flask for dissolving. The flask was then placed inside the container through the top opening and the flask lid removed immediately before completely sealing the container. Twelve hours later, the lid of the container was opened and the fruit was then stored at 10°C for 30 d. The modified method followed the procedure used by Alves *et al.* [15].

C. Chitosan coating method

The chitosan was prepared using the method of Jiang *et al.* [12]. The 0.5% or 5 g of chitosan powder (chitosan from shrimp shells, Sigma Chemicals) was dissolved with 50 ml of glacial acetic acid and 850 ml distilled water.

The pH of chitosan solution was adjusted to pH 5.0 with 1 M NaOH.

D. Quality attributes

Weight loss was measured by the difference between the initial and final weight of each replication. It was expressed as percent (%) using the following equation:

$$\% \text{ Weight loss} = \frac{(\text{Initial weight of fruit} - \text{Final weight of fruit}) \times 100}{\text{Initial weight of fruit}}$$

Fruit firmness was measured using a Shimadzu EZ test and a 0.5 mm-diameter plunger set to pierce 1-cm depth. Readings were taken in three positions of fruit area, averaged and recorded in newtons (N).

Total soluble solids (TSS) was measured by direct readings of mango juice using a digital hand refractometer (Atago Pocket refractometer PAL-1) with results expressed in °Brix. Measurements were taken from three pieces of the ventral shoulder, middle and beak of the fruit slice.

Titrateable acidity (TA) were measured from 10 g of mango pulp, homogenized with 100 mL of deionized water at speed 2 for 30 s with an homogenizer (model Heidolph DIAx 900). The homogenate was filtered using a Whatman No. 1 filter paper. Twenty five mL of solution was drawn from the filtrate in a titrateable acid cup using a pipette. TA and pH were measured using a Titrator Mettler Toledo model DL53 and TA was expressed as a percentage (%) of citric acid following the procedure of Chen [16]. Soluble sugars (sucrose, fructose, glucose) were measured from 1 g of mango mesocarp tissues with 5 mL of deionized water using a 1:5 tissue-to-deionized water ratio were ground in a chilled mortar and pestle. The homogenates were centrifuged at 12,000 x g for 10 min in a cooling centrifuge at 4°C by using a high-speed micro centrifuge (model Hitachi Himac CF 15RX). Syringes were used to inject the filtrate into solution through PVDF microfiltration membrane (hydrophilic PVDF, 0.22 µm pore size) (model Millipore Millex-GV). A 10-fold dilution of the soluble sugar solution (0.1 mL the soluble sugar solution with 0.9 mL of deionized water) was prepared. The solution (0.1 mL) was injected using a smaller syringe through a rubber septum in the Sugar Analyzer (model DKK-TOA SU-300 Version 1.4) following the procedure as modified from Wang [17]. Soluble sugar contents were expressed as mg g⁻¹ fresh weight (mg g⁻¹fw). Starch content was measured from about 0.05 g of dried mango sample which was dried by using a Freeze Dryer FD-series was added to 5 mL of deionized water and shaken at 120 rpm, 30°C for 3 h. Then the solution was centrifuged at 12,000 x g for 10 min (25°C) and the residue retained. The residue was dried in precision ovens at 70°C for 12 h. Then, 1 mL of deionized water was added in a centrifuge tube and boiled in hot water bath for 15 min. After cooling, 1 mL of 9.2 N HClO₄ (perchloric acid) was added in a centrifuge tube and shaken at 150 rpm, for 15 min. After that the solution was centrifuged at 5000 x g, 25°C for 10 min. Then 20 µl of supernatants was added, plus 0.5 mL of 5% phenol and 2.5 mL of H₂SO₄ to each tube and left for 30 min. The solution was measured at a wavelength 490 nm following the procedure as modified from Dubois *et al.* [18] and Sadasivam and Manickam [17] with glucose as the standard. Starch was expressed as percent dry weight (%DW).

Electrolyte leakage (EL) measurement was modified by the method of Suwapanich and Haewsungcharern [20] and Fan and Sokorai [21]. Twelve mesocarp tissue plugs (5 mm diameter x 10 mm length) were excised from fresh-cut slices using a No. 5 brass cork borer. The mesocarp plugs were cleaned of damaged cells by rinsing gently with 70 ml deionized water for 3 seconds then incubated in 30 ml solution of 0.7 M mannitol for 3 h (25°C). Thereafter, the electrical conductivity of the solution was measured by using a Conductivity meter (Suntex model SC-23000) as an initial reading. Total electrolytes were determined after freezing at -20°C, thawing, and re-warming to room temperature. EL was expressed as a percentage (%) of the conductivity of total tissue electrolytes and calculated from the following equation:

$$\% \text{ EL} = \frac{\text{Initial conductivity}}{\text{Total conductivity}} \times 100$$

Fruit decay was scored on a scale 1 to 9 based on the incidence of anthracnose caused by *Giosporiodise* sp. and stem-end rots caused by infected fruit using the method of Silva *et al.* [22] as 9 = absence of dark spots, skin colour alterations and/or lesions; 8 = 1-3 % very light dark spots; 7 = 4-6 % of light dark spots; 6 = 7-10 % of light dark spots; 5 = 11-25 % of light dark spots and/or very light lesions; 4 = 26-40 % of dark spots, skin colour alterations and/or lesions; 3 = 41-60 % of dark spots, severe lesions and skin colour alterations; 2 = 61-75 % of dark spots, severe lesions and skin colour alterations and 1 = more than 75 % of dark spots and very sever lesions.

E. Storage life

Storage life was measured at the completely ripened stage or at the limit of acceptability and was expressed in days. The fruit was considered ripened when their skin was completely yellow ($h^{\circ} \leq 100$). The limit of acceptability was determined by fruit appearance; fruit showing visible wilting, the rest for disease incidence and severity with each fruit was considered unsuitable for consumption.

F. Statistical analysis

The experiment was laid out using a completely randomized design (CRD). Three replicates per treatment were evaluated for fruit quality and storage life. The data were analyzed using an Analysis of Variance (ANOVA). Where possible, mean comparisons were made using the Duncan's multiple range tests (DMRT) at $p \leq 0.05$. Statistical analysis was carried out using the SAS system.

III. RESULTS AND DISCUSSION

A. Quality attributes

Weight loss of mango increased during storage (Fig. 1A). Application of 1-MCP, chitosan coating and 1-MCP combine with chitosan treatment did not significantly different in weight loss from the control (untreated) during storage at 10°C.

The increase of weight loss because reduced metabolic activity produces a decrease in the respiration rate, which, in turn, results in lower rates of weight loss [15] and moisture evaporation through the skin. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere and the storage temperature [13]. Similar results indicated in Chaiprasart and Hansawasdi *et al.* [23] who report that 1-MCP application did not affect weight loss of mango and Ratanachinakorn *et al.* [24] showed that chitosan coating did not affect in pummelo.

Firmness decreased during storage (Fig. 1B). Mango treated with 1-MCP, 1-MCP combine with chitosan coating and chitosan coating delayed firmness loss compared to control after 20 d storage at 10°C. The reduction of firmness due to enzymatically mediated degradative changes in the cell walls during ripening. The enzymes are pectinesterases and polygalacturonases may be either synthesized, activated, or a combination of both, at or near the onset of the ripening process [25]. The results were in accordance with previous studies in which chitosan, 1-MCP and 1-MCP combine with chitosan delayed the decline of firmness compared to control in Indian jujube fruit [10]. Similar results supported in several fruits of sapodilla [4], apricots [8], mango [2, 15, 26], banana [9] and papaya [11].

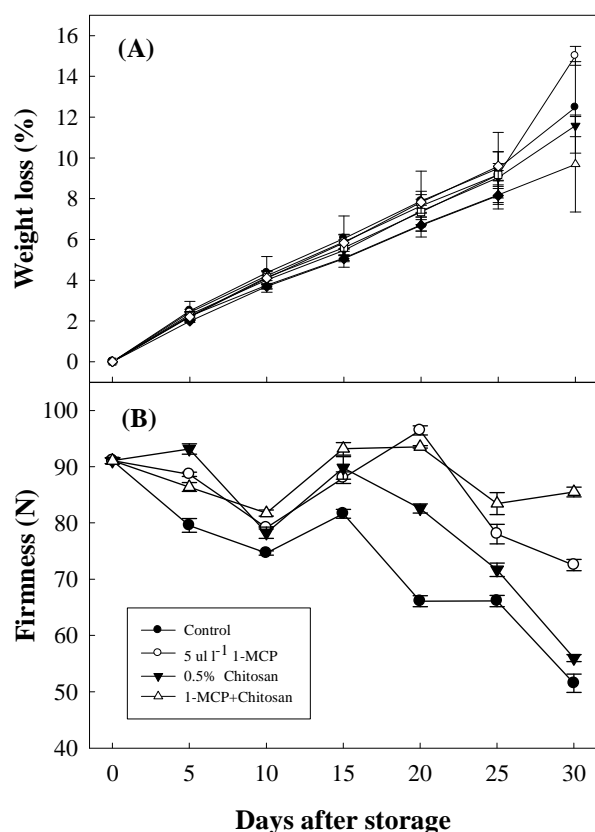


Fig. 1 Changes in weight loss (A) and firmness (B) of 'Jinhwang' mango treated with 1-MCP application, chitosan coating and 1-MCP combine with chitosan treatment after different interval storage at 10°C. Each value is the mean of three replications with SE bar

TSS increased during storage and all of treatments did not affect to maintain TSS in mango during storage (Fig. 2A). TSS increase, while TA decreased in the ripening mango. Increasing in TSS during fruit ripening was attributed to the increased activity of enzymes responsible for the hydrolysis of starch to soluble sugars [4] and is caused by a decline in the amount of carbohydrates and pectins, partial hydrolysis of protein and decomposition of glycosides into sub-units during respiration [14].

Cocozza *et al.* [27] reported that 1-MCP had no effect on TSS in mango treated with 100 and 500 nl l⁻¹ 1-MCP. Manganaris *et al.* [28] observed that no differences in TSS content between the control and 1-MCP-treated plum fruit stored directly at 20°C or at 5 or 0 °C for 10 days and subsequently transferred to 20°C. Chitosan coating did not retard the increase in the TSS content in pummelo [24] and strawberry [13].

TA of mango slightly increased (Fig. 2B) and application of all treatments did not delay the reduction of TA during storage. The decrease of TA during storage may due to a reduction in the organic acids consumption or their conversion to sugars during respiratory metabolism [15]. In addition, Increased activity of citric acid during ripening or reduction in acidity may be due to their conversion into sugars and their further utilization in the metabolic processes of the fruit respiration [14].

Similar findings observed by Wang *et al.* [2] reported that TA of mango did not change significantly after 1-MCP treatment. Zhong and Xia [10] found that the application of 1-MCP and chitosan coating treatments did not affect TA loss of Indian jujube fruit during storage. Moreover, 1-MCP did not affect in apricot fruit [8], mango [15, 27, 22], and sapodilla [4].

Glucose and fructose contents of mango almost constantly changed while sucrose increased during storage (Fig. 3). The fructose was higher than sucrose and glucose, respectively and thereafter, the sucrose was higher than and glucose fructose, respectively. The sucrose content of mango untreated (49.97 mg g⁻¹ fw) was higher than fructose and glucose contents (22.17 and 13.60 mg g⁻¹ fw, respectively) after 20 days storage at 10°C. During storage of mango, glucose and fructose contents did not significantly different between the treatments (Fig. 3A, 3B).

However, only combine treatment (27.23 mg g⁻¹ fw) delayed the increase sucrose content after 20 days storage (Fig. 3B). Therefore, sucrose was the principal sugar of mango, follow by fructose and glucose, respectively. The results were in accordance with Lizada [29] who reported that sucrose had the highest concentration among the fructose and glucose, and fructose was found in higher levels than glucose throughout ripening. Sucrose was the predominant sugar that accumulates in the fruit of 'Haden' mango during ripening, finally accounting for over 60% of the total soluble sugars [31].

As a consequence of starch hydrolysis, total sugars increase during ripening, with glucose, fructose and sucrose constituting most of the monosaccharides [30]. Invertase hydrolyzed sucrose in fruit during ripening, forming glucose and fructose [25].

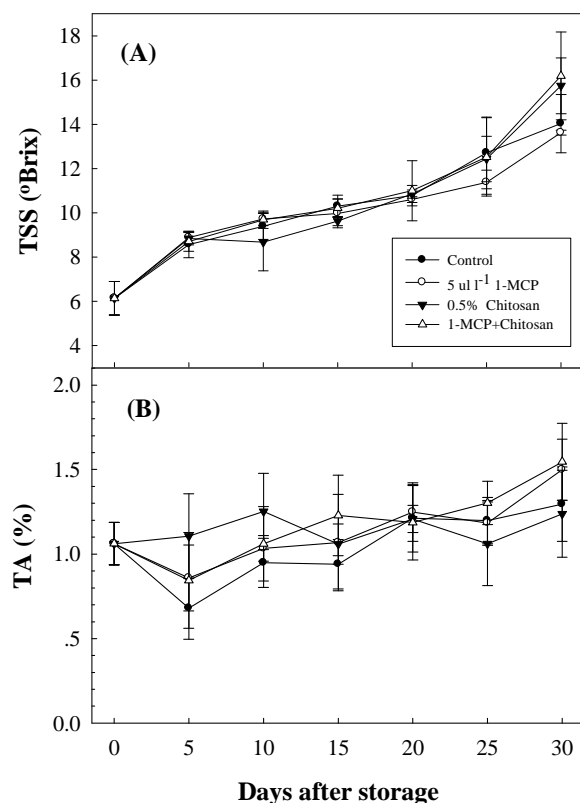


Fig. 2 Changes in TSS (A) and TA (B) of 'Jinhwang' mango treated with 1-MCP application, chitosan coating and 1-MCP combine with chitosan treatment after different interval storage at 10°C. Each value is the mean of three replications with SE bar

Starch content of mango tended to decrease after storage (Fig. 4A). Mango treated with 1-MCP application (51.36 %DW) was significantly higher starch than 1-MCP combine with chitosan, chitosan coating and untreated (38.49, 34.80 and 33.03 %DW, respectively) after 25 d storage at 10°C. This indicated that 1-MCP application delayed the decrease of starch content in mango. Starch content decreased during storage due to the conversion of starch to sugar, which increases the fruit's sweetness [32]. Starch hydrolysis in the ripening mango associated with amylase activity, which exhibits the properties of both α -amylase and β -amylase [30].

EL as membrane permeability of mango fruit increased during storage that correlated with fruit ripening (Fig. 4B). All treatments did not affect to maintain EL in mango during storage at 10°C. During storage, the fruit increased in the high activity of the cell wall degrading enzymes induce the fruit softening and increased membrane permeability [20].

Diseases did not infect in mango after 20 days storage at 10°C thereafter, fruit did not appear diseases in the peel (Fig. 5A). Decay scale readings of this cultivar treated with chitosan coating and 1-MCP combine with chitosan treatment (6.67 and 6.00, respectively) were significantly delayed the fruit decay more than untreated and 1-MCP application (5.33 and 4.00, respectively) after 30 days storage (Fig. 3B). Therefore, 'Jinhwang' cultivar treated with chitosan and combine treatment, showed the infection of diseases in 4-6 and 7-10 %, respectively of light dark spots during storage at 10°C.

Similar findings were observed in several fruits of longan [33], litchi [12] and strawberry [13]. The decay on fruits was better controlled as compared with uncoated fruits because chitosan induces chitinase, a defense enzyme, which catalyzes the hydrolysis of chitin, a common component of fungal cell walls, thus preventing the growth of fungi on the fruit [14].

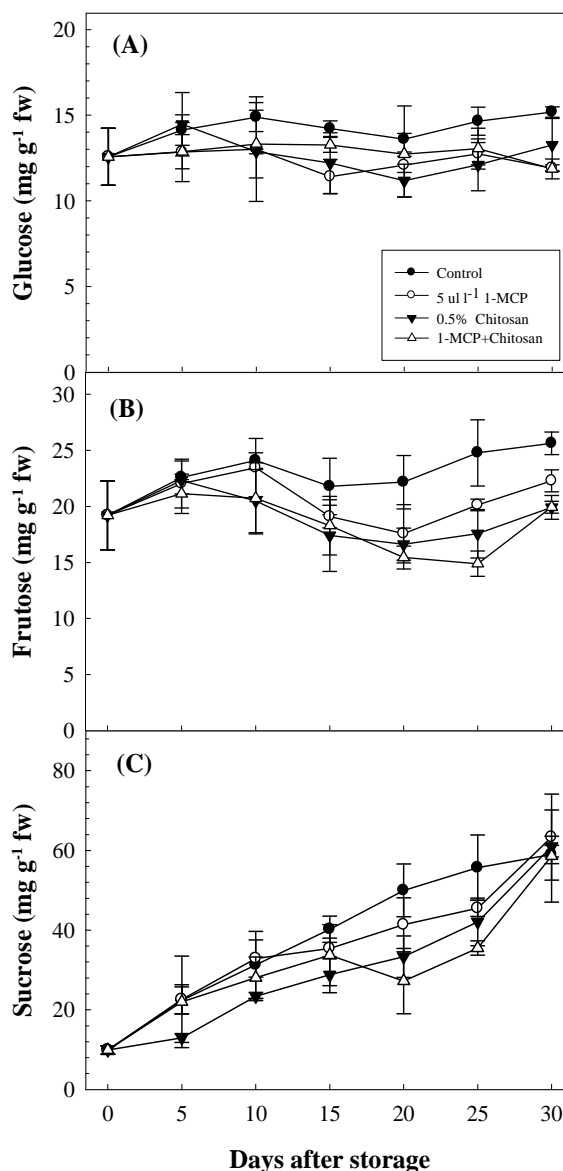


Fig. 3 Changes in glucose (A), fructose (B) and sucrose (C) contents of 'Jinhwang' mango treated with 1-MCP application, chitosan coating and 1-MCP combine with chitosan treatment after different interval storage at 10°C. Each value is the mean of three replications with SE bar

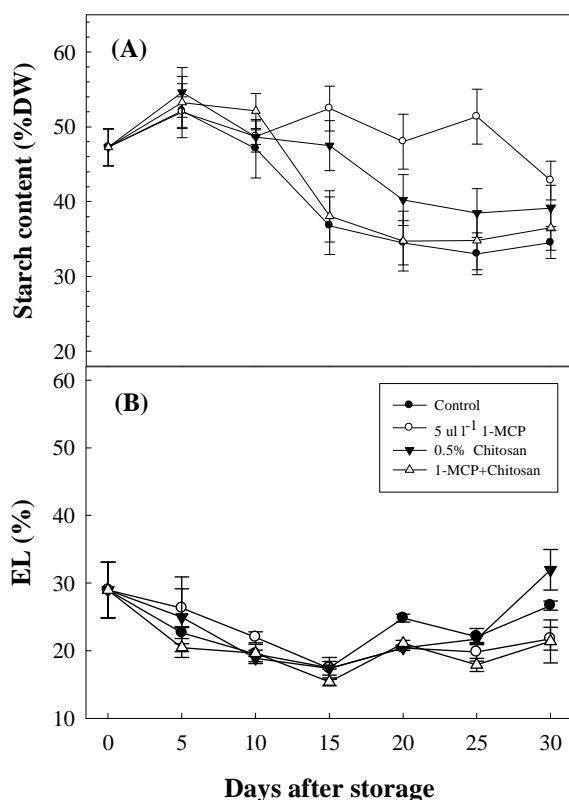


Fig. 4 Changes in Starch content (A) and EL (B) of 'Jinhwang' mango treated with 1-MCP application, chitosan coating and 1-MCP combine with chitosan treatment after different interval storage at 10°C. Each value is the mean of three replications with SE bar

B. Storage life

Chitosan coating and 1-MCP combine with chitosan treatment prolonged storage life of mango up to 29 days after storage at 10°C that was significantly longer than, 1-MCP and control (28 and 27 days after storage, respectively) (Fig. 5B). These results were similar with the studies of Penchaiya *et al.* [26] and Jansasithorn and Kanlayanarat [9], who reported that 1-MCP treatment prolonged the storage life of mango and banana to 15 and 20 days, respectively of storage at 20°C. Zhong and Xia [10] who reported that Indian jujube fruit treated with 1-MCP and/or chitosan showed extended storage life at room temperature storage.

IV. CONCLUSION

Application of chitosan coating prevented the fruit decay and prolong storage life up to 29 days after storage while 1-MCP maintain starch content and extended storage life at 28 days. Moreover, application of 1-MCP combine with chitosan exhibited a potential for maintain sucrose content and prevent fruit disease and infection including also represented a potential for storage life extension at 10°C. Therefore, using all of application of 1-MCP or chitosan coating and/or combine treatment in 'Jinhwang' cultivar at 10°C appropriated to maintain quality and prolong storage life of mango fruit.

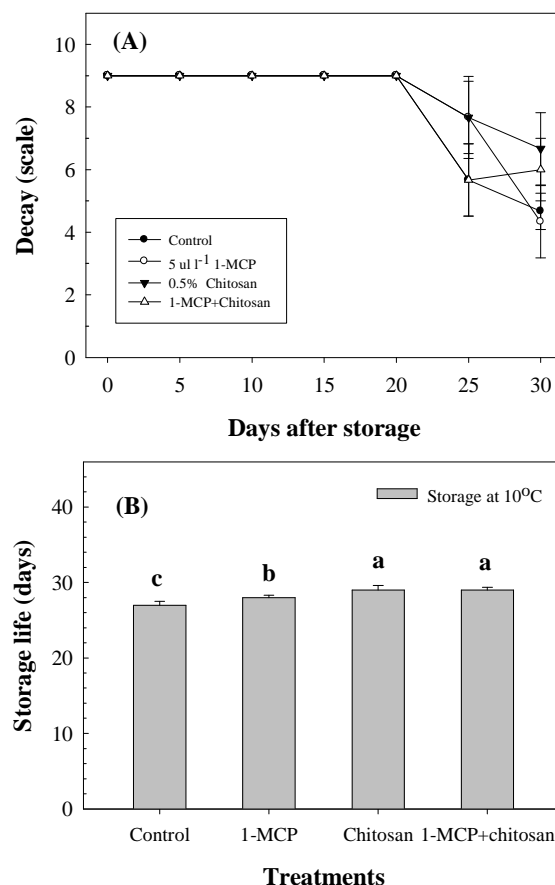


Fig. 5 Changes in fruit decay (A) and storage life (B) of 'Jinhwang' mango treated with 1-MCP application, chitosan coating and 1-MCP combine with chitosan treatment after different interval storage at 10°C. Each value is the mean of three replications with SE bar

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