Journal of Applied Horticulture, 25(1):79-86 , 2023
https://doi.org/10.37855/jah.2023.v25i01.14
Journal of Applied Horticulture
ISSN: 0972-1045

Effect of edible coating and perforated packaging on the quality and storability of mango (cv. Cat Chu) at suboptimal storage temperature

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Abstract

Mango fruit (*Mangifera indica* cv. Cat Chu) is generally susceptible to chilling injury (CI), and postharvest deterioration induces limits in its commercial potential. This study aimed to find the effects of edible coating and perforated packaging on the quality and storability of mango fruit stored at a suboptimal temperature of 8 ^{o}C for 35 days and ripening for five days at 20 ^{o}C of each seven days of storage. The edible coatings (chitosan (0.5 %) combined with lemongrass essential oil (0.025 %) (chitosan) and carnauba wax (0.5 %) (carnauba)), perforated packaging (Low-density polyethylene (25 µM) needle-perforated ten holes (0.5 mm diameter) (LDPE); LDPE perforated eight holes (0.4 cm diameter) (control)), and combination between the coating and perforated packaging (Chitosan and LDPE (needle-perforated) (Chi-LDPE); carnauba wax and LDPE (needle-perforated) (Car-LDPE)) investigated in this study. The results showed mango cv. Cat Chu in needle-perforated packaging and combination with coating had the lowest weight loss, followed by control, chitosan, and carnauba wax with the highest weight loss. The CI symptom was white-corky in the pulp of ripened mango, which appeared in all treatments except chitosan coating for 35 days at 8 ^{o}C and ripening fruit at 20 ^{o}C. The chitosan coating inhibited the respiration rate and electrolyte leakage and decreased the disease index in mango fruit during storage. The quality of ripening mango fruit was highly maintained during the extended duration of cold storage. This result revealed that the chitosan coating improved chilling tolerance and prolonged the shelf life of mango at the suboptimal temperature of 8 ^{o}C for 35 days. This application might be a green means of fruit preservation, but further enhancement of disease control is needed.

Key words: Edible coating, perforated packaging, mango, chilling injury, disease, quality, suboptimal temperature

Introduction

The mango (*Mangifera indica* L.) has garnered widespread recognition for its exquisite flavour and exceptional nutritional attributes, earning it the esteemed title of the "King of Fruits." However, the mango's susceptibility to decay, sensitivity to low temperatures, and rapid ripening, which results in softening, collectively pose challenges to its storage, handling, and transportation. Regrettably, these inherent characteristics contribute to a heightened level of fruit perishability, consequently leading to significant postharvest losses. These losses impede its commercial viability and underscore the urgency for effective preservation strategies to harness its full potential (Zheng *et al.*, 2012). Mangoes are one of the main tropical fruits grown in Vietnam, most widely grown in the Mekong Delta. Dong Thap province in the Mekong Delta has 13,600 ha of mango orchards. Cat Chu mango is a popular variety in this province for consumption in both domestic and export markets (Vietnam Fruit Association, 2021). The appropriate temperature for Cat Chu mango was 12°C for three weeks, with chilling injury (CI) development at lower storage temperatures (Nguyen and Thai, 2004). The low-temperature storage is the most commonly used technique to extend the shelf life and to ensure the nutritional aspect and sensory quality of mangoes. However, keeping mango fruit below 12 ^{o}C enhances physiological and pathological deterioration, mainly due to chilling injury. Therefore, methods that can alleviate CI may raise global marketing by reducing postharvest degradation and increasing shelf life. Modified atmosphere packaging (MAP) effectively alleviated CI symptoms in mango fruit. However, anaerobiosis and the development of undesirable off-odours under low O_2 and elevated CO_2 atmospheres are common occurrences that severely modify the volatile profile of packaged produce during extended storage. Perforation-mediated MAP is an alternative system to conventional MAP with polymeric films to control the gas exchange rates while storing fresh products (Celeb *et al.,* 2013). Macro-perforated packaging, commonly preferred in commercial set-ups, provides additional gaseous diffusion and is beneficial in reducing the off-flavour of fresh produce (Techavises and Hikida, 2008). However, it is often accompanied by higher weight loss, and the content is potentially exposed to outside contaminants. These limitations could be addressed by using natural polymeric coating materials as primary packaging on the surface of fresh produce. Mango storage in perforated low-density polyethylene reduced the appearance of chilling injury at suboptimal storage temperatures (Patil *et al.,* 2019). Mango fruits of cv. Amrapali packed in 5 % perforated LDPE polythene films could be stored for 16 days at 20-2 ^{o}C (Taduri *et al.,* 2017). Edible coatings represent new packaging strategies in the postharvest management of fresh produce. They are reported to create a micro-modified atmosphere around the product by acting as a gas and water vapour barrier (Baldwin *et al.,* 2012). This helps in

retarding food deterioration and enhancing its quality. Chitosan was found to maintain the quality of sweet peppers stored even at 1.5 ^{o}C, by limiting water loss to keep the fruit firm and reducing decay development and, especially, chilling injury, without affecting the peppers' nutritional content (Kehila *et al.,* 2021). Incorporating essential oils in edible coatings has gained interest in the agricultural sciences due to these volatile compounds' bactericidal and fungicidal properties. Lemongrass essential oil has been successfully used in various formulations to control anthracnose in mango fruit (Duamkhanmanee, 2008). The coating of chitosan and lemongrass oil was effective in maintaining guava postharvest quality for ten days at 12 ^{o}C (de Oliveira *et al.,* 2020). Yu *et al.* (2021) showed that chitosan coating with cinnamon essential oil was promising to comprehensively maintain the postharvest quality of mango cv. Tainung, due to its enhanced physical and sustained-release properties. The carnauba coating in mango cv. Kensington Pride was effective in retarding fruit ripening, retaining fruit firmness, and improving fruit quality attributes, including levels of fatty acids and aroma volatiles (Dang *et al.,* 2008). Surface coating with 'Nipro Fresh', followed by shrink-wrap packaging of trays containing mangoes, and their subsequent storage at 12-13 °C and 85-90 % relative humidity, extended the shelf life by 54 days (Gomez *et al.,* 2021). Mango was coated with Semperfresh^{TM} at 1 % with (EPE) foam net packaging, which has the potential to control postharvest chilling and maintain quality (Tarabih, 2020). Kawhena *et al.* (2022) showed that the coating combination with micro-perforated Xtend® proved to be an effective treatment for maintaining the quality of 'Wonderful' pomegranates during storage. Based on the above information, this study evaluated the effectiveness of edible coating and perforated packaging and their combination on chilling tolerance, prolonging the shelf life, and maintaining the quality of mango cv. Cat Chu at a suboptimal temperature of 8 ^{o}C for up to 35 days.

Materials and methods

Cat Chu mango fruits at the same commercial maturity were collected from the orchard in Dong Thap province, in the Mekong delta of southern Vietnam. The trees in this experiment were 20 to 25 years old. These mango samples were brought to the laboratory of postharvest technology, Southern Horticultural Research Institute (SOFRI), Vietnam for postharvest treatment. A completely randomized design with a factorial arrangement was used as the study design comprising three replicates. Treatments included chitosan (0.5 %) combined with lemongrass essential oil (0.025 %) (Chitosan); carnauba wax (0.5 %) (Carnauba); Low-density polyethylene (25 µM) perforated ten needle holes (0.5 mm diameter) (LDPE); Chitosan and LDPE (needle-perforated) (Chi-LDPE); carnauba wax and LDPE (needle-perforated) (Car-LDPE) and LDPE perforated eight holes (0.4 cm diameter) (control). The fruits were then randomly batched into six groups for the different treatments and treated fruits. Upon drying, all fruits were packed in five kg corrugated fiberboard boxes. Fruits were observed and assessed for quality in seven-day intervals for 35 days at 8 ^{o}C, 80-90 % RH and ripening for five days at 20 °C each storage period.

Physical and biochemical parameters

For estimating weight loss (WL) (%), pre-weighed fruit samples were weighed on a physical balance, OHAUS – CS5000 (5.000 g ± 2 g), USA, after each storage interval. The weight loss at each interval during storage was expressed as a percent of the initial weight. Colour measurement of peel and pulp of mango (L* and b*)*:* the color change of mango fruits was measured with Chroma Meter, Minolta CR-400, Japan. The peel and pulp color of mango are measured at three places. Fruit firmness (kg cm^{-2}) was measured with Fruit Texture Analyser (GUSS-15, Germany) (using a cylindrical probe of 8 mm diameter, downward penetration at 11 mm, and a measured speed of 5 mm s^{-1}). After peel removal, the fruit was penetrated at three places near one side's equator. Electrolyte leakage (%): was measured using the method of Zhao *et al.* (2009), taking medisocarp tissue from the equator was 3 mm near the peel of the fruit. The respiration rate (mg CO_2 kg^{-1} h^{-1}) was estimated as per Aindongo *et al.* (2014), with some modifications using O_2 - CO_2 automatic gas analyzer (Dansensor, CheckMate 3, Denmark). Total soluble solids concentration was measured by Refractometer (Japan), measurement scales: 0-53 ^{o}Brix. Titratable acidity (%) was measured by SI ANALYSIS Titroline 7000, Germany. Titratable acidity was calculated and expressed as a percentage of citric acid. The ascorbic acid (mg 100 mL^{-1}) content of mango juice samples was determined by the 2, 6-dichlorophenol indophenol visual titration method described by Srivastava and Kumar (2017). Total sugar (%) content was estimated by Lane and Eynon's volumetric method by Ranganna (2000) with some modifications. Disease index (%) was measured using the method of Shao *et al.* (2019) on mango.

Statistical analysis: The data collected were subjected to analysis of variance (ANOVA) using SAS software package version 8.1. A comparison of the means was performed using LSD's multiple range tests and $P \leq 0.05$ was considered statistically significant.

Results and discussion

Effect of edible coating and perforated packaging on physiological properties of mango fruit storage at 8 ^{o}C: Edible coating and packaging significantly affected fruit weight loss during cold storage (Fig. 1A). Weight loss progressively increased during the storage of mango fruits. The coating of chitosan (10.14 %) and carnauba (10.51 %) increased weight loss compared to the other treatments for 35 days at 8 ^{o}C. Meanwhile, perforated LDPE and combination with edible coating significantly reduced weight loss (1.86 % to 2.16 %) compared to control (4.03 %) in mango fruit during cold storage. This could indicate the effectiveness of needle-perforated packaging in reducing the rate of moisture loss in mango fruit. The relative humidity around the fruit in MAP packaging was due to the retention of higher RH in cold storage (Mpho *et al.,* 2013). The MAP and low temperature could inhibit metabolic activities more effectively and reduced the dissipation of moisture (Wei *et al.,* 2021). These results were consistent with the findings of Elkashif *et al.* (2016) in mango fruit and Vazquez-Celestino *et al.* (2016) in mango cv. Manila.

The respiratory peaks in mangoes of control (38.81 mg CO_2 kg^{-1} h^{-1}) and Car-LDPE (30.11 mg CO_2 kg^{-1} h^{-1}) were observed on the 21st day of storage. Meanwhile, the respiration peaks of mangoes in carnauba (38.65 mg CO_2 kg^{-1} h^{-1}) and chitosan (34.17 mg CO_2 kg^{-1} h^{-1}) were delayed by up to 7 days on the 28th day of storage. Mangoes in control, carnauba, and chitosan greatly decreased the respiratory rates. At the same time, LDPE (39.80 mg CO_2 kg^{-1} h^{-1}) and Chi-LDPE (38.77 mg CO_2 kg^{-1} h^{-1}) highly

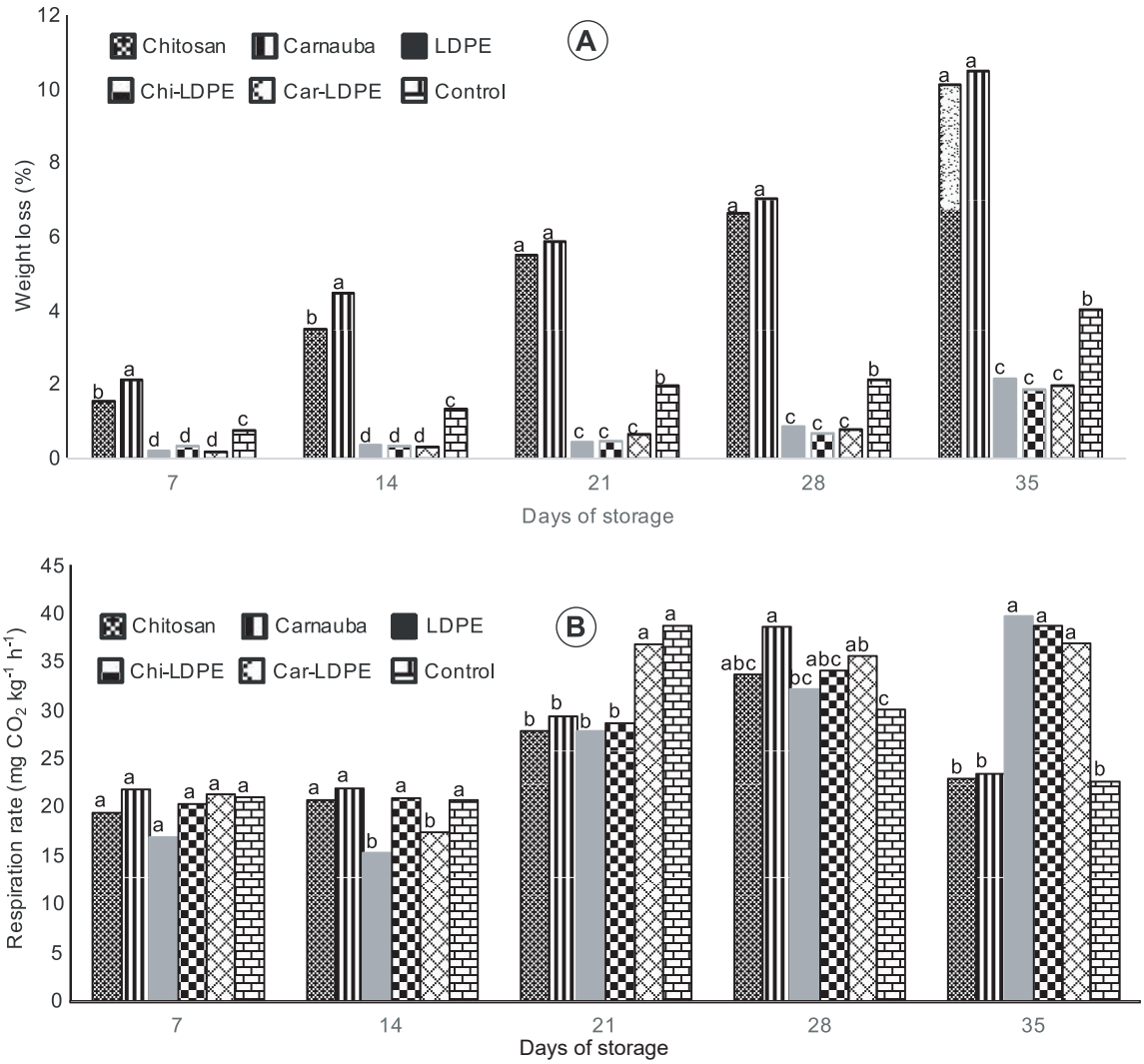

Fig. 1. Effect of edible coating and perforated packaging on weight loss (A) and respiration rate (B) of mango storage at 8 ºC

increased the respiratory on the 35th day of storage (Fig. 1B). The delay in the time of the peak respiration of the mangoes indicated that these treatments delayed the senescence of mangoes and had a better effect on fruit preservation. Surface coating followed by needled-perforated LDPE created the barriers to O_2 influx, and the resultant modification of the atmosphere due to higher levels of CO_2 reduced fruit respiration. These results showed that the needle-perforated LDPE and the combination of chitosan effectively inhibited respiration during storage. A similar result was found on mango cv. Chinese (Wei *et al.,* 2021).

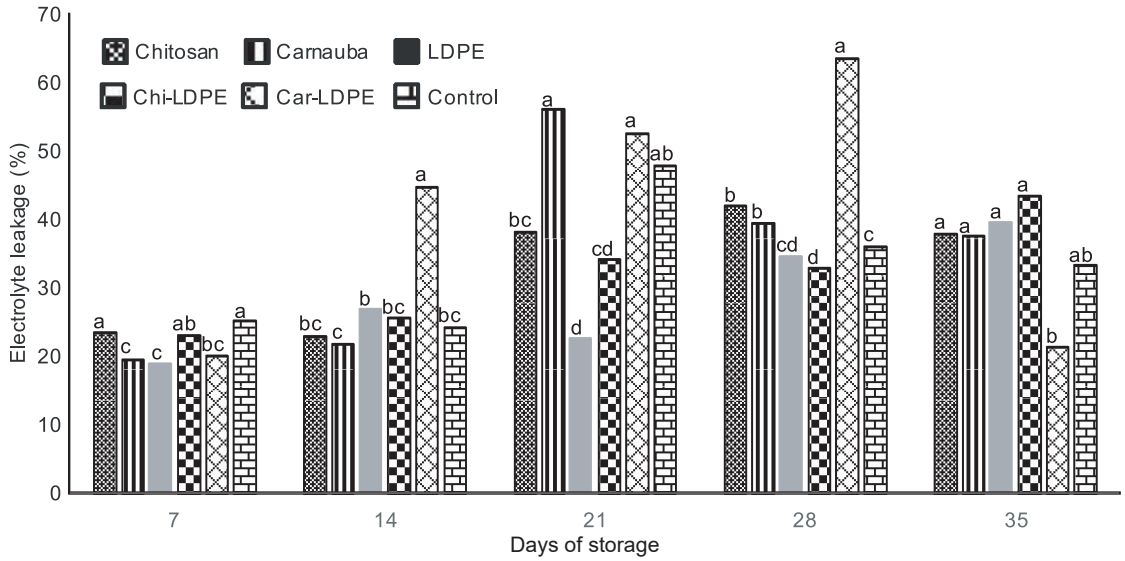

Fig. 2. Effect of edible coating and perforated packaging on electrolyte leakage of mango storage at 8 ºC

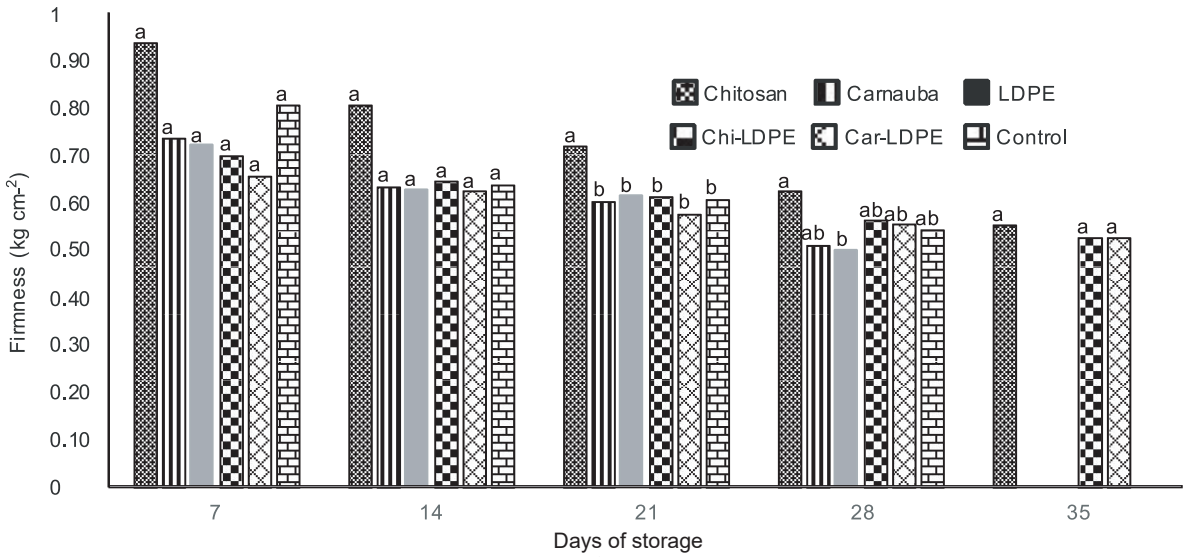

Fig. 3. Effect of edible coating and perforated packaging on the firmness of ripened mango for 5 days at 20 ºC of each storage period

The electrolyte leakage (EL) of mangoes in treatments slowly increased during 14 days of storage, except Car-LDPE was at high rise (Fig. 2). Mangoes in carnauba (56.06 %), Car-LDPE (52.59 %), and control (47.90 %) significantly increased EL compared with the other treatments on the 21st day of storage. On the 28th day, the EL of mango in Car-LDPE (63.44 %) was the highest rise. LDPE and Chi-LDPE still gradually increased EL in mangoes, while other treatments decreased on the 35th day of storage. These results indicated the effectiveness of needle-perforated packaging and combination with chitosan coating in delaying EL in mangoes at 8 ºC. Carnauba coating was ineffective in delaying EL and significantly affected the membrane integrity of mango more than chitosan coating during storage at 8 ºC. EL increased with the extended storage duration, possibly due to the increasing chilling injury and ripening (Suwapanich and Haewsungcharoen, 2007). These results were consistent with Tarabih's (2020) findings in mango cv. Naomi.

Effect of edible coating and perforated packaging on physiochemical properties of mango after removal from 8 ºC and ripening for 5 days at 20 ºC of each storage period: Fruit firmness in ripened mango decreased throughout the period and reached similar values at the end of the shelf life (Fig. 3). Ripen mango in chitosan showed the highest firmness values (0.72 kg cm^{-2}) and significant difference ($P \leq 0.05$) compared to other treatments for ripening mango on the 21st day of storage. Meanwhile, the firmness values of ripening mango in LDPE, carnauba, and control were lower than other treatments on the 28th day of storage. Mango in chitosan maintained a high firmness value (0.55 kg cm^{-2}) compared with other treatments on the 35th day of storage. These results indicated that mango firmness was maintained highly in chitosan combined with lemongrass oil during cold storage and ripening at 20 ºC. The effect of coating on maintaining firmness was mainly attributed to slowing the metabolic activity, respiration rate, and enzyme activity. Thereby, the maturation process of fruits could be affected by the restriction of gas exchange, water loss, and moisture migration from the fruit peel (Hassan *et al.,* 2018). Serrano *et al.* (2005) stated that postharvest decay was the main cause for the loss of fruit firmness in the packaging alone and non-packed fruits when compared to other treatments. A similar finding was also reported in mango (Yu *et al.* (2021)) and guava (de Oliveira *et al.,* 2020).

Disease in all treatments appeared during 14 days of cold storage, except Chi-LDPE did not develop the disease in mango (Table 1). Chi-LDPE had the lowest disease index in mango (15.32 %) and differed significantly as compared to other treatments during cold storage. Meanwhile, mangoes in carnauba (35.26 %) and Car-LDPE (27.86 %) had high disease indexes compared to other treatments and controls on the 28th day of storage. The disease index in mango of treatments increased highly but was not different on the 35th day of storage. The disease index of mangoes in chitosan and Chi-LDPE were low compared to the other treatments when the fruits were removed from 8 ºC and ripened at 20 ºC for 5 days. In contrast, when mangoes were stored for a longer period of time, carnauba, Car-LDPE, LDPE, and control had significantly higher disease index in ripening mangoes. These results explained that chitosan and Chi-LDPE improved antifungal activity and reduced the respiration rate of mangoes at 8 ºC. Similar results were found on sweet pepper (Kehila *et al.,* 2021), guava (de Oliveira *et al.,* 2020), mango cv. Tainung (Yu *et al.,* 2021), and mango (Wei *et al.,* 2021).

Color is a key factor for determining consumer perception when purchasing fruits. The L* values (color lightness) of ripened mango peel were high in LDPE, control, Car-LDPE, and chitosan compared with carnauba and Chi-LDPE during ripening (Fig. 4A). The b* values of ripened mango peel in all treatments reduced for 28 days of storage and increased again at the end of storage. Ripened mango in carnauba, Car-LDPE, and Chi-LDPE greatly reduced the b* values of peel compared with other treatments during storage.

Meanwhile, the L* values of ripened mango pulp increased in all treatments with the extension of duration storage. Chitosan, Chi-LDPE, and control increased L* values in the pulp of ripened fruit higher than other treatments on the 28th day and the end of storage. The b* values of ripened mango pulp in all treatments were similar to the change of peel fruit. Chitosan and carnauba had high b* value in ripening mango pulp compared with other treatments on the 28th day of storage.

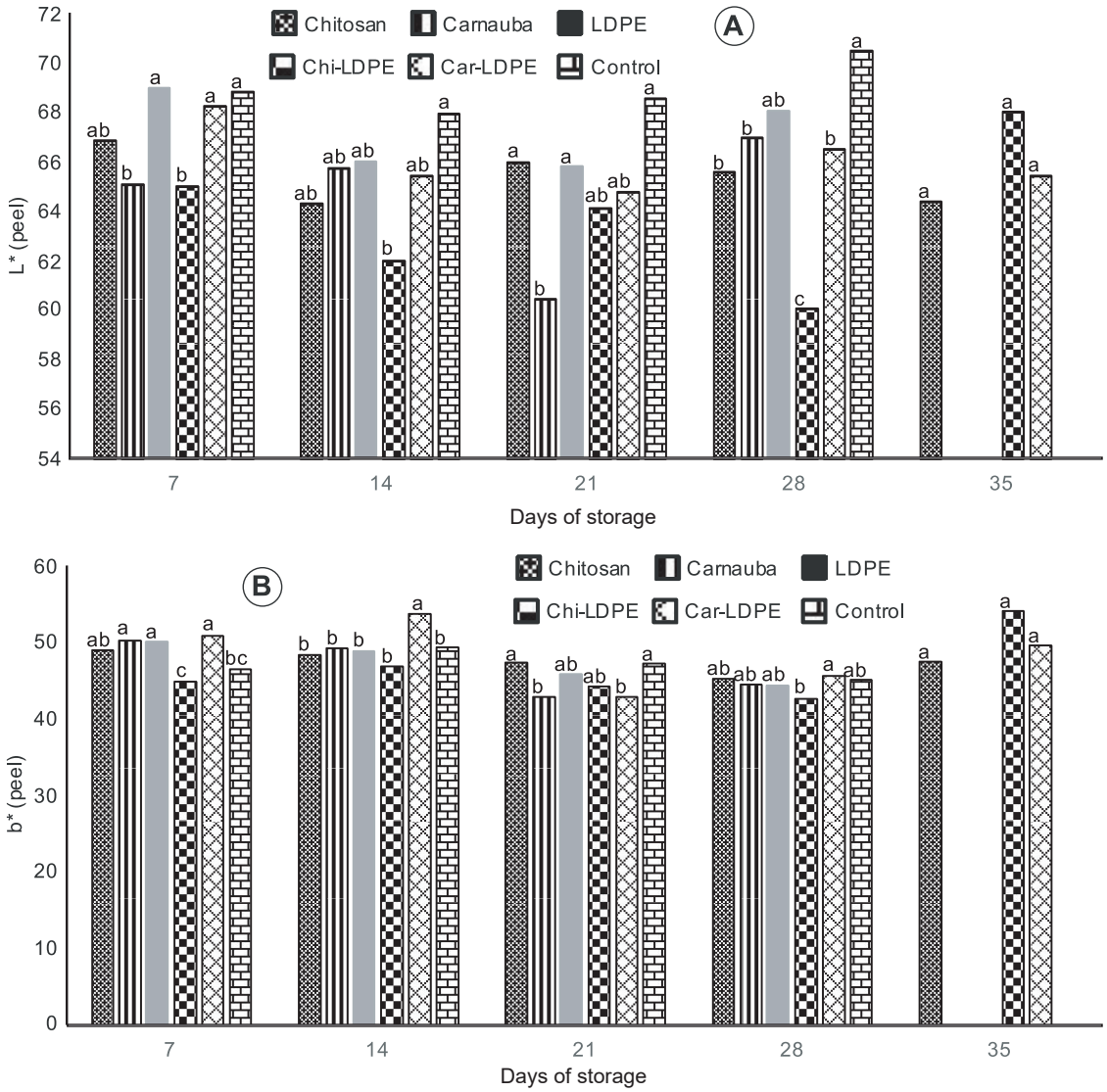

Fig. 4. Effect of edible coating and perforated packaging on the peel (L*; b*) of ripened mango for 5 days at 20 °C of each storage period

Table 1. Effect of edible coating and perforated packaging on disease index of mango at 8 °C and ripening for 5 days at 20 °C of each storage period

Treatment	Disease Index-storage (%)					Disease Index-Ripening (%)				
	7 ds	14 ds	21 ds	28 ds	35 ds	7 ds	14 ds	21 ds	28 ds	35 ds
Chitosan	0	9.00 (17.35)	14.00 (21.94)	15.33 (23.04)	32.00 (34.45)	9.33 |(17.71)	24.00 (29.14)	54.67 (47.71)	65.67 (54.13)	94.67 (77.51)
Carnauba	0	10.67 (18.99)	15.33 (23.04)	33.33 (35.26)	37.00 (37.45)	33.67 (35.46)	44.00 (41.55)	61.00 (51.24)	85.00 (67.31)	100.00 (89.09)
LDPE	0	3.00 (8.35)	9.00 (17.35)	15.33 (23.04)	33.33 (35.25)	15.33 (23.04)	33.33 (35.25)	60.33 (51.02)	73.67 (59.14)	100.00 (89.09)
Chi-LDPE	0	0.00 (0.91)	7.00 (15.32)	14.00 (21.94)	29.33 (32.76)	12.00 (20.09)	22.00 (27.86)	38.00 (38.05)	54.67 (47.71)	87.33 (69.28)
Car-LDPE	0	6.33 (14.57)	14.67 (22.48)	22.00 (27.86)	32.67 (34.86)	15.33 (23.04)	42.67 (40.76)	71.00 (57.45)	80.33 (63.77)	98.33 (83.66)
Control	0	5.00 (12.78)	10.67 (18.99)	15.33 (23.04)	35.33 (36.47)	15.33 (23.04)	36.67 (37.25)	59.33 (50.42)	79.00 (62.91)	98.33 (83.66)
SEm (±)		1.61	0.78	1.19	0.48	1.41	1.45	1.65	1.72	-1.85
LSD (0.05)		5.81	3.26	3.18	NS	3.4	6.18	7.69	5.93	6.98

Means in parenthesis were arcsine transformed; NS: non-significant

These results indicated the effect of coating and perforated packaging on mango ripening after storage at 8 °C. The chitosan coating inhibited the effect of suboptimal temperature on the change in color of mango fruit; thereby, the process of ripening fruit was normal at the extension of duration storage. While ripened mango pulp in perforated packaging (LDPE and control) and combination with coating appeared white-corky pulp tissues at the extension of duration storage at 8 °C. The permeability could explain these effects to gas and the atmosphere exchange of coating and perforated packaging on inhibition of

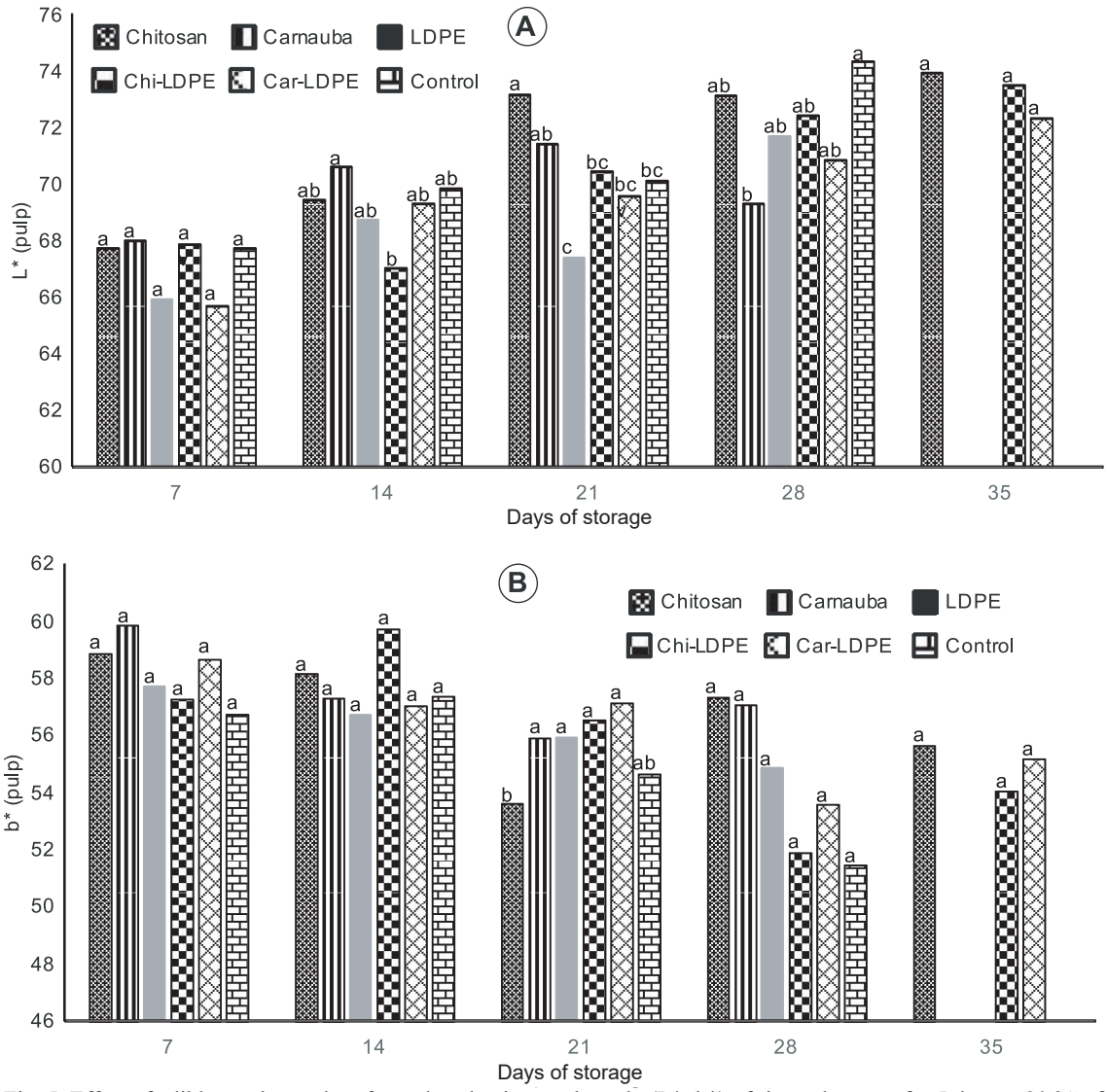

Fig. 5. Effect of edible coating and perforated packaging on the pulp (L*; b*) of ripened mango for 5 days at 20 °C of each storage period

the physiological metabolism and disorder membrane of mango under the extension of duration storage at suboptimal temperature. Similar results have been found in the effect of edible coating and packaging on color change in mango (Wei *et al.*, 2021) and guava (de Oliveira *et al.*, 2020).

After 35 days of storage at 8 °C and ripening for 5 days at 20 °C of each storage period, mangoes treated with control, LDPE, and carnauba had a high disease index (approximately 100%) compared with other treatments. Therefore, the fruit quality assessment at these treatments was not investigated at the end of storage.

The effect of edible coating and packaging on the total soluble solids (TSS) content of mango was shown in Table 2. There was a significant difference ($P \leq 0.05$) in TSS during storage and ripening due to the treatments except on the 28th day of storage. TSS of ripened mango in Chi-LDPE (16.45 °Brix) was the highest

Table 2. Effect of edible coating and perforated packaging on total soluble solids and total sugar of ripened mango for 5 days at 20 °C at each storage period

Treatment	Total soluble solid (°Brix)					Total sugar (%)				
	7 ds	14 ds	21 ds	28 ds	35 ds	7 ds	14 ds	21 ds	28 ds	35 ds
Chitosan	14.90	14.00	12.35	15.45	16.70	10.17	9.20	8.46	9.84	11.61
Carnauba	13.65	18.75	14.65	13.40		9.00	14.27	9.73	8.50	
LDPE	14.20	18.60	14.65	14.90		9.53	14.63	9.63	9.13	
Chi-LDPE	16.45	15.20	13.50	13.75	11.55	12.28	10.56	8.77	8.13	7.54
Car-LDPE	14.45	15.05	14.05	13.70	13.35	9.93	10.35	9.53	8.40	8.46
Control	14.00	15.65	14.70	12.90		9.56	10.50	8.88	8.43	
SEm (±)	0.28	0.46	0.23	0.29	0.76	0.32	0.54	0.15	0.18	0.63
LSD (0.05)	1.49	1.28	0.99	NS	0.60	1.77	1.70	0.80	1.08	0.93

Table 3. Effect of edible coating and perforated packaging on titratable acidity and ascorbic acid of ripened mango for 5 days at 20 ºC at each storage period

Treatment	Titratable acidity (%)					Ascorbic acid (mg100 mL^{-1})				
	7 ds	14 ds	21 ds	28 ds	35 ds	7 ds	14 ds	21 ds	28 ds	35 ds
Chitosan	0.18	0.11	0.48	0.57	0.33	98.47	53.47	48.99	35.47	27.03
Carnauba	0.36	0.15	0.25	0.44		62.76	40.20	32.09	25.02	
LDPE	0.26	0.13	0.25	0.46		92.00	55.07	42.83	27.03	
Chi-LDPE	0.23	0.23	0.20	0.34	0.19	90.54	51.01	47.93	35.14	21.50
Car-LDPE	0.16	0.11	0.31	0.41	0.15	102.03	52.70	42.23	30.41	24.29
Control	0.22	0.13	0.38	0.33		86.31	47.91	35.47	20.24	
SEm (±)	0.02	0.01	0.02	0.03	0.03	4.39	1.72	2.22	1.63	2.37
LSD (0.05)	0.09	0.03	0.08	NS	0.08	NS	NS	NS	8.60	NS

compared with other treatments on the 7th day of storage. The fruit in carnauba, LDPE, Car-LDPE, and control increased in TSS during ripening at 18.75, 18.60, 15.05, and 15.65 ºBrix, respectively, on the 14th day of storage. All treatment trends reduced TSS in ripened mangoes at the extension of duration storage, except chitosan increased TSS again (16.70 ºBrix). Among them, Chi-LDPE (11.55 ºBrix) and control (12.90 ºBrix) significantly reduced TSS in fruits at the end of storage.

The total sugar (TS) of fruits in all treatments was related to TSS. TS in mango of all treatments changed similarly to TSS and had a significant difference ($P \leq 0.05$) during storage and ripening (Table 2). This increase and decrease in TSS and TS is directly correlated with hydrolytic changes in starch and conversion of starch to sugar in the ripening process in mango fruits and further hydrolysis decreased the TSS and TS during storage. The low temperature may be attributed to inhibiting starch conversion to sugar (Nair and Singh, 2009). In addition, sugars are continuously consumed as substrates during respiration, which may cause the TSS and TS to decline (Barreto *et al.,* 2016). These results indicated the effectiveness of chitosan coating on the influence of suboptimal temperature for the ripening process of mango at the extension of duration storage. Carnauba coating, perforated LDPE alone or in combination with coating, and control were greatly affected by suboptimal temperature, inducing TSS and TS reduction in ripened mango at the extended storage.

The titratable acidity (TA) of ripened mango at all treatments was significantly different ($P \leq 0.05$) during storage except for the 28th day of storage (Table 3). The TA of ripened mangoes was reduced in all treatments on the 14th day of storage. Then, the TA of all treatments increased highly in ripening mangoes on the 28th day of storage. At the end of storage, the TA of ripened mango tended to reduce in all treatments, but mango in chitosan (0.33 %) maintained high TA compared to Chi-LDPE (0.19 %) and Car-LDPE (0.15 %). The change in TA as mangoes ripen is significantly affected by the rate of metabolism, especially respiration, which consumes organic acid and thus declines acidity during storage. Besides, acidity was increased as the storage temperature was lowered and as the storage period was extended. The increase in acidity during ripening may be attributed to the decrease in the degradation of citrate and malate, which are predominant acids in mangoes (Nair and Singh, 2009).

Mango ripening at all treatments reduced ascorbic acid (AA) content according to the storage time. This change was not significantly different ($P \leq 0.05$) between treatments except on the 28th day of storage (Table 3). AA of ripening mango in chitosan coating (35.47 mg 100 mL^{-1}) was a high value compared with other treatments and different ($P \leq 0.05$) to carnauba coating and control on the 28th day of storage. AA is easily oxidized, and its content tends to decline during storage. The edible coating on the surface of mango could effectively reduce the exposure to oxygen and decrease the oxidative enzyme activity in the organism. Meanwhile, the perforated packaging in an aerobic environment may have reduced AA (Wei *et al.,* 2021). Chilling injured mango fruit showed decreased accumulation of ascorbic acid (Maul *et al.,* 2012). This result indicated the effectiveness of chitosan coating in maintaining the AA content of ripening mango during storage at 8 ºC. Similar results have been reported in the previous study using chitosan coating to preserve mango (Wei *et al.,* 2021).

The study evaluated the effect of edible coating and perforated packaging on the quality and storability of mango cv. Cat Chu for 35 days of storage at 8 ºC and ripening for 5 days at 20 ºC at each storage period. The results revealed that chitosan coating decreased the disease index and inhibited the respiration rate in mango fruit during storage at 8 ºC. Chitosan coating maintained the quality of mango fruit in ripening after cold storage. In addition, pulp of mango did not appear white-corky in chitosan coating for 35 days at 8 ºC and ripening at 20 ºC. This result revealed that the chitosan coating improved chilling tolerance and prolonged the shelf life of mango cv. Cat Chu at 8 ºC. This application might be used as a green means of fruit preservation, but further enhancement of fruit disease control is needed.

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Received: December, 2022; Revised: January, 2023; Accepted: February, 2023