



Research Article

Comparison of the efficacy of chitosan and chitin nanofibers on the postharvest quality and shelf life of *Amrapali* mango

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ARTICLE INFO	ABSTRACT
<p>Article history Received: 19 November 2025 Accepted: 30 March 2026 Published: 31 March 2026</p> <p>Keywords Edible coating; Chemical attributes; Fruit firmness; Vitamin C; Nanofiber</p> <p>Correspondence Md. Yamin Kabir ✉: yaminkabir@at.ku.ac.bd</p> <p> OPEN ACCESS</p>	<p>Although mango is a popular tropical fruit, it is climacteric and exhibits limited storage life due to a high respiration rate. Mangoes are also susceptible to particular storage pathogens at postharvest and thus possess a short shelf life. Mature Amrapali mangoes were treated with two concentrations of chitin nanofiber (CNF) - 0.1% CNF and 0.3% CNF, and two concentrations of chitosan, e.g., 0.1%, and 0.3% to evaluate their effects on the postharvest quality and shelf life. Disease-free and physiologically mature mangoes were collected from orchards. The experiments were designed using a Completely Randomized Design with three replications, and each replication consisted of 10 fruits. Fruits were evaluated for physical quality (weight loss, fruit firmness, and color changes), chemical attributes [changes in total soluble solids (TSS), titratable acidity (TA), vitamin C content], disease incidence, disease severity, and shelf life. Chitosan (0.1% and 0.3%) decreased the disease incidence and disease severity, retained more vitamin C, and increased the shelf life of mangoes. Although, CNF decreased weight loss of mangoes and kept the fruit firmer than the chitosan, it was less effective regarding chemical attributes including vitamin C and shelf life. Application of 0.3% chitosan significantly inhibited disease progression, lowering disease incidence and severity to 33.33% and 23.92%, respectively, while the untreated control showed 100% incidence and 99.33% severity. As both the chitosan concentrations (0.1% and 0.3%) had very similar effect, 0.1% chitosan can be recommended for postharvest mango preservation. More experiments should be conducted with different mango varieties and chitosan and CNF concentrations.</p>
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Introduction

Mango (*Mangifera indica* L.) – the 'King of fruits' from Anacardiaceae – is a familiar fruit in the tropics and subtropics (Bini et al., 2024), and is widely cultivated in Bangladesh (Sampa et al., 2019). In Bangladesh, it occupies more than 121 thousand ha, having 1.95 million metric tons of production, and the contribution of mango to the total fruit crop production is 26.38% (BBS, 2022). Mango is very popular in Bangladesh due to its excellent taste, distinctive flavor, rich nutritional value, wide adaptability, and diversity. However, mangoes are highly perishable, ripe quickly after harvest, and, thus, susceptible to various postharvest diseases (Giovannoni et al., 2017). These problems restricted long-distance handling, storage, and transportation for marketing and consumption, which impacted the world mango trade. As a result, a considerable number of mangoes are wasted every year (Parvin et al., 2023). Moreover, a lack of postharvest management ultimately reduces the shelf life and deteriorates the overall quality of mango.

Postharvest losses of fruits remain a significant challenge in tropical and subtropical regions, undermining profitability and food security. To mitigate these losses, a wide range of strategies has been explored, including chitosan-based edible coatings (Asha et al., 2025; Aziz et al., 2021; Dhali et al., 2025; Hossain et al., 2025; Munira et al., 2024, 2025; Parvin et al., 2025; Parvin et al., 2023; Prashanth et al., 2022), improved packaging technologies (Azene et al., 2014), modified-atmosphere (MA) and controlled-atmosphere (CA) storage (Irtwange, 2006; Thakur et al., 2022), calcium chloride treatments (Dhali et al., 2024; Dovel, 2018; Lekhon et al., 2024; Madani et al., 2014; Shao et al., 2019), aloe vera gel coatings (Shah & Hashmi, 2020; Jodhani & Nataraj, 2021), botanical extracts (Kabir & Hossain, 2024), chitin nanofibers (Bagchi et al., 2025; Munira et al., 2025), and the use of growth regulators (Naleo & Maiti, 2018). However, CA and MA storage is very costly, and the use of chemical fungicides for preventing storage decay in mangoes is no longer

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preferred due to detrimental effects on the environment, the creation of chemical residue, and the development of resistance in the pathogen population (Sellitto et al., 2021). Chitosan, a natural polysaccharide derived from chitin, is widely recognized as a promising biopolymer for postharvest fruit preservation due to its film-forming ability, antimicrobial properties, biodegradability, and biocompatibility (Lin et al., 2011; Terry & Joyce, 2004; Fisk et al., 2008). Its semi-permeable coating reduces oxygen diffusion, moisture loss, and respiration, thereby slowing ripening and senescence while maintaining internal fruit physiology and limiting microbial decay (Shi et al., 2013; Li & Yu, 2000). More recently, chitin nanofibers (CNF)—derived through nanofibrillation of chitin into water-dispersible fibers with diameters below 100 nm and high aspect ratios (Xia et al., 2003)—have also been used as natural coating materials to extend shelf life and preserve the postharvest quality of fresh fruits (Shamshina et al., 2019; Shams et al., 2025). The current study aims to identify the optimum concentration of chitosan and CNF for postharvest mango preservation.

Materials and Methods

Experimental site and material

The experiment was conducted at the Horticulture Laboratory, Agrotechnology Discipline, Khulna University, Khulna, with Amrapali mango (*Mangifera indica* cv. Amrapali). Mature and uniform fruits free of blemishes and disease were collected early in the morning on a bright sunny day from a farmer's field of Satkhira and transported immediately to the Horticulture Laboratory of Khulna University using an air-cooled vehicle.

Experimental design, preparation and application of treatments

The experiment was conducted with five treatments: CNF 0.1%, CNF 0.3%, chitosan 0.1%, chitosan 0.3%, and an untreated control with three replications. For each replication of a treatment, 10 mango fruits were used. CNF was extracted from the shells of tiger shrimp (*Penaeus monodon*). Shrimp shells were meticulously cleaned in water to wash the clinging dust, dirt, and other debris. Before letting them dry in the air, the shrimp shells were repeatedly cleaned with tap water. Using a typical grinder, the dry shells were reduced in size to particles between 2 and 4 mm. About 300 g dried, crushed shrimp shells were demineralized, deproteinized, and depigmented using HCl (37%), NaOH (99.9%), and Ethanol 50%, respectively (Ifuku et al., 2011; Ifuku, 2014). The suspension was blended by a super-speed blender (Vita-Mix Blender, Osaka Chem. Co. Ltd.) and a normal-speed blender (Panasonic MX Blender, Panasonic Holdings Corporation), and

transferred to the super colloidal machine. The CNF was mechanically processed by passing it through a Super Masscolloider (MKCA6-51, Saitama-ken, Japan). The grinding stone clearance was set to -0.15 with a 1500 rpm rotating stone speed. After going through a super-speed blender for 10, 15, and 20 milling cycles, the CNF was extracted. The required concentrations (0.1% and 0.3%) of CNF were prepared by adding more distilled water. Chitosan manufactured by Sigma-Aldrich was used to prepare the required chitosan concentrations.

For each replication, 10 mangoes with similar physiological maturity were selected for the experiments. Each set of mangoes was placed separately on a newspaper. The CNF and chitosan were sprayed on the fruits uniformly with a hand sprayer, except for the control. On each date [4, 6, 8, and 10 days after treatment (DAT)] of chemical measurements, 12 fruits were sampled from four treatments (i.e., three fruits per treatment). However, data on physical parameters were collected every day.

Determination of Weight Loss (%)

The weight loss of mango was calculated according to the technique stated by AOAC (2012). Throughout storage, the samples were weighed daily on a digital balance. The findings were expressed using the following formula to get the percentage weight loss:

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

Firmness Determination

Firmness of mango was estimated hedonically as stated by Hassan (2006) following a scale of rating 1-6, where 1 is hard green, 2 represents sprung, 3 means between sprung and eating ripe, 4 indicates eating ripe, 5 is Overripe, and 6 means decayed.

Assessment of Fruit Color by Using a Chromameter

Mango skin color was measured on color coordinates as L*, a*, b*, Chroma (C*), and hue angle (h°) from opposite positions of each fruit in Chroma Meter CR-410. Chromaticity L* means the lightness of the fruit color ranging between 0 (black) to 100 (white). Chromaticity a* denotes the redness (+a*) or greenness (-a*), and chromaticity b* signifies the yellow (+b*) or blue (-b*) color skin of fruit. The intensity of color saturation from dull to bright (low-to-high values, respectively) was referred to as chroma (C*). In terms of color interpretation, the angles of red, yellow, green, and blue were 0°, 360°, 90°, and 180°, respectively. Absorbance or reflection is indicated by the hue angle

(h°), and the values relate to the intrinsic luminosity (McGuire, 1992).

Total Soluble Solid (TSS), Titratable Acidity (TA), and Vitamin C estimation

TSS, TA, and vitamin C content were measured on DATs 4, 6, 8, and 10 following standard methods (Asha et al., 2025; Dhali et al., 2024). On a particular date, a single fruit from each replication was destroyed to determine TSS, TA, and vitamin C. Thus, three mangoes (out of 10) were spent on the chemical analysis. A Hand Refractometer (REF 105) was used to measure the total soluble solids (°Brix) when a drop of juice is placed on its prism using the AOAC technique (2012). The amount of TA was quantified by titrating 5.0 ml of aliquot (fresh juice was extracted from the fruits of each replication and diluted with distilled water, maintaining a ratio of 1:2 (e.g., 10 ml juice: 20 ml water), and 5 ml aliquot was used for titration) against NaOH (0.1 N) as stated by Nerdy (2018) and Munira et al. (2025) as follows:

$$\text{Malic acid (\%)} = \frac{0.0067 \times \text{Vol. of NaOH} \times 30 \times 100}{5 \times 10}$$

Where 0.0067 indicates milli-equivalent weight of malic acid; 30 for total volume (ml); 5 for the extract juice sample (ml); and 10 for volume of aliquot (ml).

The dye (2,6-dichlorophenol indophenol) titration method was followed to evaluate vitamin C (mg/100g) (Lekhoni et al., 2024; Munira et al., 2025; Nerdy, 2018).

$$\text{Vitamin C (mg/100g}^{-1}\text{)} = \frac{e \times d \times b}{c \times a}$$

Where *a* is the weight of the specimen, *b* is the volume produced with metaphosphoric acid, *c* is the volume of the aliquot, *d* is the dye factor, and *e* is the mean burette reading. Three measurements were taken for each of TSS, TA, and vitamin C at every date.

Assessment of Disease Incidence (%) and Disease Severity (%)

Disease incidence is defined as the percentage of diseased mangos. Fruits with infections were identified by their visual symptoms. Using the following formula, the proportion of disease incidence in mangos was calculated (Dhali et al., 2024; Sivakumar et al., 2002):

$$\% \text{ Disease incidence} = \frac{\text{Number of infected mangos}}{\text{Total number of mangos under study}} \times 100$$

The percentage of the affected area of infected fruit indicates the disease severity and was calculated through eye estimation.

Shelf Life (Days)

The storage life of mangoes was measured by the number of days needed to ripen completely while maintaining optimal eating quality and marketing potential. It was also evaluated using physical parameters: weight loss, skin color, firmness, and disease incidence.

Statistical Analyses

A one-way Analysis of Variance (ANOVA) for single-factor CRD was performed on the data through IBM SPSS Statistics for Windows (Version 27.0.1.0) [IBM Corp. (2020), Armonk, NY, USA]. Tukey's Honestly Significance Difference (HSD) Test was used to compare treatment means at a 5% level using the same software.

Results and Discussion

Cumulative Weight Loss

Weight losses (%) of mango increased gradually throughout storage and varied significantly ($P < 0.05$) at DAT and afterward (Table 1). At the final day of storage (DAT 9), the minimum weight loss was evaluated in CNF 0.3% coated mangoes (16.67%), while the highest weight loss was recorded in the control (27.22%). Similarly, at DATs 5, 6, 7, and 8, CNF 0.3% treated fruits had the lowest weight loss (8.52, 11.027, 11.85, 14.36, respectively) compared to control (10.69, 14.48, 22.52, 25.32, respectively). Chitosan and CNF coatings inhibited mango weight loss (Munira et al., 2025; Parvin et al., 2023; Zhu et al., 2008), which agrees with our present evaluation. It may occur due to a reduction in transpiration rate due to CNF application. Moreover, higher weight was lost for the uncoated mango compared to the chitosan and cinnamon essential oil-treated fruits (Yu et al., 2021).

Table 1. Cumulative weight loss (CWL) of mango as influenced by treatments at different days after treatment (DAT).

Treatments	Cumulative weight loss (%)							
	DAT 2	DAT 3	DAT 4	DAT 5	DAT 6	DAT 7	DAT 8	DAT 9
Control	1.2512 ^a	4.6356 ^a	7.400 ^a	10.699 ^a	14.486 ^a	22.52 ^a	25.320 ^a	27.22 ^a
CNF 0.1%	1.2956 ^a	4.0163 ^{ab}	7.074 ^{ab}	10.44 ^a	12.603 ^{ab}	14.22 ^{bc}	18.180 ^{cd}	20.56 ^b
CNF 0.3%	1.2261 ^a	4.0114 ^{ab}	5.764 ^b	8.520 ^b	11.027 ^b	11.85 ^c	14.367 ^d	16.67 ^c
Chitosan 0.1%	1.2417 ^a	3.9013 ^{ab}	6.485 ^{ab}	10.025 ^a	12.82 ^{ab}	15.64 ^b	19.817 ^{bc}	20.88 ^b
Chitosan 0.3%	1.0300 ^a	3.3601 ^b	5.740 ^b	10.023 ^a	12.56 ^{ab}	14.42 ^{bc}	22.817 ^{ab}	24.56 ^{ab}
<i>P</i>	0.7722	0.0356	0.0142	0.0029	0.0261	<0.001	0.0016	0.002

CNF: Chitin nanofiber. The data represent the mean of three measurements. The mean values were separated by Tukey's HSD Test at 5%. The mean is not statistically different among the treatments if a column has a similar letter(s).

Fruit Firmness

As time passed in storage, the firmness of the mango changed gradually from hard to over-ripe, which is an indicator of fruit ripening. Firmness did not alter from DAT 1 to DAT 2, regardless of the treatments (Table 2). However, the ripening of the mango started from DAT 3 and continued in the later stages of the storage. From DAT 3 to DAT 9, significant variation ($P < 0.05$) among coated and uncoated mango fruits were observed where slower changes were recorded for CNF 0.3% coated fruits (1.33, 2.33, 2.67, 3.33, 3.67, 3.67 and 4) and control fruits showed a drastic change (3, 3.67, 4.33, 4.67, 5.67, 6, and 6). The faster changes in firmness are an indication of a higher ripening rate of control fruits compared to the CNF 0.3% treated

mango. Firmness changed slowly if mango fruits were coated with chitosan (Hasan et al., 2020). These changes in firmness occur as a result of converting starch into sugar.

Changes in Fruit Skin Color

Lightness (L^*) of mango increased during storage which is the indication of ripening (Table 3). However, significant variation ($P < 0.05$) was only observed on DAT 5 where highest L^* value was recorded in chitosan 0.1% coated mango (56.40) which means most luminous yellow color compared to control (47.26). Nunes et al. (2007) found an increased L^* value of mango through chitosan treatment which is in agreement with our present study.

Table 2. Effects of chitin nanofiber (CNF) and chitosan on firmness of mango at different days after treatment (DAT).

Treatments	Firmness								
	DAT 1	DAT 2	DAT 3	DAT 4	DAT 5	DAT 6	DAT 7	DAT 8	DAT 9
Control	0	1	3 ^a	3.67 ^a	4.33 ^a	4.67 ^a	5.67 ^a	6 ^a	6 ^a
CNF 0.1%	0	1	1.67 ^{ab}	2.67 ^a	4 ^a	4 ^a	4.67 ^b	5 ^b	5.33 ^b
CNF 0.3%	0	1	1.33 ^{ab}	2.33 ^{ab}	2.67 ^b	3.33 ^b	3.67 ^c	3.67 ^c	4 ^c
Chitosan 0.1%	0	1	1 ^b	1.67 ^b	3.33 ^{ab}	4 ^a	4.67 ^b	5 ^b	5.33 ^b
Chitosan 0.3%	0	1	2 ^{ab}	2.67 ^a	3.33 ^{ab}	4.67 ^a	4.67 ^b	5.67 ^{ab}	5.67 ^{ab}
<i>P</i>	-	-	0.0149	0.0215	0.0226	0.0435	0.0085	0.0001	0.0027

Firmness was measured hedonically based on a scale of 1-6, in which 1 = Hard green, 2 = Sprung, 3 = Between sprung and eating ripe, 4 = Eating ripe, 5 = Over ripe, 6 = rotten. The error bar represents the mean \pm SE (standard error) of three measurements. ** means significance at a 1% probability.

The value of a^* changed from negative to positive with the advancement of storage period which is the indication of reduction of greenness (Table 3). The value of a^* was only statistically significant at DAT 5 where more negative a^* value was recorded for chitosan 0.1% (-2.10) and the value of control was 2.30. A positive shifting of a^* value indicates increased ripening and redness. A similar result was also found by Ngo et al. (2021) in mango fruits by nano-chitosan treatment.

The value of b^* gradually increased from DAT 1 to DAT 7 regardless of the treatments (Table 3). However, on

DAT 9, the value started declining as a result of fruit senescence and the darkness of the mango peel. On final day of storage, highest retention of b^* value was obtained in CNF 0.1%, chitosan 0.1% and chitosan 0.3% retaining the value of 30.52, 30.75 and 30.57, respectively. In this way, no significant variation was found among treatments while the lowest value was evaluated for control (27.85). Munira et al. (2025) did not find any differences in b^* values among coated fruits of mango when used CNF as a postharvest treatment but the changes were slower in coated fruits than control. These findings are similar to our current investigation.

Table 3. Every alternate day fruit color (L*, a*, b*, Chroma (C*), and h°) of mango as affected by treatments at postharvest.

Treatments	DAT 1	DAT 3	DAT 5	DAT 7	DAT 9
L*					
Control	47.38a	47.47a	47.26a	50.52a	52.32a
CNF 0.1%	49.03a	48.10ab	51.11b	55.13a	56.61ab
CNF 0.3%	47.43a	48.08ab	50.74b	53.09a	54.32ab
Chitosan 0.1%	50.77a	51.88ab	56.40c	56.45a	59.56b
Chitosan 0.3%	47.24a	49.20b	49.33a	54.61a	54.98b
<i>P</i>	0.4240	0.1950	0.0130	0.8280	0.0977
a*					
Control	-2.07ab	0.35a	2.30a	7.84a	9.99a
CNF 0.1%	-1.87ab	-0.92a	-0.80c	6.17a	7.24a
CNF 0.3%	-1.24a	-0.99a	-0.79c	3.95a	6.36a
Chitosan 0.1%	-3.07b	-2.04a	-2.10b	4.87a	8.39a
Chitosan 0.3%	-1.54a	-1.88a	-1.44b	5.60a	7.96a
<i>P</i>	0.0595	0.5058	0.0229	0.7544	0.7139
b*					
Control	17.01b	19.90a	26.21a	31.83a	27.85b
CNF 0.1%	23.48a	23.16a	28.42a	33.29a	30.52ab
CNF 0.3%	16.01b	17.64a	19.74b	30.94a	29.00b
Chitosan 0.1%	20.54a	22.30a	28.15a	33.09a	30.75ab
Chitosan 0.3%	15.16b	17.61a	25.36ab	32.96a	30.57ab
<i>P</i>	0.0376	0.3005	0.0998	0.6885	0.0916
Chroma (C*)					
Control	17.14b	20.01a	26.39a	32.87a	24.23b
CNF 0.1%	18.23b	22.25a	23.50ab	30.96a	27.31b
CNF 0.3%	17.06b	18.68a	19.94b	31.57a	28.82b
Chitosan 0.1%	20.76a	22.42a	28.30a	33.59a	30.15a
Chitosan 0.3%	15.23b	17.69a	25.53ab	33.44a	27.51b
<i>P</i>	0.0369	0.2811	0.0892	0.7667	0.1599
Hue (h°)					
Control	96.86ab	89.43a	84.71b	76.15a	70.91a
CNF 0.1%	94.62ab	92.70a	90.25a	78.48a	77.86a
CNF 0.3%	94.27b	93.20a	89.06ab	83.40a	78.28a
Chitosan 0.1%	97.96a	95.88a	94.72a	81.88a	74.45a
Chitosan 0.3%	95.01ab	94.78a	92.99a	80.43a	73.60a
<i>P</i>	0.1542	0.6205	0.0196	0.6794	0.6725

Data presented as mean, where an L* is lightness (0 = black and 100 = white); a* (negative = greener and positive = redder); and b* (negative = bluer, positive = more yellow). Chroma (C*) means color saturation and h° represents hue angle.

A progressive increase was found in C* value of mango from DAT 1 to DAT 7 irrespective of the treatments (Table 3). However, the value started to reduce after DAT 7, and on the final day of storage, the highest value was recorded for chitosan 0.1% (30.15), and the lowest was in the control (24.23), indicating changes in mango peel from greener to yellow. According to Al-Dairi & Pathare (2024), an initial increase of C* value was observed in banana and our study also followed similar trend.

The hue angle of mango (h°) substantially reduced throughout the storage, and all treatments followed a similar trend, including control (Table 3). However, the difference was only significant ($P < 0.05$) on DAT 5, where maximum retention was evaluated for Chitosan 0.1% coated fruits (94.72), whereas the lowest value

was observed in the control (84.71). However, on DAT 9, CNF 0.1% and 0.3% CNF showed maximum hue angle, which was 77.86 and 78.28, respectively, compared to the control (70.91) showing a delay in the ripening process of mango. Ngo et al. (2021) and Munira et al. (2025) also observed a decreasing trend in h° with pectin/nano-chitosan and chitin nanofiber coating that is similar to our study.

Chemical Attributes

With the advancement of maturity, titratable acidity (TA) of Amrapali mango declined for all treatments (Table 4), including control, with a statistically significant ($P < 0.05$) difference. As a postharvest treatment, CNF 0.1% coating had the highest TA retention capacity (0.47%, 0.43%, 0.31%, 0.29% and 0.28%) followed by CNF 0.3% (0.41%, 0.44%, 0.26%,

0.27% and 0.26%) on DATs 1, 3, 5, 7 and 9 respectively while uncoated control had the lowest value of TA (0.44%, 0.40%, 0.22%, 0.18% and 0.12%). The 'Amropali' mango had the highest TA content when coated with chitosan oligosaccharides (Nitu et al., 2025). These findings are similar to our present study. Significant differences ($P < 0.05$) in TSS content of mango were recorded with the increase in ripening process (Table 4). From DAT 1 to DAT 5, TSS increased gradually and then declined. On DAT 9, the lowest TSS was recorded for CNF 0.3% (13°Brix), while the maximum was found in the control (21.33°Brix). Mangoes coated with chitosan and cinnamon oil showed similar TSS content (Yu et al., 2021).

In comparison to the coated mangos, the uncoated fruits showed a larger decrease in vitamin C concentration (Table 4), which indicates enhancement of ethylene production and senescence in uncoated fruits. As a postharvest treatment, chitosan 0.3% coating showed maximum vitamin C retention capacity and which was 20.89, 25.42, 19.76, and 20.92 mg/100g on DATs 3,5,7, and 9, respectively. In contrast, at the similar DATs, control had the lowest vitamin C content (19.29, 21.60, 15.40, and 14.58 mg/100g, respectively).

Likewise, untreated fruit had the lowest vitamin C concentration, whereas mangoes treated with chitosan showed the highest retention (Parvin et al., 2023). These changes may occur due to the film-forming capacity of chitosan, which can reduce physiological and biochemical processes (Ngo et al., 2021). Nevertheless, for all treatments, the amount of vitamin C steadily reduced as the fruits started to decay and the amount of vitamin C declined (Munira et al., 2025).

Incidence and Severity of Disease

The signs of disease started from DAT 4 (Table 5). However, significant differences were observed on DAT 5. Untreated mangoes showed a rapid increase in disease, while the lowest was recorded in chitosan 0.3% coated fruits during the storage period. As a postharvest treatment, chitosan 0.3% restricted the disease incidence by creating a barrier to oxygen and carbon dioxide as an antimicrobial agent, where the incidence was 2.77%, 8.33%, 16.66%, 19.44%, 27.55% and 33.33% from DAT 4 to DAT 9, respectively. According to the evaluation by Parvin et al. (2023), chitosan coating reduced the disease incidence of mango, similar to our study.

Table 4. Effects of chitin nanofiber (CNF) and chitosan on total soluble solid (TSS, °Brix), titratable acidity (TA %), and vitamin C content (mg 100g⁻¹) of mango at different days after treatment (DAT).

Treatments	DAT 1	DAT 3	DAT 5	DAT 7	DAT 9
TA (%)					
Control	0.4410 ^c	0.4087 ^c	0.2263 ^b	0.1803 ^c	0.1233 ^c
CNF 0.1%	0.4747 ^b	0.4373 ^b	0.3133 ^a	0.2967 ^a	0.2800 ^a
CNF 0.3%	0.4177 ^a	0.4493 ^a	0.2667 ^b	0.2713 ^a	0.2670 ^{ab}
Chitosan 0.1%	0.4757 ^b	0.3780 ^d	0.2143 ^{ab}	0.2620 ^{ab}	0.2077 ^b
Chitosan 0.3%	0.4900 ^b	0.4187 ^c	0.2967 ^a	0.2253 ^b	0.2520 ^{ab}
<i>P</i>	<0.001	<0.001	0.0392	0.0010	0.0007
TSS (°Brix)					
Control	7.6667 ^c	15.667 ^c	25.000 ^a	21.667 ^a	21.333 ^a
CNF 0.1%	12.667 ^a	20.000 ^a	22.667 ^b	19.000 ^b	17.333 ^b
CNF 0.3%	7.3333 ^c	14.667 ^d	19.667 ^c	16.000 ^c	13.000 ^c
Chitosan 0.1%	10.333 ^b	17.000 ^b	22.000 ^c	19.000 ^b	18.000 ^{ab}
Chitosan 0.3%	7.3333 ^c	17.667 ^b	23.000 ^b	21.333 ^a	18.333 ^{ab}
<i>P</i>	<0.001	<0.001	<0.001	0.0002	0.0068
Vitamin C (mg/100g)					
Control	15.560 ^b	19.290 ^c	21.600 ^c	15.407 ^c	14.587 ^c
CNF 0.1%	15.120 ^b	20.900 ^a	21.290 ^d	18.230 ^b	17.690 ^b
CNF 0.3%	15.850 ^{ab}	20.250 ^b	21.390 ^{cd}	18.600 ^{ab}	19.790 ^{ab}
Chitosan 0.1%	16.490 ^a	20.860 ^a	22.060 ^b	18.567 ^{ab}	19.500 ^{ab}
Chitosan 0.3%	16.590 ^a	20.890 ^a	25.420 ^a	19.767 ^a	20.920 ^a
<i>P</i>	0.0242	0.0001	<0.001	0.0008	0.0032

The data represent the mean of three measurements. The mean values were separated by Tukey's HSD Test at 5%. The mean is not statistically different among the treatments if a column has a similar letter(s).

Table 5. Disease Incidence (%) of mango as influenced by treatments at postharvest.

Treatments	DAT 1	DAT 2	DAT 3	DAT 4	DAT 5	DAT 6	DAT 7	DAT 8	DAT 9
Disease incidence (%)									
Control	0	0	0	8.33a	24.97a	52.77a	66.66a	83.33a	100a
CNF 0.1%	0	0	0	2.77b	11.11b	16.66b	33.33b	44.44bc	72.22b
CNF 0.3%	0	0	0	2.77b	8.33b	19.44b	27.77b	49.97b	77.77b
Chitosan 0.1%	0	0	0	8.33a	13.88b	19.44b	27.77b	44.44bc	63.88b
Chitosan 0.3%	0	0	0	2.77b	8.33b	16.66b	19.44b	27.55c	33.33c
<i>P</i>	-	-	-	0.4516	0.0374	0.0013	0.0384	0.0016	0.0006

The mean values were separated by Tukey's HSD Test at 5%. The mean is not statistically different among the treatments if a column has a similar letter(s).

Table 6. Disease Severity (%) of mango as influenced by treatments at postharvest.

Treatments	DAT 1	DAT 2	DAT 3	DAT 4	DAT 5	DAT 6	DAT 7	DAT 8	DAT 9
Disease severity (%)									
Control	0	0	0	9.00 ^a	9.72 ^a	19.58 ^a	61.76 ^a	79.23 ^a	99.33 ^a
CNF 0.1%	0	0	0	5.83 ^b	5.83 ^{ab}	12.72 ^{ab}	17.88 ^{bc}	36.33 ^b	56.46 ^b
CNF 0.3%	0	0	0	6.67 ^b	6.67 ^{ab}	7 ^b	31.67 ^{bc}	53.88 ^{ab}	61.49 ^b
Chitosan 0.1%	0	0	0	8.33 ^{ab}	8.33 ^a	13.61 ^{ab}	41.27 ^{ab}	60.92 ^{ab}	55.92 ^b
Chitosan 0.3%	0	0	0	2.67 ^b	2.67 ^b	5.77 ^c	11.06 ^c	15.39 ^c	23.92 ^c
<i>P</i>	-	-	-	0.0941	0.0966	0.0325	0.0088	0.0181	0.0001

The mean values were separated by Tukey's HSD Test at 5%. The mean is not statistically different among the treatments if a column has a similar letter(s).

Severity of disease was substantially reduced by chitosan treatment throughout the storage period (Table 6). From DAT 4 to DAT 9, severity was increased gradually, irrespective of the treatments. Among all treatments, chitosan 0.3% coating was more effective and significantly superior to control as well as other treatments. On the final day of storage, control showed maximum disease severity (99.33%), whereas fruits coated with chitosan had only 23.92%. Other treatments, including CNF 0.1%, CNF 0.3%, and chitosan 0.1% reduced the severity of disease, which was 56.46%, 61.49%, and 55.92%, respectively, on DAT 9. Similarly, Chitosan and 1-MCP reduced disease severity as reported by Wongmetha and Ke (2012).

Shelf Life

Chitin nanofiber extended the keeping period of mangoes in storage. The highest shelf life (6.67 days) was in mangoes coated with chitosan 0.1% and chitosan 0.3%, which were statistically similar to CNF 0.1% (5.67 days) and CNF 0.3% (5.67 days) (Figure 1). The lowest shelf life (4.83 days) was recorded from the control (Figure 1). Chitosan (0.1%) extended the storage life of mangoes by 1.84 days compared to the control. Similarly, irradiated chitosan also extended the shelf life of mangoes (Abbasi et al., 2009). Moreover, chitosan and chitosan with cinnamon oil extended the shelf life of mangoes (Yu et al., 2021; Parvin et al., 2023).

Mechanism of Action

The comparable efficacy of 0.1% and 0.3% chitosan in preserving mango postharvest quality can be attributed to a saturation effect. Chitosan forms a semi-permeable coating on the fruit surface, which acts as a barrier to moisture loss and reduces respiration, thereby slowing senescence and delaying ripening (Ribeiro et al., 2007). This film also limits the penetration of pathogens, contributing to reduced disease incidence. Once a threshold concentration of chitosan is reached, additional increases do not substantially improve these barrier properties, which explains why 0.1% and 0.3% concentrations exhibit similar protective effects.

Beyond its physical barrier function, chitosan exhibits antimicrobial activity by interacting with microbial cell membranes. These interactions increase membrane permeability, induce leakage of cellular contents, and inhibit pathogen growth, effectively reducing both disease incidence and severity (Nasaj et al., 2024). The results suggest that 0.1% chitosan already achieves sufficient antimicrobial action to control surface pathogens, and increasing the concentration to 0.3% provides only marginal additional benefit. By simultaneously limiting moisture loss, respiration, and microbial proliferation, chitosan coatings not only extend the shelf life of mangoes but also help preserve key chemical attributes, including vitamin C and total soluble solids.

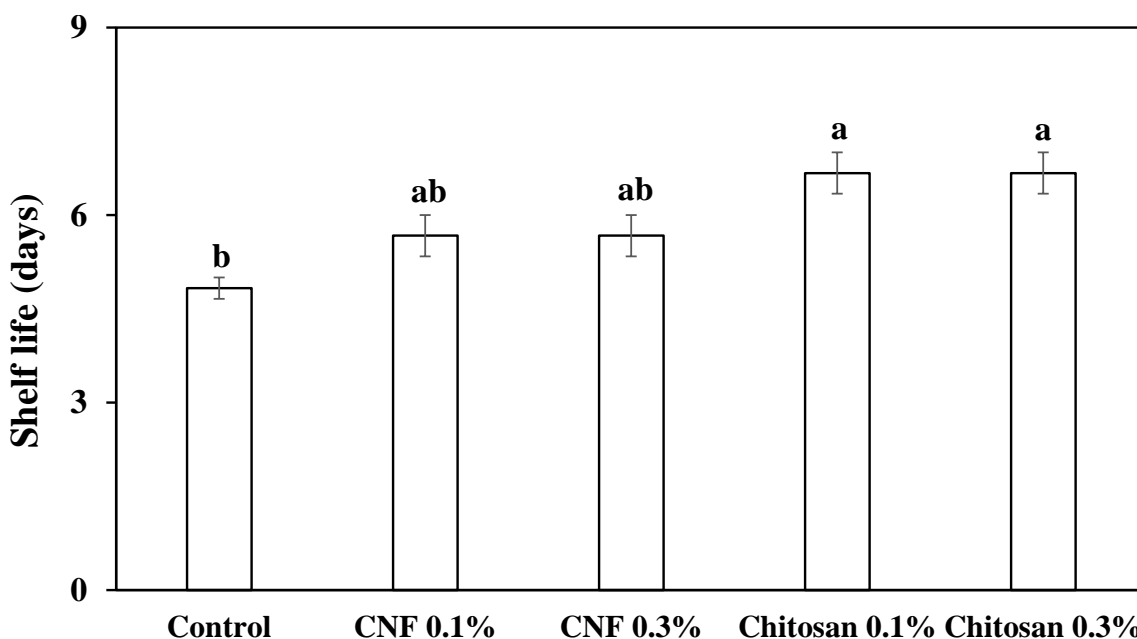


Figure 1. Effects of chitin nanofiber (CNF) and chitosan on the shelf life of mangoes. The error bar represents mean \pm SE (standard error). The treatment means are separated by Tukey's HSD Test at a 5% probability.

In contrast, chitin nanofiber (CNF) primarily enhances physical quality parameters, such as firmness and weight retention, by forming a dense nanofiber network on the fruit surface. This network reduces transpiration, reinforces the fruit structure, and delays softening, which explains the improved firmness and lower weight loss observed in CNF-treated mangoes (Ifuku et al., 2009). However, CNF lacks intrinsic antimicrobial properties, which accounts for its lower effectiveness in controlling postharvest pathogens compared with chitosan.

These differences underscore the distinct mechanisms underlying CNF and chitosan activity: CNF is more effective at maintaining structural integrity, while chitosan offers dual protection, combining physical barrier and antimicrobial effects. Consequently, chitosan is better suited for extending shelf life and controlling disease, whereas CNF can be particularly useful when the primary goal is to preserve firmness and minimize weight loss. Selecting the appropriate coating thus depends on the desired postharvest outcome—whether structural maintenance or comprehensive quality and disease management.

Conclusion

Chitosan coating significantly enhanced shelf-life extension in mangoes by preserving key physicochemical quality parameters. The 0.1% chitosan treatment was the most effective, extending the shelf life of Amrapali mangoes by nearly two days, whereas 0.3% chitosan, although beneficial, was less efficient

than the lower concentration, suggesting a concentration-dependent response in shelf-life regulation. Although CNF had positive effects regarding postharvest mango management, it was less effective than chitosan. However, as the effectiveness of the treatment varies due to varied concentrations, further research is required for other mangoes and different fruits. Economically, the adoption of low-dose chitosan coatings could substantially lower postharvest losses, prolong marketing periods, and enhance profitability for mango producers and supply-chain stakeholders.

Authors contribution

Md. Yamin Kabir: Supervision, Analysis, Writing – review & editing; Safayet Akon: Methodology, and Investigation; Shirazoom Munira: Analysis and Writing; Fouzia Fariha Nila: Methodology and Investigation

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Competing interest

The authors report that there are no competing interests to declare.

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