

FOOD INNOVATION FOR EXTENDING SHELF LIFE OF WHITE SHRIMP, TILAPIA, AND *NAM DOK MAI* MANGO WITH CHITOSAN EXTRACTED FROM LEFTOVER WHITE SHRIMP SHELL

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Abstract

This study repurposes white shrimp shells, an agricultural waste, to extract chitosan—a natural biopolymer with antimicrobial properties—for enhancing food safety and extending shelf life. Chitosan was extracted using a simple, cost-effective process involving chemical treatments and drying. The extracted chitosan, characterized as high DA chitosan (% DA = 75.93 ± 1.40) with enhanced solubility, with functional groups similar to those found in commercial chitosan. Preservation tests demonstrated that the extracted chitosan effectively extended the shelf life of unpeeled shrimp by 3-5 days, peeled shrimp by 1-2 days, and tilapia by 2-3 days while maintaining sensory quality, including color, pH stability, and odor control. For *Nam Dok Mai* mangoes, chitosan coatings at the peduncle area preserved marketable quality for up to 10 days. This method provides a cost-effective, sustainable solution for local producers, promoting value-added agricultural practices and benefiting both seafood and fruit preservation.

Keywords: Chitosan Extraction; Shelf-Life Extension; Natural Preservatives; Agricultural Waste Utilization; Seafood Preservation; *Nam Dok Mai* Mango Coating

Introduction

The freshness of food is essential for human health, consumer acceptance, and international trade, particularly for highly perishable products like seafood, fruits, and meats (Arancibia *et al.*, 2015). Various methods, including refrigeration, vacuum packaging, and irradiation, are employed to extend shelf life, but these approaches can be costly and often insufficient to meet market demands (Jeon *et al.*, 2002). Additionally, synthetic preservatives

such as antioxidants and antimicrobials are commonly used, but growing consumer preferences for preservative-free foods are pushing researchers to explore natural alternatives.

Chitosan [(1,4)-2-amino-2-deoxy-D-glucose], a biodegradable biopolymer derived from shrimp and crab shells, has garnered attention for its antimicrobial properties and ability to enhance food safety and shelf life (Priyadarshi and Rhim, 2020).

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Chitosan can be applied as a food coating to improve quality by delaying lipid oxidation, reducing protein degradation, minimizing odors, and preventing discoloration (Arancibia *et al.*, 2015). Despite its potential, commercially available chitosan-based food packaging remains limited, highlighting the need for further research into sustainable food preservation solutions (Harugade *et al.*, 2023).

The disposal of shrimp shells, a byproduct of the seafood industry, contributes to environmental waste. However, shrimp shells are rich in chitin, which can be converted into chitosan for food preservation, thus repurposing waste into a valuable resource and reducing environmental impact (Rossi *et al.*, 2024; Wani *et al.*, 2024).

Using chitosan as a natural preservative offers economic benefits for local producers. By utilizing locally sourced shrimp shells, small-scale producers can access a cost-effective method that extends the shelf life of their products, enhancing marketability and reducing losses (Zulkarnain *et al.*, 2024). This study explores the use of chitosan extracted from local shrimp shells in Samut Prakan to offer an eco-friendly, cost-effective approach to food preservation.

Materials and Methods

Chitosan Extraction

Shrimp shells (100 g) were washed with distilled water, dried at 70°C, and ground. The ground shells were soaked in 2M NaOH (1:16 w/v) for 24 hours at room temperature with continuous stirring to remove proteins. The mixture was filtered and washed until neutral. To remove minerals, the treated shells were soaked in 1M HCl (1:16 w/v) for 24 hours, followed by filtration and washing to neutral pH. The chitin was deacetylated by soaking in 50% NaOH (1:10 w/v) for 24 h., filtered, washed to neutral pH, and dried at 70°C.

Chitosan Solution Preparation

A 2% w/v chitosan solution was prepared by dissolving 1 g of chitosan in 100 mL of 0.1 M HCl with continuous stirring for 2 hours. The final solution was adjusted to 2% w/v by adding 2% v/v acetic acid.

Sample Coating

Shrimp and Tilapia

Non-living white shrimp (*Litopenaeus vannamei*) and tilapia (*Oreochromis niloticus*) were coated by dipping in a 2% w/v chitosan solution prepared in 2% v/v acetic acid. The samples were stored at 4-5°C for analysis of color, pH, and odor.

Mangoes

Whole *Nam Dok Mai* mangoes (*Mangifera indica*) were coated in a 2% w/v chitosan solution in 2% v/v acetic acid. Three treatments were applied: one layer, two layers, and coating only at the peduncle. The coated mangoes were dried and stored at room temperature for analysis of color, weight loss, firmness, and pH.

Analysis

Degree of Deacetylation

Chitosan solution was titrated with 0.1 M NaOH using Methyl Orange as an indicator until the red solution turned orange-yellow. The volume of NaOH was recorded, and the Degree of Deacetylation (DD) was calculated using the formula:

$$\%DD = \frac{(V1 - V2) \times 16}{V1 \times 9.94 \times x} \times 100$$

Where X is the chitosan weight, V1 is the chitosan volume used for titration, V2 is the volume of NaOH, 9.94 is the theoretical value for NH₂ groups, and 16 is the equivalent weight for NH₂.

Solubility

A 0.1 g sample of chitosan was mixed with 10 mL of 1% acetic acid, vortexed, and left for 30 minutes. The mixture was centrifuged at 9,000 rpm for 10 minutes. The supernatant was discarded, and the precipitate was washed, centrifuged again, and dried at 70°C for 24 hours. The solubility was calculated using the formula:

$$\%Solubility = \frac{A - B}{C} \times 100$$

Where A is the initial weight of the centrifuge tube and chitosan, B is the final weight, and C is the initial chitosan weight.

Fourier Transform Infrared Spectroscopy

The samples were analyzed for functional groups using a Bruker Tensor 27 FT-IR spectrometer with a diamond ATR accessory. Measurements were taken in reflection mode with 64 scans at a spectral resolution of 4 cm⁻¹. The spectra were analyzed using OPUS 7.5 software (Bruker Optics Ltd, Ettlingen, Germany).

Degree of Acetylation

The % Degree of Acetylation (% DA) was calculated using the FTIR absorbance values with the formula:

$$\%DA = \frac{A1655}{A3450} \times 100/1.33$$

Where A₁₆₅₅ and A₃₄₅₀ are absorbances at 1655 cm⁻¹ (Amide-I) and 3450 cm⁻¹ (hydroxyl group), respectively, and 1.33 is the ratio for fully N-acetylated chitosan.

Color

The samples were photographed using an Apple iPhone XR camera (26 mm, f/1.8). Light intensity was measured using the Lux Meter app before each photo. Color measurements were taken at three points on the central part of the sample. The average lightness (L*) and chromaticity coordinates (a* and b*) were calculated.

Odor Intensity

Three testers assessed the odor intensity using their own sense of smell over 9 days. They measured the odor of shrimp and fish samples with or without chitosan coating. The intensity was recorded daily based on their subjective perception.

Weight Loss

Weight loss was measured using a Camry EK 3211 digital scale, and the percentage weight loss was calculated using the formula:

$$\%Weight\ Loss = \frac{W_i - W_f}{W_i} \times 100$$

Where W_i is the initial weight, and W_f is the final weight.

Firmness

The mango firmness was measured using a 9 mm cylindrical probe on the FRUIT SCLEROMETER at a depth of 1.3 cm from the peel.

pH

pH was measured using Macherey-Nagel™ pH Test Strips (pH range 0-14).

Results and Discussion

The study successfully developed a simple method for extracting chitosan from discarded white shrimp shells, as described in the chitosan extraction section, enabling local communities and shrimp traders to perform the extraction without specialized equipment.

As shown in the Table 1, when compared to commercial chitosan, the extracted chitosan demonstrated a lower degree of deacetylation (% DD = 48.83 ± 1.07) and a higher degree of acetylation (% DA = 75.93 ± 1.40), indicating that it belongs to the high DA chitosan category

(60-90 % DA) with enhanced solubility (% Solubility = 95.66 ± 0.45).

Table 1. Chemical properties of extracted chitosan compared to commercial chitosan (n = 5)

	% DD	% Solubility	% DA
commercial chitosan	80.48	95.66	33.88
extracted chitosan	± 5.90	± 0.45	± 0.61
extracted chitosan	48.83	97.82	75.93
extracted chitosan	± 1.07	± 2.17	± 1.40

Furthermore, the Fourier Transform Infrared Spectroscopy (FTIR) absorption spectra revealed that the functional groups in the extracted chitosan were comparable to those in commercial chitosan (Figure 1).

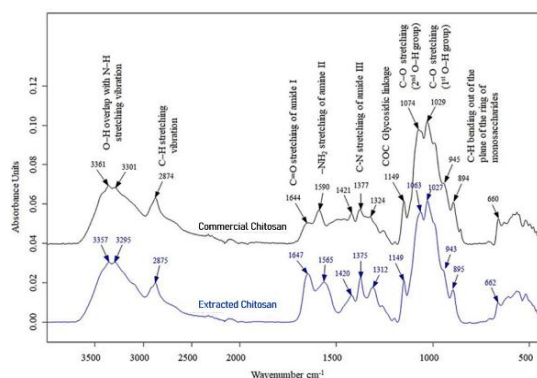


Figure 1. FTIR absorption spectra of extracted chitosan compared to commercial chitosan

In preservation tests, extracted chitosan effectively extended the shelf life of both unpeeled and peeled shrimp by 3-5 days and 1-2 days, respectively, compared to uncoated samples. Coated Unpeeled shrimp coated with extracted chitosan maintained its brightness ($\Delta L^* = -3.67$) and reduced discoloration, with minimal changes in the green-to-red (a*) and blue-to-yellow (b*) spectrums, consistent with Duan *et al.* (2010) (Table 2).

Table 2. Change in LAB color space, pH, and odor of unpeeled white shrimp after 10 days (n = 3)

	ΔL^*	Δa^*	Δb^*	ΔpH	$\Delta odor$
uncoated	-12.34	+0.33	-0.33	+2.00	+4.00
commercial chitosan	-10.64	+2.00	-0.67	+1.70	+3.00
extracted chitosan	-3.67	+1.33	+0.00	+2.00	+3.33

For peeled shrimp (Table 3), all coatings contributed to protein denaturation, leading to a lighter appearance ($L^* > 32$) by day 1. Extracted chitosan proved most effective in slowing pH increases (Nirmal and Benjakul, 2009; Conurso *et al.*, 2016) and odor intensification (Sipahutar *et al.*, 2021). Odor analysis confirmed that coated samples maintained acceptable sensory levels longer, with peeled shrimp showing slower microbial decomposition due to reduced tissue residues (Lopez-Caballero *et al.*, 2007).

Table 3. Change in LAB color space, pH, and odor of peeled white shrimp after 10 days (n = 3)

	ΔL^*	Δa^*	Δb^*	ΔpH	$\Delta odor$
uncoated	-9.67	+0.33	-6.34	+1.00	+3.33
commercial chitosan	+2.34	-0.33	-1.00	+0.30	+2.33
extracted chitosan	+1.00	-0.34	-0.33	+0.30	+3.00

For tilapia (Table 4), extracted chitosan preserved flesh color while extending shelf life by 2-3 days. Tilapia fillets coated with extracted chitosan maintained consistent brightness ($\Delta L^* = 0.00$), while the uncoated and commercial chitosan-coated samples showed increased lightness due to surface mucus buildup ($\Delta L^* = +6.00$ and $+5.00$, respectively). pH analysis indicated that the uncoated samples had the fastest alkalinity increase, linked to bacterial growth (Abbas *et al.*, 2008), with extracted chitosan proving more effective at delaying spoilage.

Table 4. Change in LAB color space, pH, and odor of filleted Tilapia pieces after 10 days (n = 3)

	ΔL^*	Δa^*	Δb^*	ΔpH	$\Delta odor$
uncoated	+6.00	-1.67	+5.67	+1.00	+4.11
commercial chitosan	+5.00	-1.66	+5.66	+0.30	+4.00
extracted chitosan	+0.00	-0.67	+10.33	+0.30	+3.44

For agricultural products like mangoes, chitosan coatings, due to their barrier properties against water vapor and gases (Wang and Jing, 2016; Nagaraja *et al.*, 2024), influenced ripening and preservation by limiting aerobic respiration and ethylene exchange, both essential for ripening (Zaharah *et al.*, 2012; Chen *et al.*, 2022). Coating

the mango peduncle with extracted chitosan preserved its marketable quality—maintaining acceptable color for both the peel and flesh, ripeness, and overall appearance suitable for consumer sale—for up to 10 days, compared to other treatments, which showed undesirable characteristics after just 5 days. The 2-layer chitosan coating minimized weight loss (14.58%) compared to the uncoated samples (18.93%), indicating the effectiveness of thicker chitosan films in moisture retention (Table 5).

Table 5. Change in LAB color space, and weight of *Nam Dok Mai* mangoes after 10 days (n = 3)

	ΔL^*	Δa^*	Δb^*	% weight loss
uncoated	-3.67	+2.34	-3.67	18.93
commercial chitosan	-2.34	+2.00	+1.33	16.39
extracted chitosan (1 layer)	-4.33	+2.33	-2.66	16.01
extracted chitosan (2 layers)	-2.67	+1.33	+0.67	14.58
extracted chitosan (at peduncle)	+0.00	+1.00	+2.67	17.96

Texture analysis of *Nam Dok Mai* mangoes (Table 6) showed that extracted chitosan increased peel rigidity, with higher firmness values (62.11 N/mm for single-layer and 54.59 N/mm for double-layer coatings), while coating the peduncle resulted in the least firm peel (15.04 N/mm). When measuring from the seed side, all treatments showed softening of the mango flesh, consistent with previous studies by Sombatpraiwan *et al.* (2012); Jarimopas and Kitthawee (2007), which reported rapid loss of firmness during ripening. After 10 days, the uncoated mangoes reached full ripeness (pH = 6.33), whereas chitosan-coated mangoes were less ripe (pH = 5.33), suggesting interference with ripening processes. Other treatments had pH values ranging from 4.00 to 4.33, indicating that the mangoes were either not fully ripe or had deteriorated due to interference with chemical processes by the coatings.

These findings highlight the potential of extracted chitosan as a natural preservative for extending the shelf life and quality of both seafood and fruits, offering significant benefits to local producers and consumers.

Table 6. Firmness and pH of *Nam Dok Mai* mangoes at day 10 (n = 3)

	<i>Firmness (N/mm)</i>	<i>pH</i>
uncoated	24.19 ± 13.78	6.33 ± 1.15
commercial chitosan	36.29 ± 12.05	4.00 ± 0.00
extracted chitosan (1 layer)	62.11 ± 26.32	4.00 ± 0.00
extracted chitosan (2 layers)	54.59 ± 39.63	4.00 ± 0.00
extracted chitosan (at peduncle)	15.04 ± 2.47	5.33 ± 1.53

Conclusions

The extraction of chitosan from discarded white shrimp shells offers a cost-effective and accessible method for preserving both seafood and agricultural products. The extracted chitosan demonstrated favorable properties, including a higher degree of acetylation and solubility, which contributed to its effectiveness as a natural preservative. Its ability to extend the shelf life of shrimp and tilapia by 2-5 days, while maintaining sensory quality such as color, pH stability, and odor, highlights its potential for use in food preservation. Additionally, the chitosan coating applied to *Nam Dok Mai* mangoes successfully slowed ripening and reduced moisture loss, preserving fruit quality for up to 10 days.

These findings suggest that extracted chitosan can serve as an effective alternative to synthetic preservatives, benefiting local communities by improving the shelf life and quality of both seafood and fruits. This natural preservative is particularly valuable for small-scale producers who lack access to specialized preservation equipment, promoting sustainable agricultural practices and reducing food waste. Further research into optimizing extraction methods and coating applications could enhance the utility of chitosan in various food preservation contexts.

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