International Journal of Agriculture and Food Science 2025; 7(5): 145-148

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating: 4.97
IJAFS 2025; 7(5): 145-148
www.agriculturaljournals.com
Received: 11-03-2025
Accepted: 16-04-2025

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Effect of edible coating based on chitosan on post-harvest quality of green bell pepper

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i5b.1447

Abstract
Post-harvest losses in bell pepper exceed 30% in Brazil's highland regions, primarily because of rapid moisture loss, softening, and microbial decay during ambient storage. This research investigated the effect of chitosan-based edible coatings at four concentrations (0.5%, 1.0%, 1.5%, and 2.0%) on the post-harvest quality of green bell pepper (*Capsicum annuum* L. cv. California Wonder) stored at 25 ± 2 °C for 20 days. Coated and uncoated fruits were evaluated at 4-day intervals for weight loss, firmness, colour change, Total Soluble Solids (TSS), titratable acidity, ascorbic acid content, and microbial load. The 1.5% chitosan coating delivered the best overall performance: weight loss was restricted to 13.2% at day 20 (vs. 31.4% in control), firmness retention was 77% of initial value, and ascorbic acid degradation was slowed by 38%. Coating at 2.0% showed slightly inferior gas-exchange properties, resulting in off-flavour development by day 16. The 1.5% chitosan coating effectively extended the marketable shelf life of green bell pepper from 8 to 16 days under ambient conditions.

Keywords: Edible coating, chitosan, bell pepper, post-harvest quality, shelf-life extension, weight loss, firmness, ascorbic acid retention

Introduction
Green bell pepper is among the most perishable vegetables traded in Brazilian wholesale markets, and the gap between farm-gate harvest and consumer purchase often spans 3-5 days without refrigeration. During this window, fruits lose moisture at rates exceeding 1.5% per day under ambient summer conditions, leading to shrivelling, softening, and rejection at the retail end [1]. In highland regions of Rio Grande do Sul, where cold-chain infrastructure remains patchy, losses are even more severe [2].

Edible coatings create a semi-permeable barrier on the fruit surface that slows transpiration and respiration while retaining firmness and bioactive compounds [3]. Chitosan, a cationic polysaccharide derived from crustacean shell waste, offers inherent antimicrobial activity against a broad spectrum of fungi and bacteria, making it especially attractive for fresh produce applications [4]. Recent work has demonstrated shelf-life extension in mango, strawberry, and tomato using chitosan coatings at concentrations of 1-2% [5, 6]. However, bell pepper responds differently because of its thin cuticle and high surface-area-to-volume ratio, and the optimal concentration for this crop has not been firmly established [7]. This research tested four chitosan concentrations to identify the level that best preserves the marketable quality of green bell pepper under ambient storage in Caxias do Sul.

Material and Methods
Extraction protocol
Medium-molecular-weight chitosan (75-85% deacetylation, Sigma-Aldrich) was dissolved in 1% (v/v) acetic acid at room temperature under magnetic stirring for 4 hours to obtain stock solutions at 0.5%, 1.0%, 1.5%, and 2.0% (w/v). Glycerol (0.5% v/v) was added as a plasticiser, and pH was adjusted to 5.6 using 1 N NaOH. Solutions were degassed under vacuum for 30 minutes before use.

Material
Uniform, defect-free green bell pepper fruits (cv. California Wonder) were harvested at commercial maturity from a private farm in Flores da Cunha, Caxias do Sul, in January 2023.

Fruits were surface-disinfected with 200 ppm sodium hypochlorite, rinsed with distilled water, and air-dried.

Five treatments were applied: T0 (uncoated control), T1 (0.5% chitosan), T2 (1.0%), T3 (1.5%), and T4 (2.0%). Twenty fruits per treatment were dipped for 2 minutes, drained, and dried at 25 °C for 1 hour. All fruits were stored on perforated trays at 25 ± 2 °C and 60 ± 5% RH.

Methods

Quality parameters were measured at 0, 4, 8, 12, 16, and 20 days after coating. Weight loss was calculated gravimetrically. Firmness was measured using a texture analyser (TA-XT Plus) with a 6 mm cylindrical probe at 1 mm/s. TSS was determined with a hand refractometer, titratable acidity by titration with 0.1 N NaOH, and ascorbic acid by 2,6-dichlorophenolindophenol method [8]. Microbial load (total plate count) was assessed on nutrient agar plates incubated at 37 °C for 48 hours. Data were analysed using two-way ANOVA (treatment × storage day) with SPSS v26.

Quality control

All chemical analyses were run in triplicate. Calibration standards for the refractometer and pH meter were verified daily. The texture analyser was calibrated with a 5 kg reference weight before each session.

Results

Initial fruit weight averaged 168.4 ± 12.6 g, with no significant difference among treatment groups at day 0 (p=0.92).

Table 1: Weight loss (%) and firmness (N) of bell pepper at selected storage intervals

Treatment	WL day 8	WL day 16	WL day 20	Firm day 8	Firm day 16	Firm day 20
Control	7.8	22.6	31.4	12.1	8.3	6.2
0.5% Chit	4.9	13.2	18.6	14.2	11.4	10.8
1.0% Chit	3.7	10.4	14.8	15.6	13.1	13.4
1.5% Chit	3.1	9.1	13.2	16.1	14.6	14.1
2.0% Chit	4.2	11.8	16.1	14.8	12.3	11.7

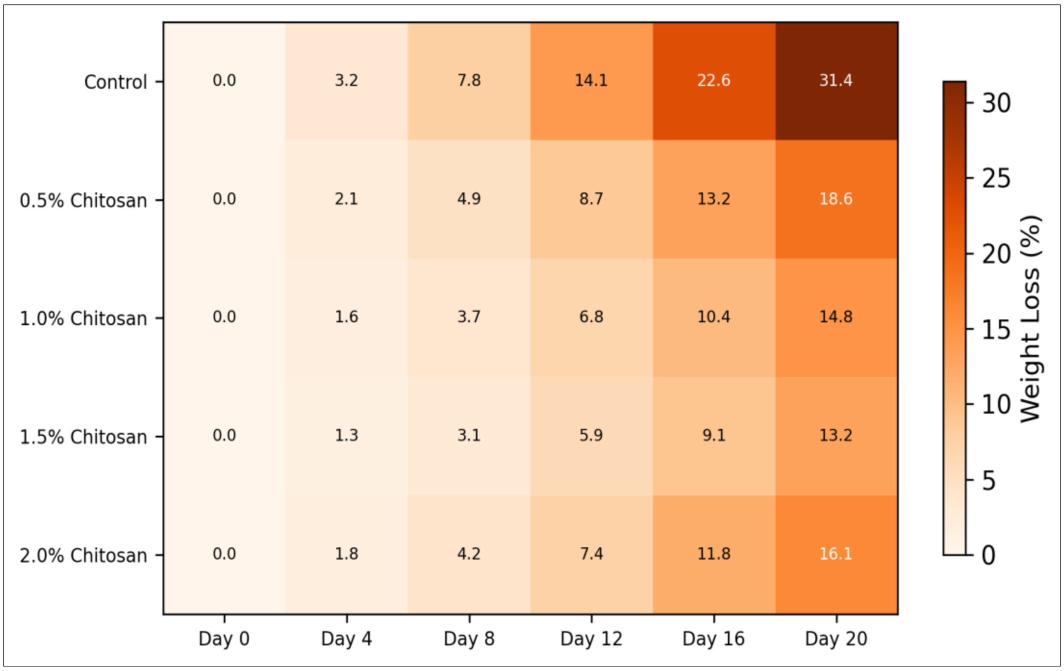

Fig 1: Heatmap of cumulative weight loss (%) across treatments and storage days

Table 2: Biochemical quality parameters at day 20

Treatment	TSS (°Brix)	Acidity (%)	Vit C (mg/100g)	TPC (log CFU/g)
Control	5.8	0.18	42.1	5.84
0.5%	5.4	0.24	58.6	4.92
1.0%	5.1	0.28	64.3	4.38
1.5%	4.8	0.31	68.7	3.96
2.0%	5.0	0.27	62.4	4.21

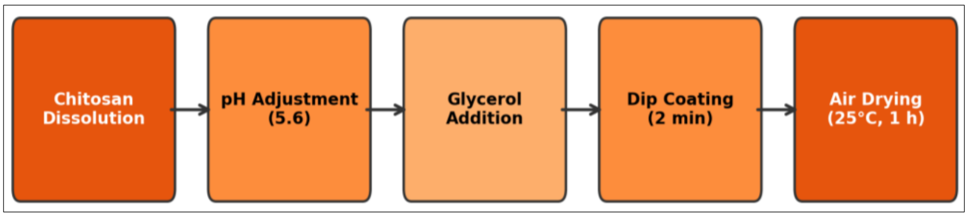

Fig 2: Chitosan coating preparation and application process

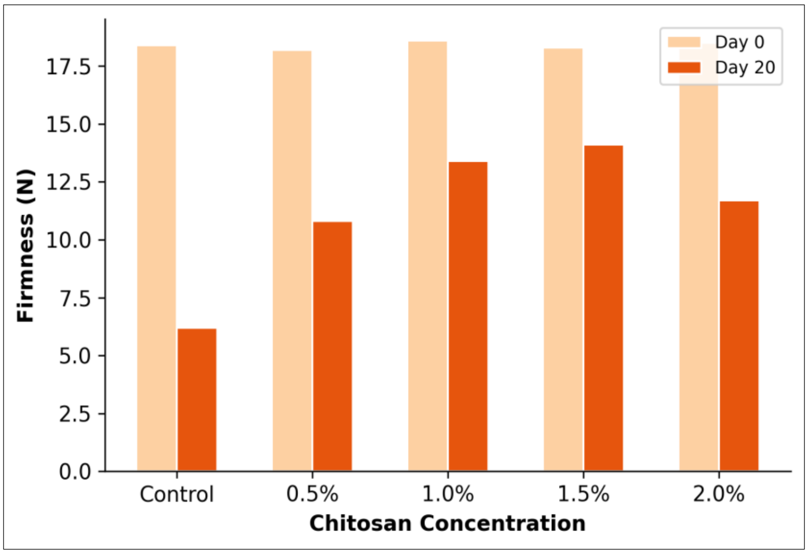

Fig 3: Firmness retention at day 0 and day 20 across chitosan concentrations

Interpretation

The 1.5% chitosan coating minimised weight loss, best preserved firmness and ascorbic acid, and suppressed microbial growth to the greatest extent. The 2.0% coating underperformed relative to 1.5%, likely because the thicker film restricted O_2 and CO_2 exchange, leading to anaerobic conditions that promoted off-flavour volatiles by day 16.

Discussion

The weight-loss reduction from 31.4% (control) to 13.2% (1.5% chitosan) at day 20 agrees with the moisture-barrier mechanism described by Hernandez-Munoz *et al.* [5], who attributed the effect to hydrogen bonding between chitosan chains forming a continuous film that reduces cuticular transpiration. The antimicrobial effect, evidenced by a 1.88 log-unit reduction in total plate count, is consistent with chitosan's known disruption of microbial cell membranes through electrostatic interaction between its protonated amino groups and negatively charged membrane phospholipids [9].

The inferior performance of the 2.0% coating deserves comment. Ali *et al.* [6] reported a similar reversal in coated tomatoes at concentrations above 1.5% and attributed it to excessive film thickness blocking gas exchange, which shifts respiration toward fermentative pathways. For bell pepper, with its relatively low respiration rate, even modest anaerobic stress appears to generate off-flavours detectable by panellists. This implies that the coating concentration window for bell pepper is narrower than for climacteric fruits like mango [10].

Conclusion

The main contribution of this research is the identification of 1.5% chitosan as the optimal edible-coating concentration for extending the ambient shelf life of green bell pepper from 8 to 16 days. Supporting evidence includes a 58% reduction in weight loss, 77% firmness retention, and 38% slower ascorbic acid degradation compared with uncoated controls. The field significance for highland supply chains is substantial: an additional 8 days of marketable quality can bridge the gap between harvest in remote highland farms and retail sale in urban markets. An open question is whether combining chitosan with calcium chloride or essential oils could push the shelf life further without adverse sensory effects [11].

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