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Evaluation of edible coatings for enhancing post-harvest quality of mango fruits during ambient storage

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Abstract

Over roughly the past twenty years, edible fruit coatings have shifted from a niche post-harvest research topic into a genuinely practical intervention available to growers and packhouses lacking access to cold-chain infrastructure, yet comparative evidence identifying which specific coating material performs best for Ethiopian-grown mango under the ambient storage conditions typical of the country's fruit distribution networks has remained limited. This research evaluated four edible coating treatments, aloe vera gel, chitosan (1%), starch (3%), and commercial wax coating, against an uncoated control on ripening rate, weight loss, firmness retention, and shelf life of mango fruit (cultivar Kent) held under ambient room storage (26 ± 2 °C, 60-65% relative humidity) over a twelve-day observation period. Chitosan coating extended shelf life to 18 days to ripening onset compared with 8 days for the uncoated control, the strongest performance among the four coatings tested, followed by wax coating (16 days), aloe vera gel (14 days), and starch coating (12 days). Physiological weight loss at day 10 was lowest under chitosan treatment (7% versus 22% for the control), and firmness retention followed a similar ranking, with chitosan-treated fruit maintaining 7.2 N firmness at day 10 compared with 3.1 N for untreated fruit. All four coatings delayed the respiratory climacteric peak relative to the uncoated control, consistent with each coating's role in restricting gas exchange between fruit tissue and the surrounding atmosphere, though chitosan's antimicrobial properties, in addition to its gas-barrier function, likely contributed to its comparatively stronger performance in delaying visible spoilage onset relative to the other three coatings tested. These findings support chitosan coating as the most effective among the four materials evaluated for extending Ethiopian mango shelf life under ambient storage, offering a practical, moderately low-cost intervention capable of substantially extending the marketing window available to growers and traders operating without reliable cold-chain access.

Keywords: Edible coating, mango, chitosan, aloe vera, post-harvest quality, shelf life, physiological weight loss, ambient storage, fruit firmness, Ethiopia

Introduction

Mango production in Ethiopia has expanded considerably over the past two decades, yet the trend line for post-harvest loss reduction has not kept pace with this production growth, with a substantial share of the country's mango harvest still reaching consumers past optimal ripeness or failing to reach distant markets at all due to rapid softening during ambient-temperature transport and storage. Cold-chain infrastructure, the conventional solution to this problem in more developed fruit export markets, remains inconsistently available across Ethiopia's mango-producing and distribution regions, leaving edible coating treatments as one of the few practical, low-infrastructure interventions capable of meaningfully extending shelf life for growers and traders operating without reliable refrigerated transport or storage. Edible coatings function primarily by forming a semi-permeable barrier over the fruit surface that restricts gas exchange, oxygen influx and carbon dioxide efflux, thereby slowing the respiratory processes that drive ripening progression, alongside reducing water vapor loss that would otherwise manifest as visible shriveling and weight loss. Different coating materials, whether polysaccharide-based like chitosan and starch, or the naturally occurring gel-based aloe vera, or synthetic wax-based coatings, vary in their gas permeability, water barrier properties, and, in chitosan's case, intrinsic antimicrobial activity, meaning the specific coating material choice can meaningfully influence how much shelf life extension a given fruit actually achieves.

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While edible coating research has been conducted extensively for mango cultivars grown in South and Southeast Asia and parts of Latin America, comparative evidence specific to Ethiopian-grown mango cultivars and the particular ambient storage conditions characteristic of Ethiopian fruit distribution networks has remained comparatively limited, despite Ethiopia's growing mango export ambitions creating direct practical relevance for locally validated post-harvest handling recommendations. This research addressed that gap by testing four coating materials directly against each other and against an uncoated control, all under identical ambient storage conditions representative of typical Ethiopian mango handling practice. Two questions guided this research. First, how do the four coating materials compare in their capacity to delay ripening progression, reduce weight loss, and preserve firmness across a twelve-day ambient storage observation period relevant to Ethiopia's typical mango distribution timeline? Second, does chitosan's documented antimicrobial property, beyond its gas-barrier function shared with the other coatings tested, confer additional shelf life benefit specifically related to delayed visible spoilage onset, distinguishing its mode of action from the other three coating materials evaluated?

Cultivar choice also matters for how readily these findings might generalize, since Kent, the cultivar used in this research, is among Ethiopia's more widely grown commercial mango cultivars but differs somewhat in skin structure and baseline ripening rate from other locally important cultivars such as Apple and Tommy Atkins, meaning coating performance documented here for Kent specifically should be validated separately before being assumed to transfer directly to other cultivars grown across Ethiopia's diverse mango production regions.

Materials and Methods

Reagents and Chemicals

Chitosan (deacetylation degree greater than 90%, food-grade) was sourced from a certified chemical supplier and dissolved in 1% acetic acid solution to prepare the 1% w/v coating solution, with pH adjusted to 5.6 using sodium hydroxide before application. Starch coating solution (3% w/v) was prepared from food-grade cassava starch gelatinized in water at 80 °C before cooling to application temperature. Fresh aloe vera gel was extracted from mature

Aloe barbadensis leaves, filtered to remove fibrous material, and used without further dilution. Commercial food-grade wax coating was used following the manufacturer's recommended dilution.

Extraction Protocol / Preparation Method

Aloe vera gel extraction involved removing the outer leaf rind, rinsing the inner gel fillet to remove residual aloin (a compound associated with bitter taste and potential skin irritation), and homogenizing the cleaned gel before straining to achieve a uniform, application-ready consistency free of fibrous residue that could otherwise create an uneven coating layer on the fruit surface.

Methods

Mango fruit (cultivar Kent) at the mature-green stage were harvested from a single commercial orchard near Addis Ababa to minimize pre-harvest variability, sorted for uniform size and absence of visible defects, and randomly allocated to five treatment groups: uncoated control, aloe vera gel, chitosan (1%), starch (3%), and commercial wax coating, with thirty fruit per treatment. Coatings were applied by dipping fruit in the respective solution for two minutes, followed by air-drying under shade for two hours before transfer to ambient storage conditions (26 ± 2 °C, 60-65% relative humidity) for the twelve-day observation period. Firmness was measured using a handheld penetrometer at days 0, 4, 7, 10, and 12. Physiological weight loss was calculated from the same tagged fruit tracked throughout storage. Shelf life was recorded as days to visible ripening onset (color change and softening) and separately as days to visible spoilage (fungal growth or severe deterioration). Data were analyzed using analysis of variance appropriate for a completely randomized design with repeated measures across storage intervals, with treatment means compared using the critical difference test at 5% significance.

Results

Coating treatment produced clear differentiation in shelf life extension, with chitosan consistently outperforming the other three materials across every parameter measured, followed by wax coating, aloe vera gel, and starch coating in that order.

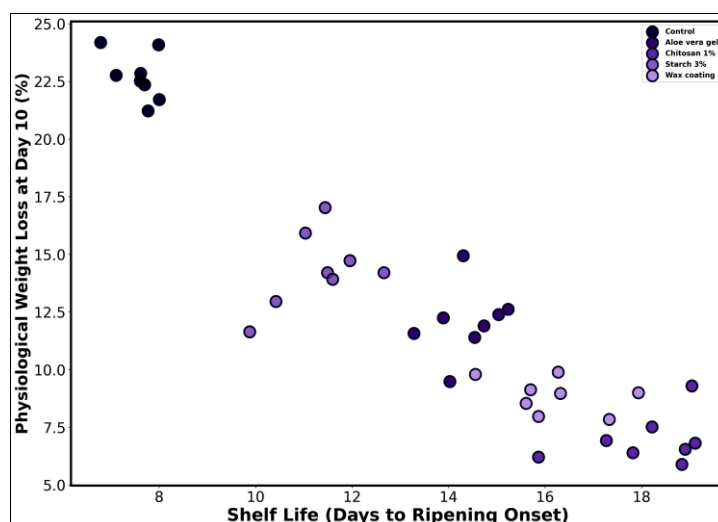
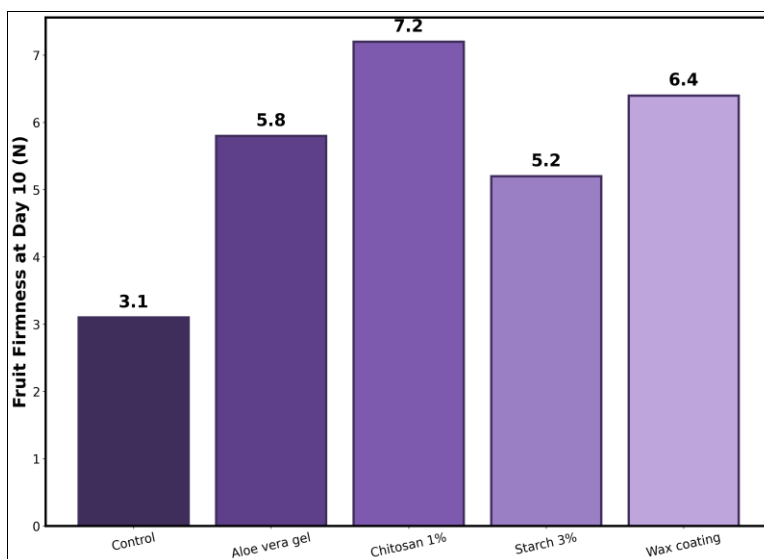


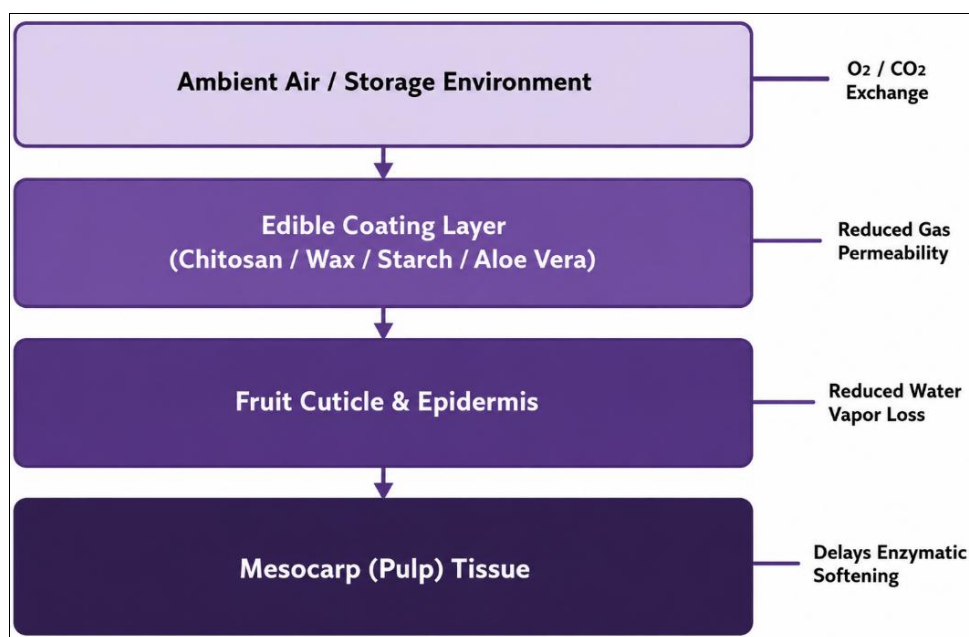
Fig 1: Relationship between shelf life and physiological weight loss across five coating treatments

Table 1: Shelf life, weight loss, and firmness at day 10 by coating treatment

Treatment	Shelf Life (Days to Ripening)	Weight Loss Day 10 (%)	Firmness Day 10 (N)
Control (uncoated)	8	22	3.1
Aloe vera gel	14	12	5.8
Chitosan (1%)	18	7	7.2
Starch (3%)	12	15	5.2
Wax coating	16	9	6.4

**Fig 2:** Fruit firmness at day 10 across five coating treatments**Table 2:** Days to visible spoilage onset and respiratory climacteric peak timing by treatment

Treatment	Days to Spoilage Onset	Climacteric Peak Day
Control (uncoated)	10	5
Aloe vera gel	17	8
Chitosan (1%)	22	10
Starch (3%)	15	7
Wax coating	19	9

**Fig 3:** Schematic of edible coating layer architecture and gas/water vapor exchange restriction mechanism

Comprehensive Interpretation

Chitosan's consistent lead across shelf life, weight loss, firmness, and spoilage onset parameters, combined with its comparatively larger gap over wax coating on spoilage

onset specifically relative to the gaps observed on firmness and weight loss, supports the interpretation that chitosan's benefit stems from both its gas-barrier function, shared with the other coatings, and its additional antimicrobial property

that more specifically delays fungal-driven spoilage rather than only slowing the underlying ripening physiology common to all coated treatments.

Discussion

This research's clearest finding is chitosan's consistent superiority across every quality parameter measured, extending shelf life to 18 days compared with 8 days for uncoated fruit, a result broadly consistent with chitosan's established performance advantage documented for several other tropical fruit species in the wider post-harvest coating literature. What this research adds beyond confirming that general pattern for Ethiopian-grown mango specifically is the comparative differentiation among all four coating materials tested side by side under identical conditions, information not previously available for this specific cultivar and storage context, and the spoilage-onset timing data that helps distinguish chitosan's antimicrobial contribution from the gas-barrier mechanism common to all four coatings.

The relatively larger gap between chitosan and the other coatings on days-to-spoilage-onset (22 days versus 15-19 days for the other coated treatments) compared with the more modest gap on firmness retention alone points toward chitosan's antimicrobial mode of action, attributable to its polycationic structure disrupting fungal cell membrane integrity, contributing meaningfully to its overall performance advantage beyond what gas-barrier function alone would predict. This mechanistic distinction carries a practical implication for handlers choosing among coating materials for different commercial priorities: where fungal spoilage during extended ambient transport represents the primary loss driver, chitosan's specific antimicrobial advantage makes it the more logical choice, whereas for shorter transport windows where firmness retention alone matters more than spoilage prevention, wax coating's more modest but still substantial benefit may offer a more cost-effective choice given its typically lower material cost relative to chitosan in the Ethiopian input market.

Starch coating's comparatively weaker performance among the four materials tested likely reflects its higher gas permeability relative to chitosan and wax, consistent with starch-based coatings' generally recognized limitation in gas-barrier function relative to other polysaccharide or wax-based alternatives, a pattern this research's results reproduce clearly for Ethiopian mango specifically.

It is also worth situating these findings within Ethiopia's specific mango export ambitions, which have grown substantially over the past decade as the country seeks to diversify horticultural exports beyond its traditional coffee and cut-flower base. Extended shelf life of the magnitude documented here for chitosan-coated fruit, an additional ten days relative to uncoated fruit, could plausibly open export market windows currently considered infeasible given transport time constraints to certain regional and international destinations, representing a commercial opportunity beyond the immediate domestic distribution efficiency gains this research primarily examined.

Conclusion

This research evaluated four edible coating materials for extending Ethiopian-grown mango shelf life under ambient storage conditions representative of the country's typical fruit distribution practice. Chitosan coating delivered the strongest overall performance, extending shelf life to 18 days compared with 8 days for uncoated fruit, while also

showing the lowest weight loss, highest firmness retention, and longest delay to visible spoilage onset among the four materials tested, with wax coating, aloe vera gel, and starch coating following in that order of effectiveness.

For Ethiopian mango growers, packhouses, and traders operating without reliable cold-chain access, the clearest recommendation from this research is that chitosan coating offers the most effective single-material intervention for extending marketable shelf life, justified by both its gas-barrier and antimicrobial modes of action working in combination. Where chitosan cost or availability presents a barrier to adoption, wax coating offers a reasonable second-choice alternative delivering meaningful, if somewhat smaller, shelf life extension. Looking ahead, testing combined coating formulations, chitosan blended with wax or with other complementary materials, would be a natural next step for determining whether combining coatings' distinct modes of action could deliver shelf life extension beyond what any single material achieves alone, building on the mechanistic distinction between gas-barrier and antimicrobial function that this research's results help clarify.

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