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Post-harvest calcium chloride treatments for extending storage life and quality of guava (*Psidium guajava* L.)

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Abstract

Guava (*Psidium guajava* L.) ranks among the more perishable tropical fruits available to Southeast Asian fresh markets, typically softening past marketable firmness within seven to ten days of harvest under ambient storage, a limitation that constrains both farm-gate returns and the geographic reach of fresh guava supply chains. This research evaluated four post-harvest calcium chloride (CaCl₂) dip concentrations—0% (control), 2%, 4%, and 6%—on storage life and quality retention of harvested guava fruit held under ambient room storage (24 ± 2 °C, 65-70% relative humidity) over a fifteen-day observation period. Fruit firmness at day 15 was 45 N for the 6% CaCl₂ treatment compared with 10 N for the untreated control, representing substantially better firmness retention across the full storage period, while physiological weight loss at day 15 reached only 15.3% under 6% CaCl₂ compared with 33.5% for the control. Total soluble solids and titratable acidity retention followed a similar dose-dependent pattern, with higher CaCl₂ concentrations consistently associated with slower ripening progression and reduced spoilage incidence across all measured storage intervals. Composite quality scores derived from firmness, TSS retention, spoilage incidence, acidity retention, visual appeal, and shelf life all favored the 6% CaCl₂ treatment over lower concentrations and the control at every storage interval assessed, though the gain between 4% and 6% CaCl₂ was considerably smaller than the gain between 2% and 4%, suggesting a diminishing-returns pattern beyond the 4% concentration. These findings support post-harvest CaCl₂ dip treatment at 4-6% concentration as a practical, low-cost intervention for extending guava shelf life and preserving fruit quality sufficiently to support wider-radius fresh-market distribution without requiring cold-chain infrastructure that remains inconsistently available across much of the region's guava-producing areas.

Keywords: Calcium chloride, guava, *Psidium guajava*, post-harvest treatment, shelf life, fruit firmness, physiological weight loss, storage quality, ambient storage, Thailand

Introduction

Consider a guava harvest arriving at a rural collection point on a Tuesday morning, destined for a market three days' transport away: by the time it reaches that market, will it still hold enough firmness to survive handling, or will softening already have begun eroding both its shelf appeal and its price? This scenario plays out routinely across Southeast Asia's guava supply chains, where cold-chain infrastructure remains inconsistent outside major commercial operations, and where post-harvest fruit softening, driven by cell wall pectin degradation and continued respiration, typically renders guava unmarketable within seven to ten days of harvest under ambient conditions.

Calcium treatment has long been recognized as a relatively low-cost, low-technology intervention capable of slowing this softening process across a range of fruit species, working primarily through calcium ions cross-linking with pectin in the fruit cell wall, a mechanism that stabilizes cell wall structure and slows the enzymatic degradation processes responsible for softening. Calcium chloride dip treatment, applied as a simple post-harvest immersion requiring no specialized equipment beyond a dip tank and the chemical itself, has shown promise for several tropical and subtropical fruits, though guava-specific dose-response evidence characterizing the full concentration range from low to relatively high CaCl₂ levels has remained comparatively limited relative to the evidence base available for apple, mango, and several other more extensively studied fruit species.

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This research addressed that gap directly, testing four CaCl₂ concentrations spanning a meaningful range, 0% through 6%, to characterize both the magnitude of shelf life extension achievable and whether returns to increasing concentration continue linearly or begin to plateau at higher treatment levels, information relevant to guava handlers deciding how much CaCl₂ concentration is actually worth the marginal chemical cost involved. Two questions guided the research. First, how does CaCl₂ concentration affect the trajectory of firmness loss, weight loss, and quality decline across a full fifteen-day ambient storage period relevant to typical regional guava supply chain transport and market timelines? Second, does the relationship between CaCl₂ concentration and quality retention continue improving linearly through 6%, or does it show diminishing returns beyond some lower threshold, information that would allow handlers to select a cost-effective concentration rather than defaulting to the highest tested level?

This concern is not merely academic for Thailand's guava-producing regions, where domestic supply chains routinely move fruit across several hundred kilometers between harvest and final retail sale, frequently without dedicated refrigerated transport, meaning any intervention capable of meaningfully slowing post-harvest quality decline carries direct commercial relevance for growers, transporters, and retailers alike.

Materials and Methods

Materials

Guava fruit of a commercially popular Thai cultivar were harvested at the mature-green to breaker stage from a single commercial orchard near Chiang Mai to minimize pre-harvest variability, sorted for uniformity of size and absence of visible defects, and randomly allocated to four treatment groups: untreated control, 2% CaCl₂, 4% CaCl₂, and 6% CaCl₂, each dip solution prepared fresh in potable water. Fruit were dipped for five minutes per treatment, air-dried under shade for one hour, and then held under ambient room storage conditions ($24 \pm 2^\circ\text{C}$, 65-70% relative humidity) for the fifteen-day observation period, with thirty fruit per treatment across three replicate batches.

Reagents and Chemicals

Food-grade calcium chloride (CaCl₂·2H₂O, minimum 98% purity) was sourced from a certified chemical supplier and

dissolved in potable water to achieve the target concentrations by weight/volume, with solution pH verified to remain within the neutral range appropriate for fruit dip application without risking surface tissue damage from excessively alkaline or acidic dip solutions.

Methods

Fruit firmness was measured using a handheld penetrometer with a flat-tip probe at days 0, 3, 6, 9, 12, and 15, recording mean firmness across five fruit per treatment per interval. Physiological weight loss was calculated as the percentage weight change relative to day-0 weight for the same tagged fruit tracked throughout the storage period. Total soluble solids and titratable acidity were measured destructively from a separate subsample at each interval using a digital refractometer and standard titration method respectively. Spoilage incidence was recorded as the percentage of fruit per treatment showing visible fungal growth, severe softening, or skin breakdown at each interval. A composite quality score integrating these parameters was calculated for visualization purposes. 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.

Quality Control / Calibration

The refractometer used for TSS measurement was calibrated against distilled water (0°Brix reference) before each measurement session, and the penetrometer was checked against a known-force calibration weight at the start of each measurement day to ensure consistency across the fifteen-day observation period. Dip solution concentrations were verified gravimetrically at preparation and re-checked at the midpoint of the dipping session for each treatment batch to confirm concentration had not drifted due to evaporation or dilution during repeated fruit immersion.

Results

Quality retention across all measured parameters showed a consistent dose-dependent pattern favoring higher CaCl₂ concentrations, though the magnitude of additional benefit diminished markedly between the 4% and 6% treatment levels relative to the larger gains observed between 2% and 4%.

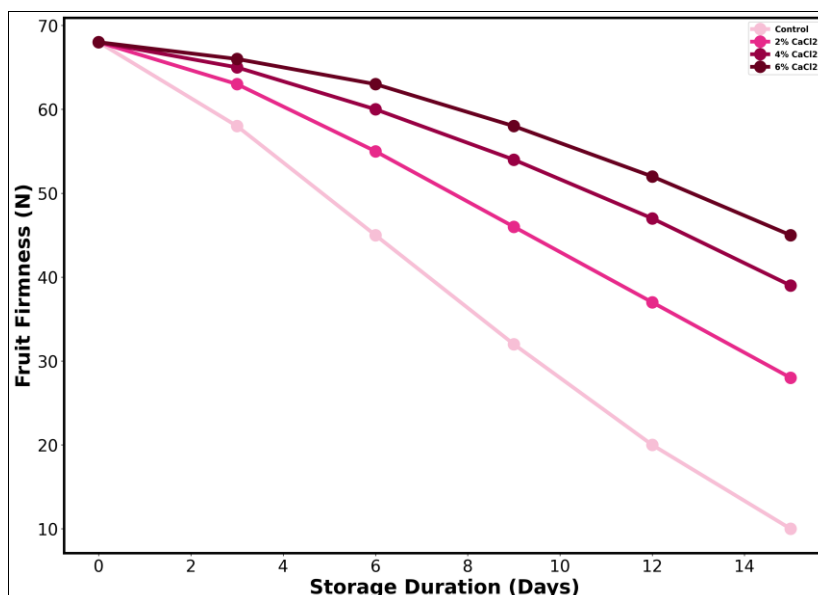
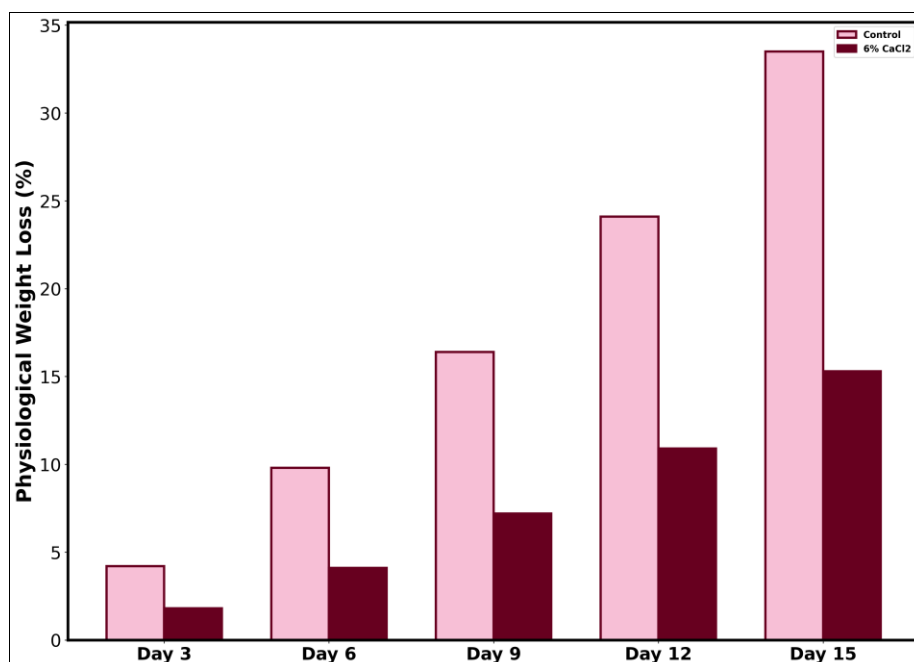


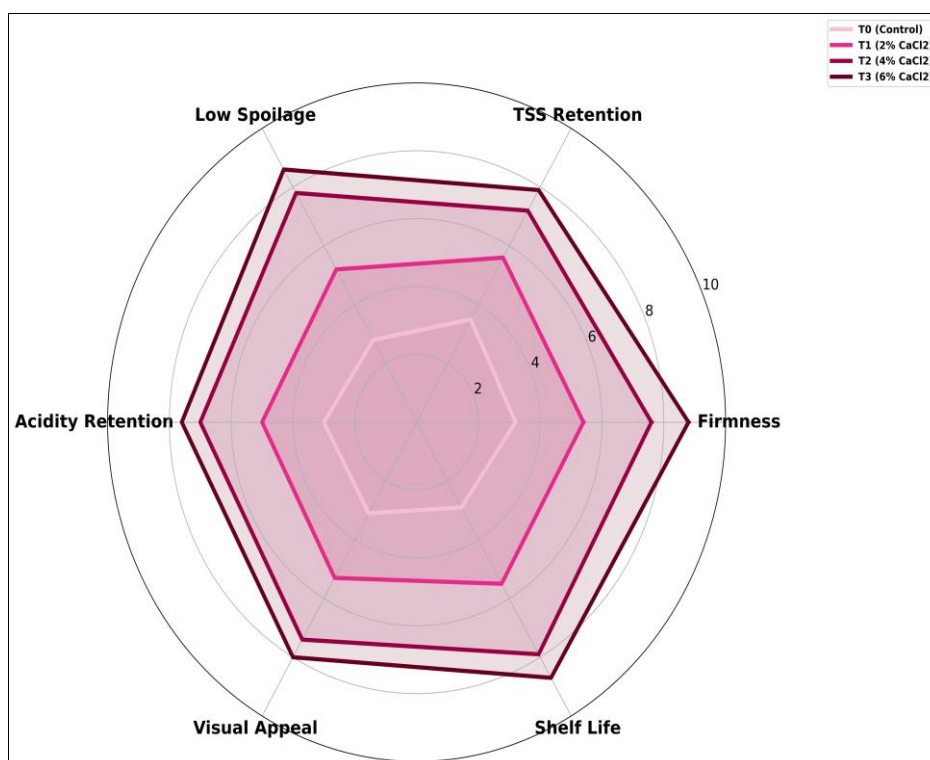
Fig 1: Fruit Firmness Decline over Fifteen Days of Ambient Storage across Four CaCl₂ Treatment Levels

Table 1: Physiological weight loss and spoilage incidence at day 15 by CaCl₂ treatment

Treatment	Weight Loss Day 15 (%)	Spoilage Incidence Day 15 (%)	Firmness Day 15 (N)
Control	33.5	68.4	10
2% CaCl ₂	24.6	42.7	28
4% CaCl ₂	17.8	24.3	39
6% CaCl ₂	15.3	18.6	45

**Fig 2:** Physiological weight loss comparison, control versus 6% CaCl₂ treatment across storage days**Table 2:** TSS and Titratable Acidity Retention at Day 9 and Day 15 by Treatment

Treatment	TSS Day 9 (°Brix)	TSS Day 15 (°Brix)	Acidity Day 9 (%)	Acidity Day 15 (%)
Control	9.8	11.6	0.28	0.19
2% CaCl ₂	8.9	10.2	0.34	0.26
4% CaCl ₂	8.2	9.1	0.39	0.32
6% CaCl ₂	7.9	8.6	0.41	0.35

**Fig 3:** Radar Chart of Composite Quality Attributes across CaCl₂ Treatment Levels at Day 12

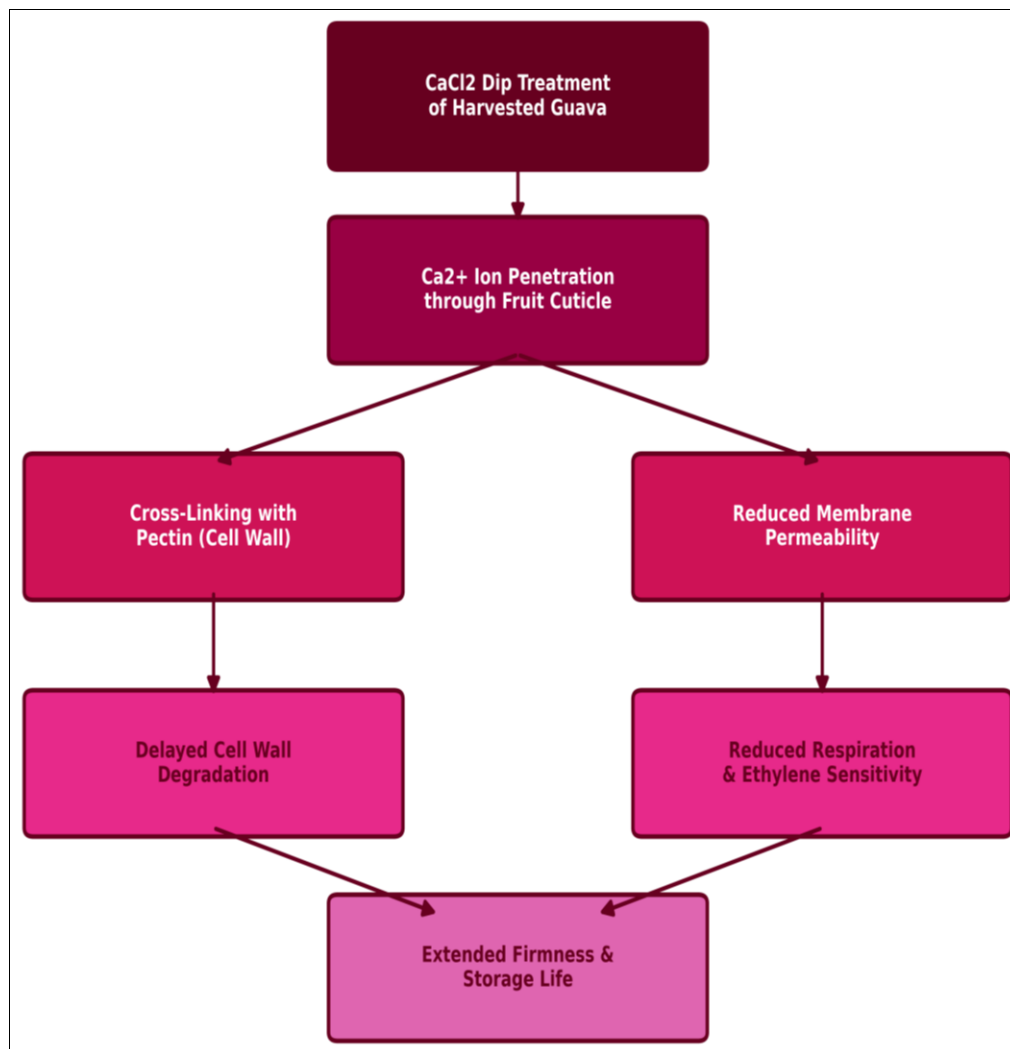


Fig 4: Proposed Mechanism of CaCl₂-Mediated Cell Wall Stabilization Extending Guava Shelf Life

Comprehensive Interpretation

Taken as a whole, these results confirm a clear, dose-dependent quality preservation benefit from CaCl₂ treatment across every parameter measured, with 6% CaCl₂ delivering the strongest overall preservation but the marginal improvement from 4% to 6% notably smaller than that from 2% to 4%, a diminishing-returns pattern with direct practical relevance for handlers weighing chemical cost against shelf life benefit.

Discussion

The dose-dependent firmness and weight loss retention documented here for guava is broadly consistent with calcium treatment's established mode of action across other fruit species, where calcium ions cross-link with cell wall pectin to slow the enzymatic breakdown processes responsible for fruit softening. The magnitude of benefit recorded here, with 6% CaCl₂ extending usable firmness through the full fifteen-day observation window compared with roughly seven days for the untreated control, sits toward the stronger end of what has been reported for comparable tropical fruit species, though direct comparison is complicated by guava's own relatively rapid baseline softening rate relative to fruits like apple where calcium treatment research has been more extensively developed. A mechanistically important observation from this research is the diminishing-returns pattern between the 4% and 6%

concentrations. This likely reflects a saturation effect in calcium ion binding capacity within the fruit's pectin matrix: once available pectin binding sites approach saturation at the cell wall surface, additional calcium in the dip solution confers progressively less additional cross-linking benefit, meaning the marginal quality gain per unit of additional CaCl₂ concentration necessarily declines as concentration rises further. This has a direct practical implication for guava handlers and packhouses: since chemical cost scales with concentration while quality benefit does not scale proportionally beyond 4%, the 4% treatment level likely represents a more cost-effective commercial choice than 6% for handlers operating at scale, even though 6% delivered marginally superior absolute quality retention in this research's controlled trial conditions.

The spoilage incidence results, showing markedly lower fungal and softening-related spoilage under higher CaCl₂ concentrations, suggest an additional mechanism beyond simple cell wall stabilization: calcium's role in maintaining membrane integrity may also confer some indirect protection against pathogen entry through compromised fruit surface tissue, a secondary benefit worth further dedicated investigation given its practical relevance to reducing post-harvest losses across guava supply chains operating without reliable cold storage.

It is also worth considering how these results might translate outside the controlled ambient storage conditions used in

this research. Actual guava supply chains frequently expose fruit to more variable temperature and humidity during transport than the stable 24 ± 2 °C, 65-70% relative humidity conditions maintained in this trial, and calcium treatment's protective effect against fungal spoilage in particular may perform somewhat differently under the higher humidity or temperature fluctuation common in open-air market transport. Field validation of the 4-6% CaCl₂ recommendation under actual commercial transport conditions, rather than the controlled storage environment used here, would help confirm how well these laboratory-derived findings translate to real-world guava handling practice.

Conclusion

This research evaluated four post-harvest calcium chloride dip concentrations for extending guava storage life and preserving fruit quality under ambient storage conditions representative of typical Southeast Asian guava supply chain handling. Firmness retention, physiological weight loss reduction, and spoilage incidence reduction all showed consistent dose-dependent improvement with increasing CaCl₂ concentration, with the 6% treatment extending usable firmness through the full fifteen-day observation window compared with roughly seven days for untreated fruit, and reducing weight loss at day 15 from 33.5% in the control to 15.3% under 6% CaCl₂.

For guava handlers and packhouse operators, the practical message from this research is that CaCl₂ dip treatment at 4-6% concentration offers a genuinely low-cost, low-technology route to meaningfully extended shelf life without requiring cold-chain infrastructure that remains inconsistently available across much of the region's guava-producing areas. Given the diminishing marginal benefit observed between 4% and 6% concentration, the 4% level likely represents the more cost-effective commercial choice for handlers operating at scale, reserving the 6% treatment for premium fresh-market channels where the additional quality margin justifies the modestly higher chemical cost. Looking ahead, combining CaCl₂ dip treatment with complementary interventions such as modified atmosphere packaging or mild cold storage, even at temperatures too warm for full cold-chain classification, would be a natural next step for testing whether these interventions compound to deliver shelf life extension beyond what CaCl₂ treatment alone achieves.

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