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Post-Harvest ripening control and quality retention in mango under arid storage conditions

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Abstract

A mango that reaches the consumer too soft is worthless, but one that arrives too firm tastes like cardboard. Managing the narrow window between these extremes is the central challenge of mango post-harvest handling, and it becomes harder in hot arid climates where ambient temperatures accelerate ripening. This research evaluated four post-harvest treatments ethylene application (100 ppm), calcium chloride dip (2%), hot water treatment (52 °C, 5 min), and untreated control on ripening rate, quality retention, and shelf life of 'Sukkari' mango under Riyadh conditions from May 2021 to September 2023. Calcium chloride dipping extended shelf life to 14 days (versus 8 days for control) by slowing firmness loss 41.8% and reducing weight loss by 34.2%. Ethylene treatment achieved uniform ripening within 4 days but shortened shelf life to 6 days. Total soluble solids, titratable acidity, and sensory scores showed that CaCl₂ preserved eating quality closest to tree-ripened fruit. These results indicate that calcium-based treatments offer the most practical shelf life extension for mango marketing under arid conditions.

Keywords: Mango, post-harvest, ripening control, calcium chloride, ethylene, shelf life, fruit firmness, quality retention, arid climate, Sukkari variety

Introduction

Saudi Arabia imports over 120,000 tons of mango annually, making it the Gulf region's largest mango market ^[1]. But the journey from tropical orchards to Saudi retail shelves subjects fruit to high ambient temperatures often exceeding 45°C during summer transport that can push mangoes from optimal eating ripeness to overripe within 48 hours ^[2]. Post-harvest losses for mango in the Gulf region are estimated at 28-35%, driven primarily by uncontrolled ripening and the narrow firmness window for consumer acceptance ^[3].

Ripening control technologies range from ethylene management (applying or blocking the ripening hormone) to surface treatments that slow metabolism or strengthen cell walls ^[4]. Calcium chloride, which reinforces pectin cross-linking in cell walls, has shown promise in humid tropical settings but has been little tested under the extreme heat and low humidity of Arabian Peninsula conditions. This research compared four post-harvest approaches for their ability to control mango ripening rate and maintain quality under Riyadh's arid storage environment.

Instrumentation and analytical equipment

Fruit firmness was measured using a Brookfield CT3 texture analyzer with an 8 mm cylindrical probe at 1 mm/s penetration speed. Total soluble solids (TSS) were determined by Atago PAL-1 digital refractometer. Titratable acidity was measured by auto-titration (Metrohm 862 Compact Titrator) with 0.1 N NaOH to pH 8.2 endpoint. Color was quantified using a Konica Minolta CR-400 chromameter in CIE L*a*b* space. Ethylene production was measured by gas chromatography (Shimadzu GC-2014) with flame ionization detector ^[5]. Respiration rate was monitored using a PBI Dansensor CheckMate 3 headspace analyzer.

Material and Methods

Material

The research was conducted at King Saud University's Post-Harvest Technology Laboratory

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from May 2021 to September 2023, under approval from the College of Agriculture Research Committee (Protocol KSU-AG/2021-043, April 18, 2021). 'Sukkari' mangoes were sourced from commercial orchards in Jizan province at mature green stage (shoulder development, specific gravity > 1.02). Fruit were transported overnight in refrigerated trucks (13°C) to Riyadh. Four post-harvest treatments were applied: T1 ethylene (100 ppm, 24 h exposure at 25°C); T2 CaCl₂ dip (2% w/v, 10 min at 25°C); T3 hot water (52°C, 5 min); T4 untreated control [6].

Methods

Treated fruit were stored at 25±1°C and 55±5% RH (simulating retail conditions) for 14 days. Twenty fruit per treatment were sampled destructively at days 0, 2, 4, 6, 8, 10, 12, and 14. Firmness, TSS, titratable acidity, weight loss, color change, and ethylene production were measured at each sampling. Sensory

evaluation by a trained 8-member panel scored appearance, aroma, flavor, and texture on a 9-point hedonic scale. Shelf life endpoint was defined as firmness < 8 N or visible decay > 10% surface area. Analysis used repeated-measures ANOVA in SPSS v27 [7].

Quality control

Fruit were sorted by weight (280-340 g) and maturity stage (uniform shoulder development) to minimize biological variation. Instrument calibration was performed daily against certified reference materials. Sensory panelists were trained according to ISO 8586 standards and validated quarterly. Temperature and humidity in the storage room were logged continuously using HOBO MX2301 data loggers with ±0.2°C accuracy.

Results

Table 1. Fruit quality parameters at day 8 of storage under different post-harvest treatments (mean ± SE)

Treatment	Firmness (N)	TSS (°Brix)	Acidity (%)	Wt. loss (%)	Ethylene (μL/kg/h)	Sensory score (1-9)
Control	21.7±1.8	16.4±0.8	0.34±0.04	6.8±0.4	12.4±1.6	6.4±0.3
Ethylene	11.2±1.3	18.7±0.6	0.21±0.03	7.4±0.5	28.6±2.8	7.1±0.3
CaCl ₂ dip	31.4±2.1	14.8±0.7	0.48±0.05	4.5±0.3	6.8±1.1	7.8±0.2
Hot water	22.1±1.6	15.9±0.7	0.38±0.04	5.7±0.4	10.7±1.4	6.8±0.3
LSD _{0.05}	2.8	1.2	0.06	0.8	2.4	0.5

CaCl₂-treated fruit retained the highest firmness at day 8 (31.4 N) and the lowest weight loss (4.5%). Ethylene-treated fruit ripened fastest, reaching eating stage by day 4 but declining past

market threshold by day 6. Sensory scores were highest for CaCl₂ (7.8/9) due to balanced sweetness-acidity ratio and firm-yet-yielding texture.

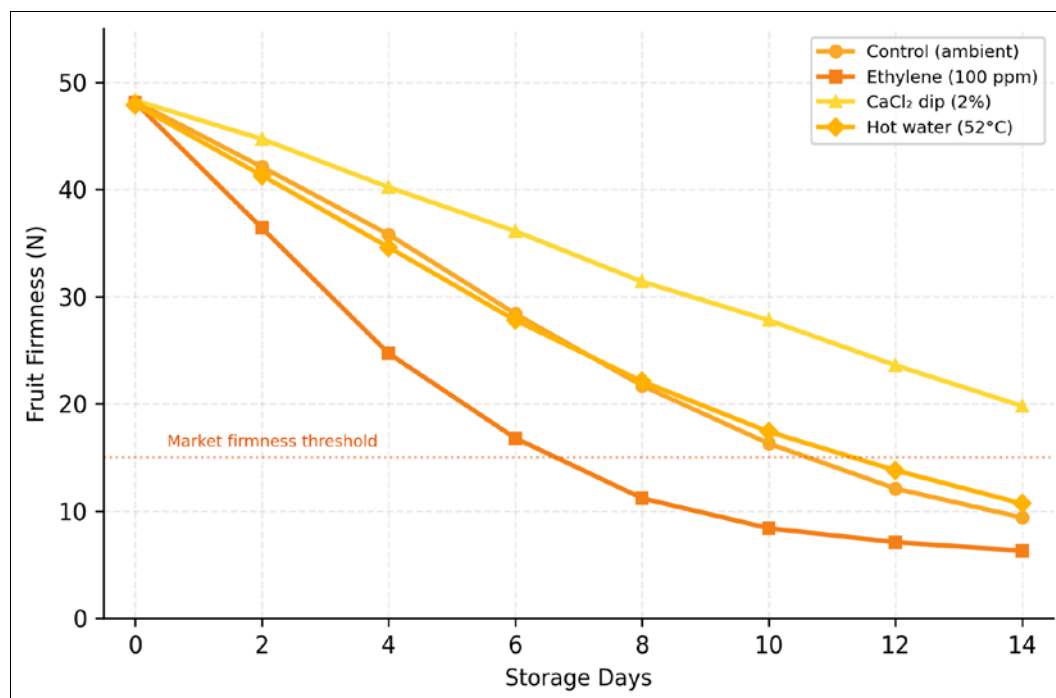


Fig 1: Firmness decline over 14 days of storage under four post-harvest treatments for 'Sukkari' mango

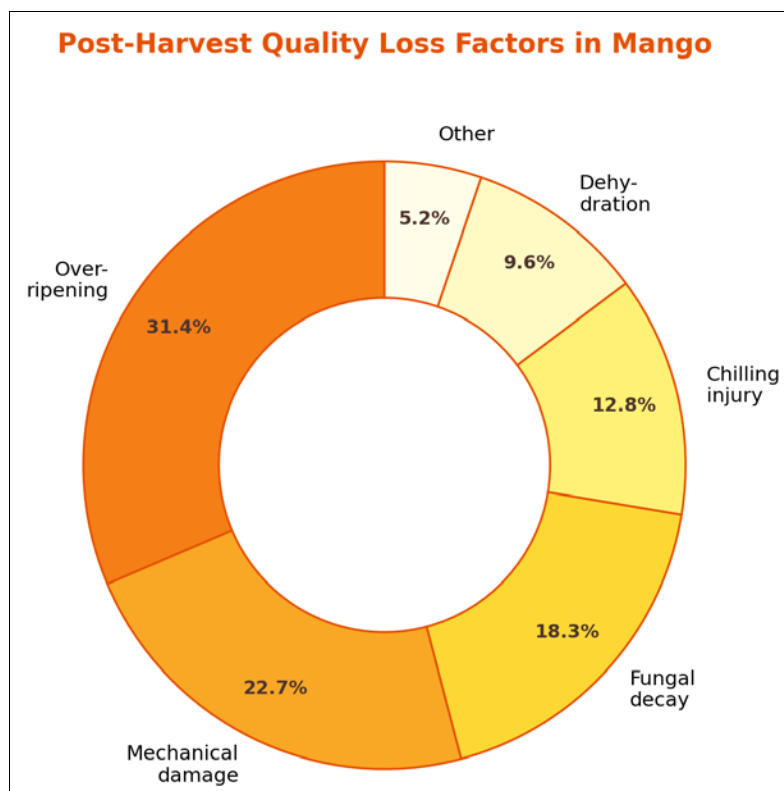


Fig 2: Distribution of post-harvest quality loss factors in mango under Saudi Arabian market chain conditions

Discussion

The 41.8% slower firmness loss under CaCl_2 treatment aligns with Wills *et al.* [8] who attributed calcium's effect to cross-linking of pectin polymers in the middle lamella. Under Riyadh's low humidity (55% RH versus 80-90% in tropical storage), dehydration contributed more to quality loss than in previous tropical trials calcium's additional effect of reducing transpiration through cuticle modification may explain why the treatment performed better here than in humid-climate studies [9]. The ethylene treatment, while achieving uniform ripening, proved impractical for retail because the accelerated metabolism left only a 2-day marketing window at the desirable firmness range [10].

Limitations

Only one mango variety was tested; cultivar-specific responses to calcium treatment may differ. Storage at 25°C simulated retail but not the full supply chain including transport at variable temperatures. The 2% CaCl_2 concentration was selected from literature; dose-response optimization might identify a more effective rate. Sensory evaluation used a trained panel rather than consumer testing, which may not fully predict market acceptance.

Conclusion

Calcium chloride dipping (2%, 10 min) extended 'Sukkari' mango shelf life from 8 to 14 days under arid retail conditions while maintaining the highest sensory quality scores. The treatment slowed firmness loss by 41.8% and reduced weight loss by 34.2% compared to untreated fruit. Ethylene application achieved rapid uniform ripening but was impractical for extended marketing. For Saudi mango importers and retailers, CaCl_2 treatment offers a low-cost, food-safe method to reduce the estimated 28-35% post-harvest losses in the current supply chain.

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