Optimization of Postharvest Storage Conditions for Tomatoes to Support Real-Time Shelf-Life Prediction

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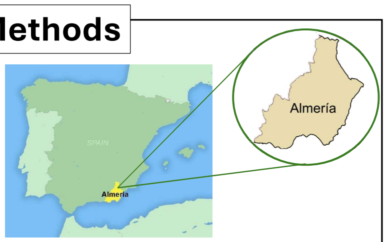
Introduction

'Durinta' tomato (*Solanum lycopersicum* L.) is one of the most widely consumed horticultural crops worldwide; however, its high perishability results in significant postharvest losses during storage and distribution. Postharvest losses of fresh horticultural produce are estimated to range between 30 and 50% globally, with fruits and vegetables representing the largest proportion of food waste. Storage conditions, particularly temperature and relative humidity (RH), play a crucial role in maintaining fruit quality and shelf life. Inadequate management of these factors can accelerate deterioration processes such as weight loss, softening, color changes, and decay development, directly affecting the commercial quality of the fruit. High storage temperatures increase respiration and ripening rates, promoting senescence and reducing storage potential. Conversely, excessively low temperatures may lead to physiological disorders and quality deterioration. In addition to temperature, RH significantly influences tomato preservation, as unsuitable RH levels can enhance water loss and texture degradation. Physicochemical parameters, together with weight loss, decay incidence, and total food loss, are widely used to evaluate postharvest quality, storage performance, shelf life, and consumer acceptability.

In this study, the effects of different combinations of temperature and RH on the postharvest quality of 'Durinta' tomatoes were evaluated using a Box–Behnken experimental design over a 47-day storage period. Storage was extended until complete food loss was reached in all treatments in order to characterize tomato deterioration kinetics under different storage conditions and provide data for future predictive shelf-life models.

Materials and Methods

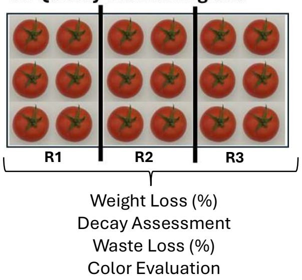


Greenhouse-grown 'Durinta' tomatoes (67 × 54 mm) obtained from producers in Almería (Spain), were stored for **47 days** under **five temperature–RH combinations following a Box–Behnken design:**

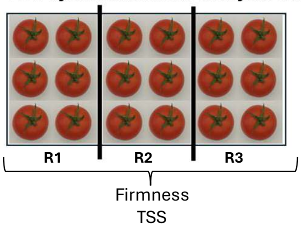
Treatment	T (°C)	HR
T1	33	67.5%
T2	19	67.5%
T3	9	48.5%
T4	9	86.9%
T5	5	67.5%

One non-destructive quality monitoring box used throughout storage and one destructive sampling box per sampling day. Each box comprised 18 tomatoes distributed among 3 replicates (n = 6 fruits per replicate).

A. Quality monitoring box



B. Physicochemical analysis box



Analyses were performed on **days 0, 3, 7, 13, 17, 20, 24, 32, 34 and 47**

Results and Discusion

1. Quality Monitoring

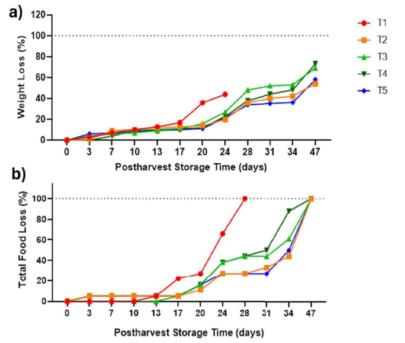


Figure 1. (a) Weight loss (%) and **(b)** total food loss (%) of tomatoes during 47 days of storage under five different conditions: T1 (33 °C, 67.5% RH), T2 (19 °C, 67.5% RH), T3 (9 °C, 48% RH), T4 (9 °C, 87% RH), and T5 (5 °C, 67.5% RH).

Tomato degradation (**Figure 2**) followed the same trend as total food loss (**Figure 1b**). Since the objective of this study was to characterize deterioration kinetics until complete food loss was reached, storage was extended under all conditions until advanced senescence and severe quality deterioration were observed. Visual assessment confirmed progressive deterioration during storage, characterized by softening, shriveling, tissue collapse, and fungal development. In T1, severe softening and decay affected more than 50% of the fruit surface from day 17 onward, indicating rapid senescence under high-temperature conditions. T2 delayed comparable deterioration until day 34, while T3 showed an intermediate onset at day 24. In T4, fungal growth became evident from day 34 onward, suggesting that high RH promoted decay development despite reducing visual dehydration symptoms. These patterns agree with the strong influence of temperature and RH on tomato senescence and microbial spoilage (Wills & Golding, 2016).

Color changes during storage were assessed using ΔE (CIELAB color difference) based on visual acceptability criteria. T2 showed the lowest ΔE value (2.99), indicating a noticeable but moderate color change close to the visual acceptability threshold.

Among treatments, T2 (19 °C, 67.5% RH) showed the lowest weight loss (**Figure 1a**), reaching approximately 53% after 47 days of storage, indicating that moderate temperature effectively reduced metabolic activity and dehydration. In contrast, T5 (5 °C) may have experienced chilling stress, increasing membrane permeability and water loss (Saltveit, 2019). The highest losses were observed in T4 (9 °C, 87% RH), which reached approximately 73% weight loss at day 47, suggesting that high humidity alone is insufficient to preserve fruit quality and may promote decay-related tissue breakdown (Hardenburg et al., 1986).

Total food loss increased progressively in all treatments, with a clear acceleration after approximately 20 days (**Figure 1b**), consistent with the onset of advanced senescence in tomato fruit (Kader et al., 2019). Temperature was the main driver of deterioration: at 33 °C, total loss reached 100% by day 28 due to accelerated respiration and decay processes (Saltveit, 2019), whereas storage at 19 °C and 5 °C delayed complete loss until day 47. At 9 °C, higher relative humidity increased decay incidence, likely by promoting microbial development despite reduced metabolic activity (Hardenburg et al., 1986). The combined effect of temperature and RH strongly influenced the visual quality evolution and marketability of tomatoes throughout storage.

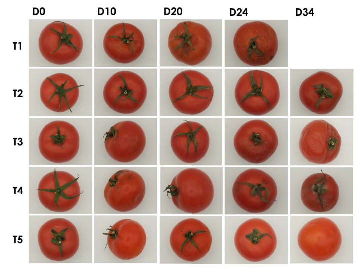


Figure 2. Visual changes in tomato degradation during 47 days of storage under different temperature (T) and relative humidity (RH) conditions, including softening, shriveling, and fungal growth, associated with rot incidence and food waste development.

2. Physicochemical Analysis

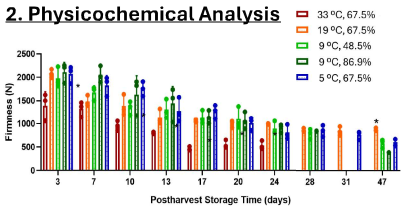


Figure 3. Effect of storage conditions on tomato firmness during 47 days of storage under five different temperature (T) and relative humidity (RH) conditions: T1 (red bars), T2 (orange bars), T3 (light green bars), T4 (dark green bars), and T5 (blue bars). (*) indicates statistically significant differences among treatments according to ANOVA followed by Bonferroni's test (P ≤ 0.05).

T1 showed a significantly faster loss of firmness, consistent with its higher weight loss and accelerated overall deterioration. This behavior reflects enhanced cell wall degradation and tissue softening under unfavorable storage conditions (Kader et al., 2019). In contrast, T2 maintained significantly higher firmness throughout storage, indicating better preservation of fruit structural integrity and overall quality (**Figure 3**).

A slight increase in TSS (from 3.9 ± 0.2 to 4.5 ± 0.1) was observed in T1, likely due to water loss and concentration of soluble solids rather than metabolic changes. This behavior is consistent with postharvest tomato dehydration and compositional stability during storage (Yahia, 2019). However, T2 showed more stable TSS (3.8 ± 0.2) values during storage, suggesting better preservation of fruit quality under moderate storage conditions. Similarly, T5 maintained relatively stable TSS values, likely due to reduced metabolic activity and slower respiration rates at low temperature.

Conclusions

1. Storage conditions significantly affected tomato deterioration kinetics and overall shelf life during prolonged storage until complete food loss was reached, providing useful information for future shelf-life modeling.
2. Low temperatures reduced dehydration and delayed deterioration; however, excessively low temperatures or high RH conditions promoted physiological and microbial damage during extended storage.
3. T2 (19 °C, 67.5% RH) showed the best balance between water retention, firmness preservation, and decay control, resulting in improved overall postharvest quality during prolonged storage.

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