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Evaluation of Vitamin C Stability in Indonesian Mango Varieties (*Mangifera indica* L.) under Different Post-harvest Storage and Extraction Conditions

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Abstract: *Vitamin C is a key antioxidant influencing the nutritional quality of mangoes, yet its level varies among cultivars and declines during storage. Although the Arumanis mango has been studied, no research has systematically compared Kiojay and Indramayu mangoes or assessed how storage temperature and duration affect their vitamin C stability. This study examines the effects of mango variety, storage temperature, storage duration, and solvent type on post-harvest vitamin C content. Three mango varieties (Kiojay, Arumanis, and Indramayu) were stored at room temperature (29.61 ± 0.50 °C) and under refrigeration (10.32 ± 2.71 °C) for two durations (< 1 day and 7 days). Vitamin C was extracted using aquades and 70% ethanol, then quantified by UV–VIS spectrophotometry at 365 nm. A three-way factorial ANOVA revealed significant effects of variety, storage temperature, duration, and solvent on vitamin C concentration ($p < 0.001$). Kiojay mango exhibited the highest vitamin C level (340.53 ppm), followed by Indramayu and Arumanis (287.69 and 233.29 ppm). Refrigerated short-term storage better preserved vitamin C than room temperature, and aquades yielded higher recovery than ethanol. These findings provide new comparative data on Indonesian mangoes and emphasize the roles of variety, temperature, and solvent choice in maintaining post-harvest vitamin C stability.*

Keywords: Indonesian mango, solvent, storage duration, storage temperature, Vitamin C

Abstrak: Vitamin C merupakan antioksidan penting yang menentukan kualitas nutrisi mangga, namun kadarnya berbeda antarkultivar dan menurun selama penyimpanan. Meskipun mangga Arumanis telah diteliti sebelumnya, belum ada studi yang secara sistematis membandingkannya dengan Kiojay dan Indramayu atau mengevaluasi pengaruh suhu serta durasi penyimpanan terhadap stabilitas vitamin C. Penelitian ini mengkaji pengaruh varietas, suhu penyimpanan, lama penyimpanan, dan jenis pelarut terhadap kadar vitamin C pascapanen. Tiga varietas mangga (Kiojay, Arumanis, dan Indramayu) disimpan pada suhu ruang (29,61 ± 0,50 °C) dan suhu kulkas (10,32 ± 2,71 °C) selama < 1 hari dan 7 hari. Vitamin C diekstraksi menggunakan aquades dan etanol 70%, kemudian dianalisis dengan spektrofotometri UV–VIS pada 365 nm. ANOVA faktorial tiga arah menunjukkan pengaruh signifikan dari varietas, suhu, durasi penyimpanan, dan pelarut terhadap konsentrasi vitamin C ($p < 0,001$). Mangga Kiojay memiliki kadar vitamin C tertinggi (340,53 ppm), diikuti Indramayu dan Arumanis (287,69 dan 233,29 ppm). Penyimpanan dingin jangka pendek lebih efektif mempertahankan vitamin C dibandingkan suhu ruang, dan aquades memberikan ekstraksi lebih tinggi daripada etanol. Temuan ini memberikan data komparatif baru pada varietas mangga Indonesia dan menekankan pentingnya pemilihan varietas, pengendalian suhu, dan pelarut dalam menjaga stabilitas vitamin C pascapanen.

Kata kunci: Lama penyimpanan, mangga Indonesia, pelarut, suhu penyimpanan, vitamin C

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1. Introduction

Vitamin C (*ascorbic acid*) is a water-soluble micronutrient that plays essential biochemi-

cal and physiological roles in plants and humans. It acts as a potent antioxidant, electron donor, and cofactor for numerous enzymatic reactions, maintaining redox balance and protecting biological systems from oxidative damage (Yameny, 2025; Santos et al., 2022). In plants, Vitamin C contributes to stress tolerance, fruit development, and postharvest preservation by mitigating the accumulation of reactive oxygen species (ROS) during ripening and storage (Zheng et al., 2022; Mishra et al., 2024). Humans, however, cannot synthesize Vitamin C due to the absence of L-gulono-1,4-lactone oxidase, making fruits an important dietary source (Gad and Sirko, 2024).

Mango fruit is rich in bioactive compounds, including vitamin C, carotenoids, and polyphenols, that determine its nutritional and functional quality (Yahia et al., 2023). Across Southeast Asia, cultivars such as Kiojay, Arumanis, and Indramayu display distinct genetic and biochemical characteristics that influence their capacity for vitamin C synthesis, accumulation, and retention during post-harvest storage. These varietal distinctions suggest that differences in fruit metabolism, enzymatic activity, and antioxidant composition may play a key role in shaping vitamin C stability (Lawson et al., 2019; Mulyani and Herlina, 2021). Therefore, evaluating variants of mango under standardized storage and analytical conditions is crucial to understanding their nutritional resilience and optimizing post-harvest quality preservation.

The stability of ascorbic acid is influenced by several postharvest factors, notably temperature and storage duration. Elevated temperatures accelerate Vitamin C degradation through oxidation to dehydroascorbic acid and further breakdown into diketogulonic and furan derivatives, leading to both nutrient loss and color changes (Ruiz et al., 2018). This thermal and oxidative instability follows first-order kinetics and is highly temperature-dependent. Storage at refrigeration temperatures (4-10 °C) significantly reduces Vitamin C degradation compared with room-temperature storage (25–35 °C), thereby maintaining fruit quality and delaying senescence. In mango, lower temperatures not only preserve vitamin C but also retard ethylene-mediated ripening and enzymatic browning (Vithana et al., 2018). Conversely, prolonged storage duration is correlated with progressive Vitamin C loss due to cumulative oxidative and enzymatic reactions (Ogori et al., 2020).

In addition to physiological and environmental parameters, solvent type during extraction profoundly affects the measured Vitamin C concentration (Cendrowski et al., 2024). Since ascorbic acid is highly polar, solvents with differing polarities, such as water (aquades) and ethanol, yield variable extraction efficiencies (Yadav et al., 2022). Aqueous solvents dissolve vitamin C effectively but may also extract interfering substances (sugars and organic acids), whereas aqueous ethanol enhances selectivity and recovery of hydrophilic antioxidants. Studies on mango peel and pulp have demonstrated that ethanol or hydroalcoholic solvents produce higher total phenolic and Vitamin C yields than pure water, improving quantification accuracy (Martínez-Ramos et al., 2020).

Despite extensive research on postharvest physiology, there is still a limited systematic comparison of vitamin C retention across mango varieties such as Kiojay, Arumanis, and Indramayu under different temperature–time regimes and solvent extraction systems. This study aims to address this gap by quantifying the effects of mango variety, storage temperature (room vs. refrigerated), storage duration (< 1 day vs. 7 days), and solvent type (aquades vs. ethanol) on vitamin C concentration. By integrating factorial statistical analysis, this research contributes to a deeper understanding of the interactive factors influencing vitamin C stability in tropical fruits and provides practical guidance for postharvest handling, nutritional retention, and analytical standardization.

2. Materials and Methods

This study employed a 3×2×2 factorial experimental design to evaluate the effects of mango variety (Kiojay, Arumanis, Indramayu), storage temperature (room vs. refrigerated), and storage duration (< 1 day vs. 7 days) on the vitamin C content of mango extracts (Feszterová et al., 2023). Each experimental combination was analyzed using two extraction solvents (aquades and 70% ethanol), resulting in 24 experimental units (Papoutsis et al., 2016). All treatments were conducted in triplicate to ensure statistical reliability.

Fresh ripe mango fruits (*Mangifera indica* L.) of three varieties (Kiojay, Arumanis, and Indramayu) were obtained from a local market in Solo, Indonesia. Fruits were manually selected to ensure uniform size, ripeness, and absence of physical defects. After cleaning and

peeling, the edible portions were homogenized using a laboratory blender. Exactly 100 g of homogenate was weighed for each sample replicate. Samples were stored under two controlled conditions: room temperature (29.61 ± 0.50 °C) and refrigerated temperature (10.32 ± 2.71 °C). Each mango variety was divided into two storage groups (< 1 day and 7 days). During storage, samples were kept in darkness to prevent photodegradation of vitamin C. Light exposure was minimized, and fruit condition was standardized to prevent bias due to ripeness differences.

After each storage period, samples were subjected to solvent extraction following a modified maceration method at ambient temperature for 48 h with occasional stirring. A 100 ppm standard ascorbic acid stock solution was prepared by dissolving 50 mg of L-ascorbic acid in a 500 mL volumetric flask using double-distilled water (Desai and Desai, 2019). Working standards (4, 6, 8, 10, and 12 ppm) were prepared from the stock solution to establish a calibration curve.

The maximum absorbance wavelength of vitamin C was determined by scanning a 5 ppm standard solution between 250 and 400 nm using a UV-VIS spectrophotometer (λmax ≈ 365 nm). Calibration was achieved by plotting absorbance (A) against concentration (C, ppm) to yield a linear regression equation ($A = mC + b$) with an R^2 value greater than 0.995. The concentration of vitamin C (ppm) was calculated by interpolation from the calibration curve and standardized for sample mass and dilution factors. Each sample was analyzed in triplicate, and the mean ± SD was reported (Andaririt et al., 2025).

Data on vitamin C concentrations were analyzed using a three-way factorial ANOVA with the following fixed factors: mango variety (3 levels), storage temperature (2 levels), and storage duration (2 levels). Prior to ANOVA, data normality was analyzed using Shapiro–Wilk, and homogeneity of variance was analyzed using Levene's test (Sureiman and Mangera, 2020). When significant effects were detected ($p < 0.05$), Tukey's HSD post-hoc test was applied for pairwise comparisons among treatment means. Results were interpreted at the 95% confidence level.

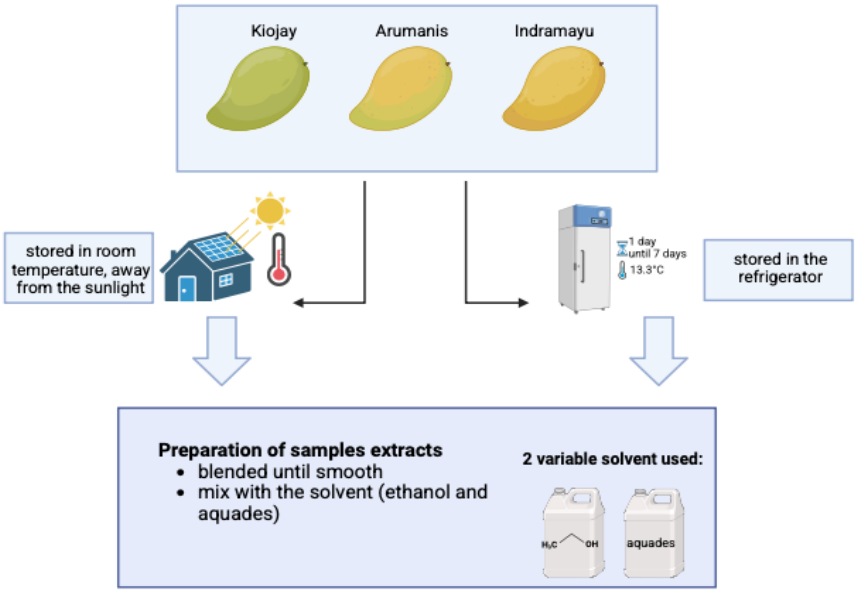

Figure 1. The preparation steps of Indonesian mango extracts

3. Results

Among all treatments, Kiojay mango consistently exhibited the highest vitamin C levels, followed by Indramayu and Arumanis, irrespective of solvent or temperature conditions (Table 1). The maximum value was observed in Kiojay mango stored in the refrigerator for < 1 day using aquades extraction, while the lowest concentration occurred in Arumanis mango stored for 7 days at refrigerated temperature extracted with ethanol (Figure 2). This trend confirms varietal dependence of ascorbic acid biosynthesis and retention, consistent with differences in enzymatic activity, maturity stage, and genetic regulation of ascorbate

metabolism reported in mango and other tropical fruits (Souza et al., 2018; Lawson et al., 2019)

Mangoes extracted with aquades contained substantially higher vitamin C than those extracted with ethanol (Table 1). The polarity of ascorbic acid promotes greater solubility in water, while ethanol partially reduces extraction efficiency due to a lower dielectric constant and potential precipitation of hydrophilic antioxidants.

Three-way factorial ANOVA revealed highly significant main effects of mango variety, storage temperature, storage duration, and solvent type ($p < 0.001$) on vitamin C content (Table 2). The adjusted $R^2 = 0.998$ indicates that the model explained nearly all variation in the data. All two- and three-way interactions were also significant ($p < 0.001$), implying that the effect of one factor depended on the level of another (e.g., solvent * temperature * time). These results confirm that vitamin C degradation in mangoes is a multivariate process influenced not only by environmental conditions but also by fruit physiology and extraction parameters.

Table 1. Vitamin C concentration in the Indonesian mangoes

Sample	Solvent		TOTAL Vitamin C*
	Aquades	Ethanol	
Kiojay	439.02 ± 23.2	242.04 ± 13.4	340.53 ± 19.1[a]
Indramayu	406.71 ± 16.5	168.67 ± 14.4	287.69 ± 16.7[b]
Arumanis	299.44 ± 17.5	167.15 ± 35.7	233.29 ± 58.7[c]

*Different letters in the same column indicate significant differences

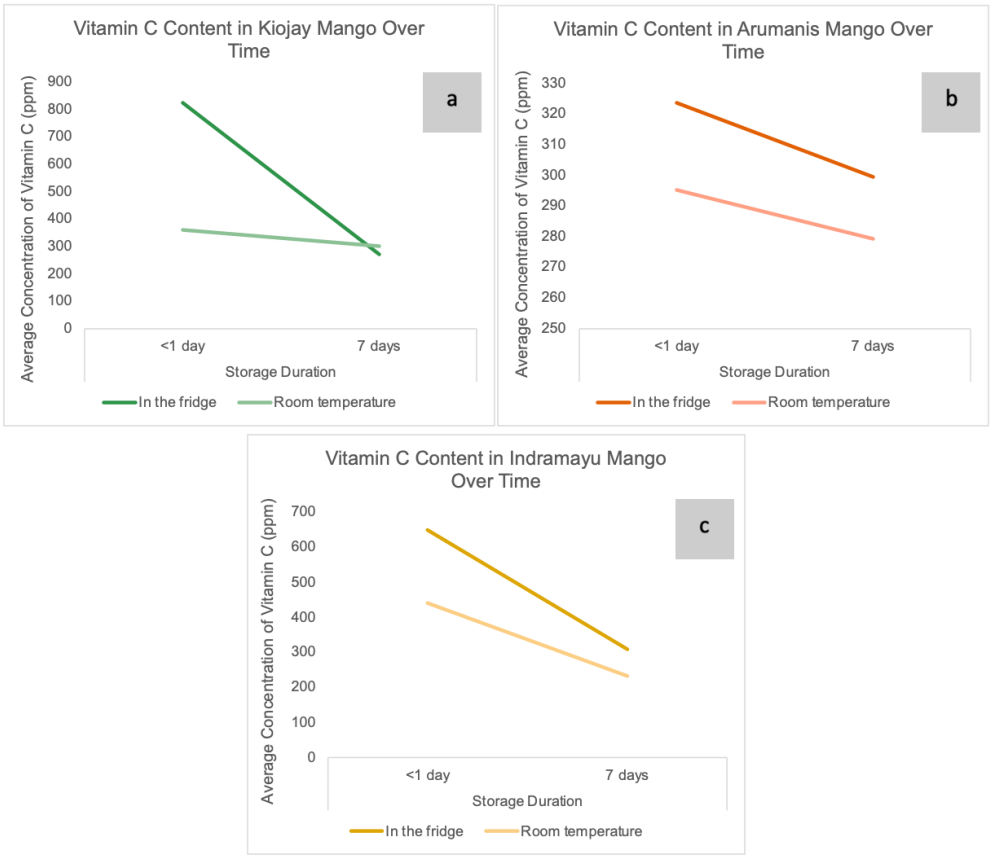

Figure 2. Comparison of vitamin C content in Kiojay (a), Arumanis (b), and Indramayu (c)

Table 2. Extraction efficiency based on different solvent types

Source	Mean Square	F	p value
Corrected Model	76569.3 [a]	1989.9	.000
Sample	68997.9	1793.2	.000
Location	106079.2	2756.9	.000
Time	239119.6	6214.6	.000
Solvent	643660.9	16728.4	.000
Sample * Location	8802.5	228.8	.000
Sample * Time	23199.5	602.9	.000
Sample * Solvent	17055.0	443.3	.000
Location * Time	73241.1	1903.5	.000
Location * Solvent	47581.0	1236.6	.000
Time * Solvent	128870.9	3349.3	.000
Sample * Location * Time	22017.0	572.2	.000
Sample * Location * Solvent	21381.7	555. 7	.000
Sample * Time * Solvent	53252.2	1383.9	.000
Location * Time * Solvent	31851.7	827.8	.000
Sample * Location * Time * Solvent	30638.7	796.3	.000

[a] R Squared = .999 (Adjusted R Squared = .998)

3.1. Effect of Storage Temperature and Duration

Vitamin C concentration declined significantly with prolonged storage ($p < 0.001$) for all varieties (Figure 2). After 7 days, the overall mean vitamin C level dropped, representing an average reduction of 33%. Refrigerated samples retained markedly higher vitamin C than those kept at room temperature. These outcomes corroborate prior observations that enzymatic oxidation and non-enzymatic degradation of ascorbic acid are temperature-dependent and follow first-order kinetics (Yin et al., 2022).

Lower temperatures suppress ascorbate oxidase activity and limit the conversion of ascorbate to dehydroascorbate and subsequent diketogulonic acid. Conversely, high ambient temperatures accelerate oxidative loss and promote reactive oxygen species generation, consistent with the chemistry described by Njus et al. (2020).

3.2. Effect of Solvent Type on Extraction Efficiency

The solvent type significantly affected vitamin C quantification (Table 2). Across all treatments, aquades extraction yielded nearly twice the vitamin C concentration compared with ethanol extraction. This is due to the high polarity and hydrogen-bonding capacity of water that stabilizes the enediol structure of ascorbic acid, minimizing oxidation during extraction.

However, ethanol extraction remains relevant for total antioxidant analysis because it also extracts less polar phenolic compounds that synergize with ascorbic acid to scavenge free radicals (Papoutsis et al., 2016). Thus, solvent selection should depend on analytical objectives: quantification versus total antioxidant assessment.

3.3. Interaction Effects

Significant interactions among variety, temperature, and solvent revealed complex patterns. For example, the reduction rate of vitamin C in Kiojay was less pronounced than in Arumanis or Indramayu, indicating stronger antioxidative resilience. The triple interaction (Variety * Temp * Duration) suggests that each variety's biochemical response to storage differs depending on both environmental and extraction conditions. This heterogeneity likely arises from varietal differences in cell-wall structure, phenolic content, and endogenous antioxidant enzyme systems that protect ascorbic acid during storage (Shi et al., 2015).

4. Discussion

The results of this study demonstrate that vitamin C concentration varies significantly across mango varieties, confirming earlier reports that varietal genetics strongly influence ascorbic acid biosynthesis and retention. Previous studies have shown that Arumanis mango

contains an average of 7.53 mg/100 g of vitamin C, higher than varieties such as Golek but lower than Macang (*Mangifera foetida*). In contrast, our findings indicate that Kiojay mango exhibits the highest vitamin C content, followed by Indramayu, then Arumanis. This result highlights that Indonesian mango varieties possess distinct metabolic capacities for ascorbate accumulation. This divergence likely arises from genotypic differences in enzymatic pathways such as L-galactono-1,4-lactone dehydrogenase and GDP-mannose pyrophosphorylase, which regulate ascorbic acid biosynthesis in tropical fruits.

The observed decline in vitamin C with prolonged storage corroborates earlier findings by Hapsari et al. (2022) and Arguni & Sandra (2025), who reported that low-temperature storage (5–10 °C) better preserves ascorbic acid levels in *Arumanis* mangoes compared to ambient conditions (27–32 °C). In our study, refrigerated samples retained up to 36% more vitamin C than room-temperature samples, validating that lower temperatures slow enzymatic oxidation and the conversion of ascorbic acid to dehydroascorbate. The significant interaction among temperature, duration, and variety ($p < 0.001$) further suggests that the rate of degradation depends on both intrinsic fruit physiology and environmental exposure. These results strengthen the kinetic model of temperature-dependent vitamin C degradation proposed in earlier post-harvest studies.

Interestingly, the effect of solvent type in this study differs partially from that in previous studies. Earlier reports suggested that ethanol or moderate-polarity solvents can extract vitamin C more efficiently than water, particularly in lemon peel and *Salacca* fruit. In contrast, the current results reveal that aquades extraction produced significantly higher measurable vitamin C concentrations than ethanol across all mango varieties. This discrepancy can be attributed to the matrix differences between fruit tissues and peels, where mango pulp contains more hydrophilic compounds, allowing better recovery with highly polar solvents such as water. Moreover, ethanol may reduce ascorbic acid stability during maceration due to partial oxidative stress or solvent-induced precipitation of polar antioxidants. Nevertheless, both findings agree that solvent polarity plays a critical role in analytical recovery and should be tailored to the target compounds and matrices studied.

Taken together, these results expand upon previous single-factor or single-variety studies by offering a comprehensive factorial model that simultaneously evaluates the influences of varietal, environmental, and methodological factors on vitamin C stability. The integration of solvent extraction effects into post-harvest analysis represents a novel contribution, providing a multidimensional understanding of how biochemical composition, temperature, and analytical methodology interact to determine nutrient preservation in tropical mangoes.

UV-VIS spectrophotometry provided an efficient method for quantifying Vitamin C, and comparing varieties yielded valuable insights. However, limitations were identified, including natural variability in Vitamin C levels across samples, unmonitored environmental factors such as humidity and light exposure, and a limited selection of solvents for extraction. The short storage period of seven days restricted the assessment of long-term degradation patterns, and reliance on UV-VIS spectrophotometry limited the depth of analysis. Future research should involve larger sample sizes with stricter selection criteria, monitor additional environmental factors, explore a broader range of solvents, and extend the storage duration to capture long-term trends. Incorporating techniques such as HPLC or LCMS alongside UV-Vis spectrophotometry would enhance the analysis of Vitamin C stability in tropical fruits.

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