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The Effect of Gibberellin Concentration on Maintaining the Quality of Tomatoes (*Solanum lycopersicum*) During Storage

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ABSTRACT

Tomatoes are perishable horticultural commodities whose postharvest quality rapidly declines due to physiological and biochemical changes during storage. One approach to preserving tomato quality is the application of gibberellin. This study aimed to evaluate the effect of different gibberellin concentration on maintaining the psychochemical quality tomatoes during storage, focusing on parameters such as weight loss, firmness, moisture content, vitamin C, and total acidity. A Completely Randomized Design with two factors: gibberellin concentration (5, 10, and 15 ppm) and storage duration (4, 8, 12, 16, and 20 days). The results revealed significant effects of both factors and their interactions on all quality parameter measured. The lowest gibberellin concentration (5 ppm) treatment consistently showed the best performance, maintaining a low weight loss (3,23%), firmness of 0.96 KgF, moisture content of 92.78%, stable of vitamin C (3.67%), and total acidity of 8.6% after 20 days. In contrast, higher concentrations (10 and 15 ppm) led to faster deterioration, with increased weight loss and decreased firmness and acidity. These findings indicate that a lower concentration of gibberellin effectively suppresses respiration and ethylene production, thereby slowing the ripening process and preserving fruit quality. This research contributes valuable insights for developing sustainable postharvest handling strategies to extend tomato shelf life, reduce postharvest losses, and enhance economic returns for producers and distributors.

INTRODUCTION

Horticultural products play a vital role in meeting daily nutritional needs and contribute to household and national income (Fajri *et al*., 2022). Fresh horticultural products are highly demanded by consumers. Among them, tomatoes have strong market potential due to their high economic value. Tomatoes are popular among all age groups because of their characteristic flavor (Salingkat *et al*., 2020), affordability, and nutritional richness, including carotene, which may reduce cancer risk, and lycopene (Fitriani *et al*., 2020). However, as highly perishable horticultural products, tomatoes are extremely sensitive to damage (Muhanniah *et al*., 2021).

High moisture content and improper handling during storage contribute to deterioration. During storage, physical and chemical changes occur, leading to quality decline (Manurung *et al.*, 2024). Postharvest handling aimed at slowing respiration is essential to maintain both quality and nutritional content.

Previous studies on postharvest handling have mostly focused on packaging modifications and waxing treatments to regulate respiration, with fewer studies exploring the use of respiration inhibitors to maintain product quality. Gibberellin, a plant growth hormone (Purwandari *et al.*, 2022), can slow respiration and reduce ethylene production (Sudradjat *et al.*, 2021). Research on gibberellins has been extensively conducted, primarily focusing on the growth stages rather than the postharvest phase. Therefore, it is necessary to investigate the effects of gibberellins on postharvest physiological processes. The concentration of gibberellins can also produce different biological effects; for instance, it may inhibit the rate of respiration, whereas excessive concentrations can lead to an undesirable delay in ripening. Iswari & Srimaryati (2014) demonstrated that applying 30 ppm gibberellin delayed ripening in *Capsicum annuum*.

This study aimed to determine the optimal gibberellin concentration to maintain tomato quality during storage, excessive concentrations of gibberellins may excessively inhibit the ripening process. We hypothesize that lower concentrations of GA_3 (5 ppm) will better maintain postharvest quality by reducing respiration and ethylene production compared to higher concentrations.

METHODS

Materials

The main material was ‘Saras’ apple-type tomatoes at 70% maturity. Other materials included gibberellin, label paper, and chemical reagents for analysis. Equipment included a weighing scale, titration apparatus, gas cylinders (O_2, CO_2, and N_2), and analytical instruments.

Experimental Procedure

Tomatoes were transported from Subang using a pickup truck in the early morning. Upon arrival, damaged fruits were removed, and healthy ones were washed under running water, drained, and air-dried for several minutes.

The dried tomatoes were weighed to determine the initial weight and then immersed in gibberellin solutions (5, 10, and 15 ppm) for 30 seconds. The number of tomatoes used for each gibberellin concentration treatment was 30 fruits, resulting in a total of 90 fruits used in this study. Treated fruits were placed on trays, labeled, and stored at ambient temperature (27–29°C). Observations were made every four days for 20 days, recording weight loss, firmness, moisture content, vitamin C, and total acidity.

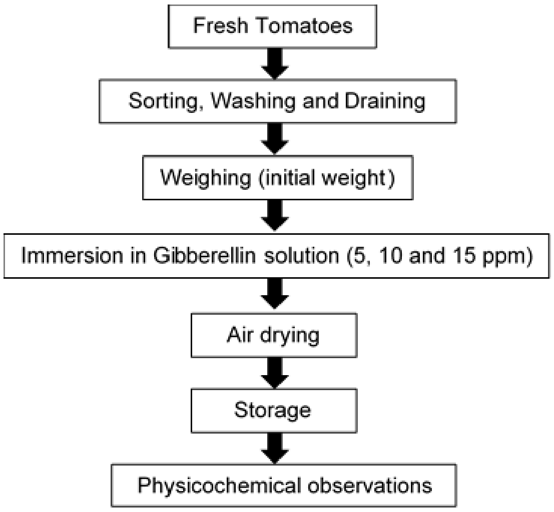

Figure 1. Research process flowchart

Procedure

Weight Loss

Weight loss was calculated by weighing the tomatoes after the cleaning and drying process to obtain the initial weight. The weighing was performed in triplicate on the prepared samples, and the results were recorded. The weight loss value was determined by calculating the difference between the fruit weight before storage and the fruit weight during storage, then dividing it by the initial fruit weight (Nurlatifah *et al*., 2017).

$$\text{Weight loss (\%)} = \frac{initial\ weight - finansial\ weight}{initial\ weight} \times\ 100\%$$

Firmness

The firmness of tomatoes was tested using a penetrometer, in which the instrument's needle penetrates the fruit surface under constant pressure until reaching a certain depth. The depth of penetration is then used to determine the fruit's firmness, expressed in kilograms-force (KgF) (Weni *et al*., 2022).

Moisture Content

The moisture content in this study was determined using the drying method (Horwitz, 2005). The dish was first heated in an oven for 30 minutes at 105℃, then cooled in a desiccator for 15 minutes and weighed to obtain its initial weight. A 2 g tomato sample was placed into the pre-weighed dish and then dried in the oven for 5 hours at 105℃ until a constant weight was achieved. Afterward, the sample was cooled in a desiccator for 30 minutes and reweighed. The moisture content was calculated by comparing the weight before and after drying.

$$\text{moisture content (\%)} = \frac{\text{(weight of dish before drying)} - \text{(weight of dish after drying)}}{\text{(weight of dish and sample before drying)} - \text{(weight of dish)}} \times 100\%$$

Vitamin C

The determination of vitamin C content was carried out by weighing 10 g of tomato sample and placing it into a volumetric flask. Subsequently, 50 mL of distilled water was added, and the sample was titrated with a standard iodine solution of 0.01 N until a color change indicated the endpoint. The vitamin C content was calculated based on the volume of iodine solution used. According to standardization, 1 mL of 0.01 N iodine solution is equivalent to 0.88 mg of ascorbic acid (Horwitz, 2005). The vitamin C content was then calculated using the following formula.

$$\text{Vitamin C} = \frac{VI \times 0{,}88 \times FP}{w} \times 100\%$$

Total Acidity

The determination of total acidity was carried out following the method described by Widodo, Suketi, and Rahardjo (2019), and the calculation was performed using the following formula.

$$\text{ATT (\%)} = \frac{Vtitrasi \times FP \times N \times BM}{w} \times 100\%$$

Experimental Design

A factorial Completely Randomized Design (CRD) was used with two factors: gibberellin concentration (A1 = 5 ppm, A2 = 10 ppm, A3 = 15 ppm) and storage duration (H4 = 4 days, H8 = 8 days, H12 = 12 days, H16 = 16 days, H20 = 20 days), with three replicates, totaling 45 experimental units.

Data Analysis

The data obtained will be statistically analyzed using Minitab software to determine the significant effects of gibberellin concentration and storage duration, as well as the interaction between these two factors. If significant effects are observed, a post-hoc analysis will be conducted using Tukey's test at a 95% confidence level ($\alpha = 0.05$) to identify which treatments differ significantly.

RESULTS AND DISCUSSION

As an essential part of postharvest quality evaluation, various physical and chemical parameters are used to assess the freshness level and shelf life of fruits during storage. In this context, measurements of weight loss, firmness, moisture content, vitamin C content, and total acidity serve as key indicators. The summary of the physicochemical test results in this study is presented in the Table 1.

Weight Loss

Weight loss is one of the key parameters used to determine the extent of mass reduction

Table 1. Summary of ANOVA analysis

Interaksi	Weight Loss		Firmeness		Moisture Content		Vitamin C		Total Acidity	
	%	SD	KgF	SD	%	SD	%	SD	%	SD
A1H4	0,68	0,056	2,93	0,010	94,4	0,036	3,3	0,036	14,2	0,036
A2H4	1,68	0,021	2,58	0,021	94,58	0,026	3,29	0,026	12,4	0,044
A3H4	1,41	0,014	2,19	0,049	94,45	0,030	3,28	0,046	12,6	0,062
A1H8	1,52	0,028	2,52	0,028	93,79	0,053	3,53	0,030	13,55	0,044
A2H8	2,42	0,042	1,84	0,035	93,6	0,080	3,42	0,017	11,2	0,056
A3H8	1,94	0,007	1,33	0,028	93,1	0,036	3,4	0,026	11	0,075
A1H12	2,17	0,042	1,51	0,028	93,16	0,046	3,57	0,026	10,93	0,056
A2H12	2,75	0,021	1,27	0,028	92,96	0,075	3,48	0,030	9,6	0,089
A3H12	2,37	0,028	1,07	0,057	92,55	0,105	3,49	0,056	9,8	0,056
A1H16	2,7	0,049	1,13	0,035	92,87	0,040	3,63	0,020	10,3	0,056
A2H16	3,56	0,064	1,05	0,106	92,71	0,040	3,58	0,036	8,8	0,066
A3H16	2,84	0,007	0,82	0,028	92,23	0,040	3,61	0,030	9	0,125
A1H20	3,23	0,021	0,96	0,049	92,78	0,036	3,67	0,036	8,6	0,062
A2H20	8,04	0,035	0,86	0,134	92,54	0,095	3,64	0,010	8	0,128
A3H20	5,67	0,099	0,43	0,028	89,66	0,601	3,3	0,046	6,87	0,036

in a product during storage, primarily due to physiological changes (Iskandar *et al.*, 2020). Variations in weight loss can affect the visual appearance and texture of the product, thereby influencing consumer appeal (Tarta *et al.*, 2024). The experiment the lowest weight loss was observed in the A1H4 treatment (5 ppm gibberellin on day 4 of storage) at 0.68%, while the highest was recorded in the A2H20 treatment (10 ppm gibberellin on day 20 of storage) at 8.20%. Analysis of variance revealed that gibberellin concentration had a significant effect on tomato weight loss throughout the storage period. The results of weight loss measurements are presented in Figure 2.

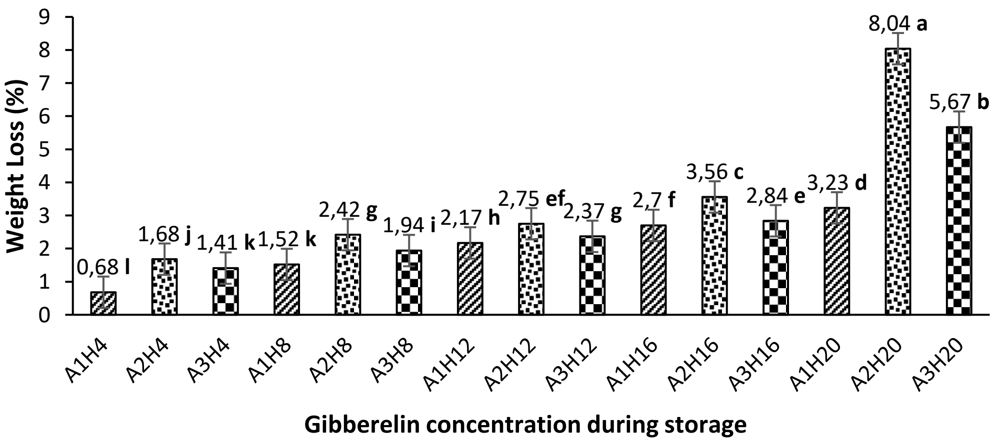

Figure 2. Gibberellin effect on weight loss (%) during storage

As shown in Figure 2, weight loss increased across all gibberellin concentrations during storage. This increase is attributable to physiological processes occurring in tomatoes during storage, which lead to progressive water loss (Cui *et al*., 2017). Gibberellin concentration also influenced the rate of weight loss, with the 5 ppm treatment effectively suppressing respiration and consequently reducing the increase in weight loss over the storage period (Yoo *et al*., 2022). Increasing the relative humidity, lowering the temperature, and controlling air movement through the use of packaging can minimize fruit weight loss caused by respiration and transpiration processes (Machado *et al*., 2022). An appropriate concentration of gibberellin can enhance the synthesis activity and accumulation of cuticular compounds, such as wax and cutin, in the fruit epidermal tissue, thereby reducing water vapor loss. These findings are consistent with those of Zhang *et al*. (2023), who reported that gibberellin application can reduce postharvest fruit shrinkage in horticultural crops.

Firmness

Firmness is a key parameter for assessing tomato quality during storage, as it is closely related to texture (Zhang *et al*., 2023). Firmness can be influenced by several factors, including the stage of maturity, storage conditions, and postharvest treatments (Pusik *et al*., 2019). In the present study, tomato firmness decreased progressively throughout the storage period. The highest firmness value was recorded in the A1H4 treatment (5 ppm gibberellin on day 4 of storage) at 2.93 KgF, while the lowest was observed in the A3H20 treatment (15 ppm gibberellin on day 20 of storage) at 0.43 KgF. Analysis of variance indicated that gibberellin concentration had a significant effect on changes in tomato firmness during storage. The changes in firmness across treatments are illustrated in Figure 3.

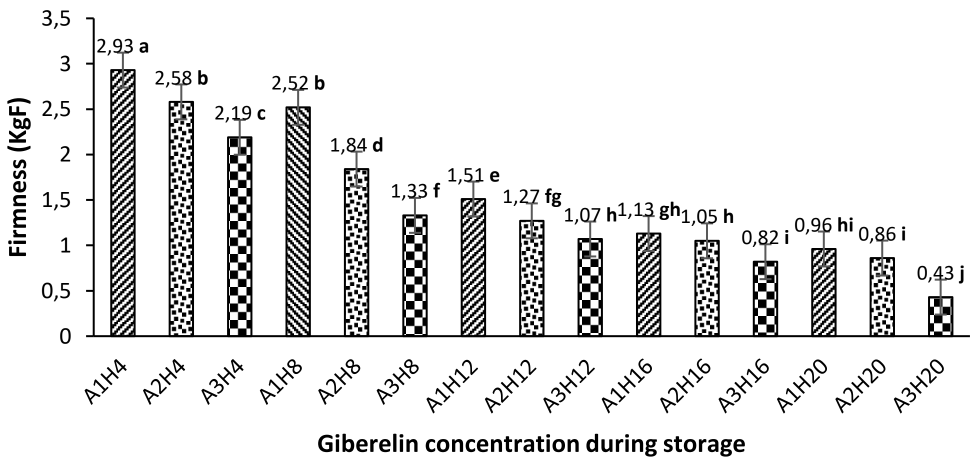

Figure 3. Gibberellin effect on firmness (KgF) during storage

As shown in Figure 3, tomato firmness decreased progressively during storage. This reduction in firmness can be attributed to the degradation of pectin within the cell walls, leading to structural changes in the tissue. The process is accelerated by enzymatic activity and respiration, which increase ethylene production and subsequently hasten ripening (Agustin & Cahyanto, 2024). Firmness is closely correlated with weight loss, where the reduction in weight is caused by transpiration, leading to decreased water content, reduced cell turgor, and consequently a softer fruit texture (Breemer & Pattiruhu, 2024). Furthermore, gibberellin concentration influenced the rate of firmness loss during storage. Gibberellin is capable of delaying ripening and maintaining fruit cell structure by suppressing respiration and reducing ethylene production (Zhang *et al*., 2023). Applying the optimal concentration can therefore help preserve firmness over time. These findings are consistent with those reported by Abdallah and Abu-Goukh (2023), who found that 100 ppm gibberellin effectively maintained lime fruit firmness during storage.

Moisture Content

As one of the horticultural products with a high moisture content, tomatoes are highly susceptible to water vapor loss caused by respiration and transpiration processes. The reduction in water content affects the fruit's weight, firmness, and freshness during storage (Pattiruhu & Breemer, 2024). The results of moisture content analysis in this study indicate that changes occurred throughout the storage period. The highest moisture content was observed in the A2H4 treatment (10 ppm gibberellin on the 4th day of storage) at 94.58%, while the lowest was recorded in the A3H20 treatment (15 ppm gibberellin on the 20th day of storage). The results of the moisture content analysis are presented in Figure 4.

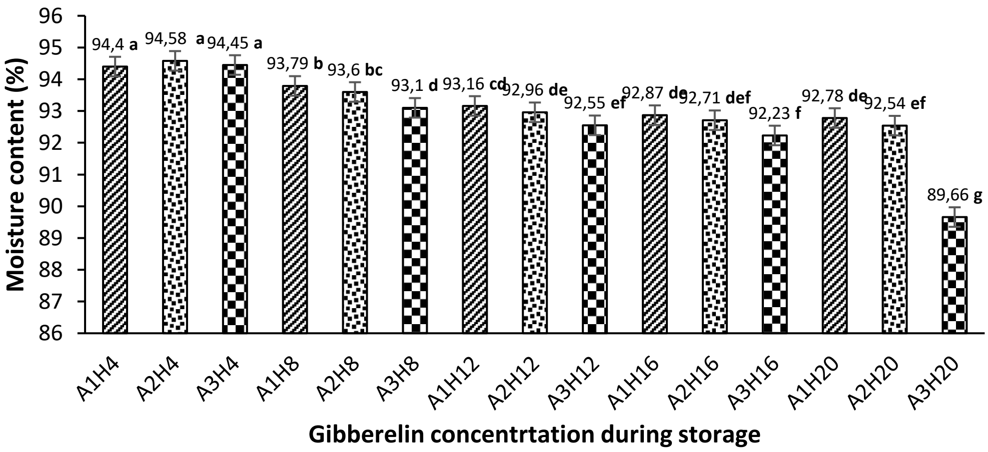

Figure 4. Gibberellin effect on moisture content (%) during storage

Figure 4 illustrates that both gibberellin application and storage duration significantly influence the moisture content of tomatoes. The reduction in moisture content over time is attributed to the evaporation process, whereby prolonged storage results in a progressive decline in moisture content (Salingkat *et al*., 2020). Gibberellin, which functions to inhibit the rate of respiration and suppress ethylene production, also plays a role in maintaining moisture levels. These findings are consistent with those reported by Ramanis *et al*. (2023), who demonstrated that the application of 12.5 ppm gibberellin was effective in preserving the quality of fresh oil palm fruit.

Vitamin C

Vitamin C is an antioxidant that plays a crucial role in maintaining the body's immune system and is present in tomatoes (Assagaf, 2020). However, vitamin C in tomatoes is highly sensitive to various environmental factors during storage. The results of the vitamin C content analysis in this study showed that the highest vitamin C level was recorded in the A1H20 treatment (5 ppm gibberellin on the 20th day of storage) at 3.67%, while the lowest was observed in the A3H4 treatment (15 ppm gibberellin on the 4th day of storage) at 2.28%. Analysis of variance revealed that both the individual treatments and their interactions had a significant effect on the vitamin C content of tomatoes. The results of the vitamin C analysis are presented in Figure 5.

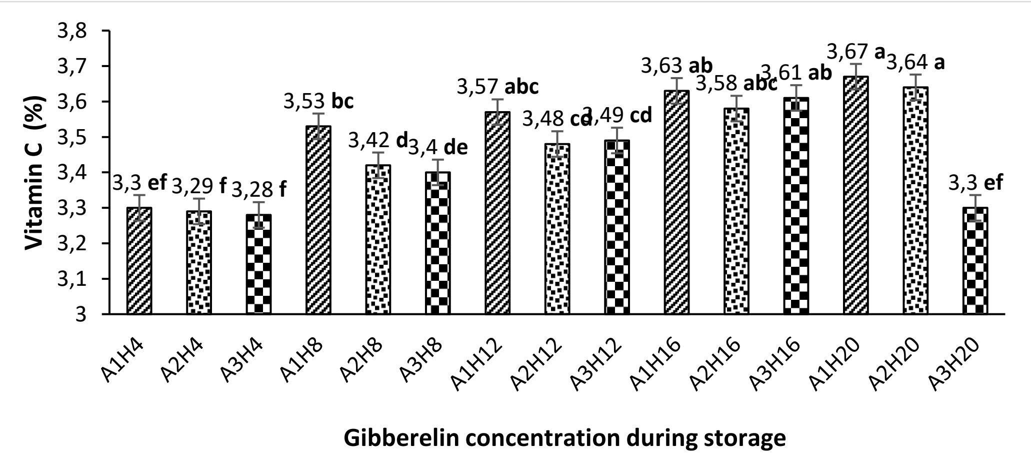

Figure 5. Gibberellin Effect on Vitamin C (%) During Storage

Figure 5 shows that up to the 16th day of storage, treatments with different gibberellin concentrations exhibited an increase in vitamin C content. However, on the 20th day, the treatment with 15 ppm gibberellin showed a decline, which contrasted with the 5 ppm and 10 ppm gibberellin treatments that maintained higher vitamin C levels on the same day. Vitamin C is easily oxidized during respiration; therefore, by suppressing the respiration rate, an appropriate application of gibberellin can help maintain the vitamin C content (Puskas *et al*., 2000). These results are consistent with the findings of Luo *et al*. (2023). The decrease in vitamin C content is also influenced by storage duration, which is associated with oxidative processes leading to the degradation of vitamin C in tomatoes (Chitravathi *et al*., 2015). This study's findings are also in agreement with those of Pattiruhu & Breemer (2024), who reported that both closed-control and open-control storage systems experienced a reduction in vitamin C content by the 16th day of storage.

Total Acidity

Total acidity is an important parameter for determining the freshness of tomatoes during storage. The organic acids present, such as citric acid, malic acid, and ascorbic acid, contribute to the characteristic flavor of tomatoes (Arkan *et al.*, 2021). In this study, the highest total acidity was recorded in the A1H4 treatment (5 ppm gibberellin on the 4th day of storage) at 14.2%, while the lowest was observed in the A3H20 treatment (15 ppm gibberellin on the 20th day of storage) at 6.87%. Analysis of variance revealed that both the individual treatments and their interactions had a significant effect on the total acidity of tomatoes during storage. The results of total acidity analysis are presented in Figure 6 below.

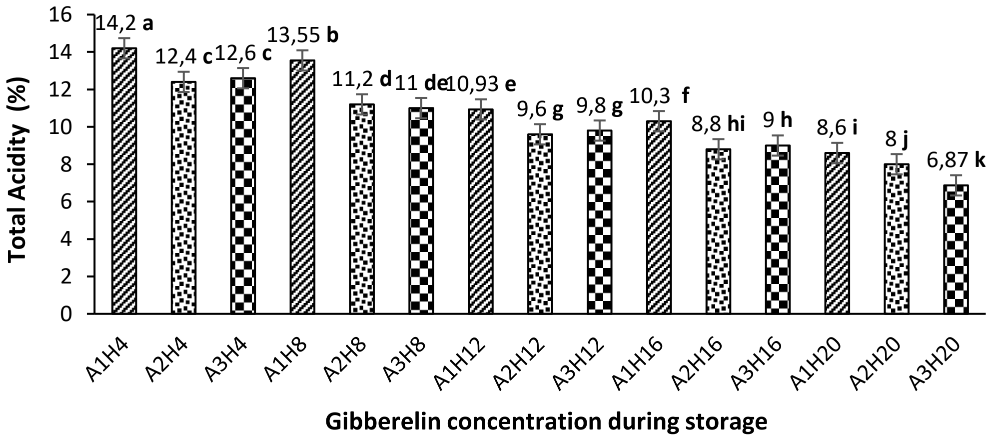

Figure 6. Gibberellin effect on total acidity (%) during storage

Figure 6 shows that throughout the storage period, the 5 ppm gibberellin concentration consistently maintained the highest total acidity. This indicates that 5 ppm gibberellin is the most effective concentration for preserving the acid content in tomatoes. An inappropriate concentration may cause fruit deterioration (Yoo *et al.*, 2022). These findings are in line with a previous study in which a 300 ppm gibberellin treatment reduced the acidity of rambutan fruit by 0.4% (Mesbah Uddin *et al.*, 2024). Storage duration in this study also had a significant effect on total acidity, as prolonged storage led to a decline in acid content due to fruit ripening, during which organic acids are converted into sugars through enzymatic reactions (Fitriani *et al.*, 2020). This result is consistent with the findings of Manurung *et al.* (2024), who reported a decrease in total titratable acidity in oranges during storage.

CONCLUSION

Based on the findings of this study, it can be concluded that there is an interaction between gibberellin concentration and storage duration in determining tomato quality. The lowest gibberellin concentration (5 ppm) was identified as the most effective for maintaining tomato quality over a 20-day storage period, resulting in the lowest weight loss (3.67%), a firmness level of 0.96 kgf, and a moisture content of 92.78%. Furthermore, the 5 ppm gibberellin concentration on the 20th day of storage was able to preserve the vitamin C content of tomatoes at 3.67% and maintain total titratable acidity at 8.6%.

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