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EFFECTS OF POSTHARVEST TREATMENTS ON THE QUALITY OF CUCUMBER *(CUCUMIS SATIVUS L.)* DURING COLD STORAGE

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ABSTRACT

Cucumber (Cucumis sativus L.) is an economically important horticultural crop that undergoes rapid postharvest deterioration due to high respiration rates and moisture loss, resulting in reduced market quality and shortened shelf life. This study evaluated the effectiveness of three simple and low-cost postharvest treatments in maintaining cucumber quality during cold storage. Uniformly mature fruits were treated with 3 mg/L potassium permanganate ($KMnO_4$), 2% sodium bicarbonate ($NaHCO_3$) for 2 minutes, or hot water at 52°C for 1 minute before storage at 10°C. Fruit quality was assessed after 7, 14, and 21 days of storage based on weight loss, firmness, reducing sugar content, and vitamin C content. All three treatments significantly improved postharvest quality compared with the untreated control. Among them, hot water treatment at 52°C for 1 minute was the most effective, resulting in the lowest weight loss while better preserving fruit firmness, reducing sugars, and vitamin C throughout storage. These findings indicate that hot water treatment is a simple, safe, and cost-effective postharvest technique for extending cucumber shelf life and maintaining fruit quality under cold storage conditions. The study provides practical recommendations for growers and postharvest handling systems seeking affordable alternatives to more complex preservation technologies.

Keywords: *Cucumis sativus L.; cucumber; postharvest treatment; cold storage; shelf life; fruit quality.*

Introduction

Cucumber (*Cucumis sativus* L.), belonging to the family Cucurbitaceae, is a globally cultivated crop used for fresh consumption and processing (Kaur & Sharma, 2022). This fruit contains approximately 95-96% water, is very low in calories, and is rich in dietary fiber, vitamins (C, K, B complex), and minerals (potassium, calcium). The exceptional nutritional value of cucumber derives from bioactive phytochemical compounds such as polyphenols, cucurbitacins (anticancer), flavonoids, and carotenoids. Consequently, it provides numerous health benefits, including antioxidant, anti-inflammatory, and antibacterial properties, as well as support for blood glucose and blood pressure control, cardiovascular protection, and digestive improvement, making it an important natural functional food (Uthpala et al., 2020; Javid et al., 2024).

After harvest, the cucumber fruit continues physiological processes with high respiration intensity and particular sensitivity to temperature stress. These characteristics are the primary causes of rapid quality deterioration, such as water loss (due to transpiration), wilting, yellowing, and increased susceptibility to postharvest diseases. To control these processes, optimal storage conditions are determined at temperatures of 10-12.5°C with 90-95% relative humidity, allowing commercial storage periods typically under 14 days (UC Davis Postharvest). However, cucumbers are susceptible to chilling injury at temperatures below 10°C when stored for more than 1-3 days and prone to yellowing at temperatures of 15°C or higher (Dhall et al., 2012).

Modified atmosphere packaging (MAP) technology combined with cold storage is considered the best method to extend storage life and maintain the sensory quality of cucumber (Manjunatha et al., 2014). Although effective, this method is costly and difficult to implement in rural areas. Therefore, simple, inexpensive, and easily applicable solutions that still ensure extended storage life and maintained quality parameters are needed.

Chemical treatment methods using $KMnO_4$ as an ethylene absorbent and $NaHCO_3$ with antimicrobial properties, along with physical methods using hot water to control microorganisms, are showing considerable promise (Mahajan et al., 2014; Belwal et al., 2025). However, the specific efficacy of these methods on important quality parameters of cucumber, such as weight loss, vitamin C content, reducing sugar content, and firmness, still requires comprehensive evaluation.

This study aims to evaluate effects of different pre-storage treatments on physicochemical parameters of cucumber fruit grown in An Huu, Dong Thap. Through analysis and comparison of parameters, the study will provide a scientific basis to identify simple, low-cost treatment methods to ensure good quality of cucumber after storage periods. The research results not only have theoretical significance but also provide high practical value, enabling growers and agricultural processing enterprises to improve production efficiency and minimize losses during storage.

1. Materials and Methods

Materials

The cucumber variety used in the study was the F1 hybrid variety Amata 765, originating from Thailand, imported by Trang Nong Company Limited.

Methods

Experimental design

Cucumber samples were collected from a specialized cultivation area in An Huu, Dong Thap, ensuring uniformity in climatic conditions, soil properties, and cultivation practices. Fruits were manually harvested at 11 days after pollination, between 7:00 and 9:00 AM. Selected fruits exhibited high uniformity in size and color, with no signs of pest infestation or mechanical damage. Immediately after harvest, samples were placed in specialized plastic baskets with cushioning liners and were transported rapidly to the laboratory within 4 hours for initial analyses.

Before storage, cucumber samples were randomly assigned to four treatments, each group containing 40 cucumbers and subjected to the following postharvest treatments:

- *Control group:* Treated with distilled water at room temperature.
- *$KMnO_4$ treatment group:* Immersed in 3 mg/L potassium permanganate ($KMnO_4$) solution at room temperature for 2 minutes.
- *$NaHCO_3$ treatment group:* Immersed in 2% (w/v) sodium bicarbonate ($NaHCO_3$) solution at room temperature for 2 minutes.
- *Heat treatment group:* Immersed in hot water at 52 °C for 1 minute.

After treatment, fruits were immediately removed and naturally air-dried on mesh racks in a clean room equipped with ventilation fans until the surface was completely dry. Each replication of ten cucumber fruits was then packaged into perforated polyethylene (PE) film bags (25 × 35 cm, 0.07 mm thickness; and two holes in each bag with a diameter of 6 mm) and then heat-sealed. Each bag contained ten fruits (equivalent to 2.0-2.5 kg per bag) to avoid compression and maintain an adequate headspace. The packaged fruits were transferred to a temperature-controlled room at 10 °C for storage. The experiment followed a completely randomized design with three independent replications per treatment. Quality parameters were evaluated at four time points: immediately after treatment (day 0, before storage) and after 7, 14, and 21 days of storage.

Analytical methods

The parameters monitored and analytical methods applied in this study are described below.

- *Weight loss (%):* Weight was measured using an electronic analytical balance with 0.01 g precision (manufactured in Japan). Fruits were wiped dry, placed directly on the balance pan, and values were recorded when the reading stabilized. Results were averaged from 5-10 fruits per sample (Kator et al., 2018). Weight loss percentage (%) of cucumber during storage was determined using the formula: (%) = $[(w_0 - w_t) / w_0] \times 100$; where w_0 (g) is the initial weight of the sample at the start of storage (day 0); w_t (g) is the weight of the sample at evaluation time t (after 7, 14, 21 days of storage).
- *Fruit firmness (kg_f/cm^2):* Fruit firmness was determined using a penetrometer with a 0-5 kg scale and 50 g graduations (5 kg × 50 g). Cucumber fruits were fixed, then a conical probe of 3-5 mm diameter was penetrated the middle section of the fruit to a depth of 5-8 mm. The maximum force (kg) at the moment of tissue penetration was recorded

as the firmness index. Each fruit was measured at three symmetrical positions, replicated with 5-10 fruits per sample, and the average value was calculated (Wang et al., 2020).

- *Reducing sugar content (%):* Reducing sugar content was determined by the Bertrand method, based on the reduction reaction of copper ions (Cu^{2+}) in Fehling's solution. Samples were extracted with hot water, filtered and neutralized, then Fehling's solution was titrated until the complete disappearance of the blue color of Cu^{2+}. Results were calculated according to the Bertrand conversion table, with each sample replicated three times and averaged (Trong et al., 2019).

- *Vitamin C content (mg/100 g):* Vitamin C content was determined by DCPIP (2,6-dichlorophenol indophenol) titration method based on the method of Pham et al. (2024), with each sample replicated three times and averaged. A 0.10 g sample was extracted in 20 mL of 4 % oxalic acid solution and centrifuged at 10,000 rpm for 30 minutes. The supernatant after centrifugation was used for analysis: a mixture of 10 mL sample extract and 10 mL 4% oxalic acid was titrated with DCPIP solution (designated as V_1) until a stable light pink color appeared for at least 90 seconds. The control sample consisted of 5 mL of 100 ppm standard ascorbic acid solution and 10 mL 4 % oxalic acid, with the volume of DCPIP consumed recorded as V1. Vitamin C content (mg/100g) was calculated based on the equation: Vitamin C (mg/100g) = $(0.5 \times V_2 \times 20) / (V_1 \times 10 \times 0.1)$. Where: V_1 (mL) is the volume of DCPIP consumed to titrate the control sample (equivalent to 0.5 mg ascorbic acid); V_2 (mL) is the volume of DCPIP consumed to titrate the sample extract; m (g) is the weight of the analyzed sample (0.1 g).

Statistical Data Processing

Experimental data were processed and statistically analyzed using Microsoft Excel 2016 and Statgraphics Centurion XV. I software. Differences were assessed as significant at the 5% probability level.

2. Results and Discussion

Assessing the impact of postharvest treatments on the quality parameters of cucumber fruit throughout storage is crucial because cucumber is a vegetable with a short shelf life (typically only 1-2 weeks) and is highly sensitive to chilling injury and water loss. Postharvest treatments primarily aim to maintain quality, reduce respiration rate, limit transpiration (water loss), and inhibit the growth of spoilage microorganisms (Hasan et al., 2019). The initial quality parameters of the cucumbers before cold storage are presented in Table 1.

Table 1. The initial quality parameters of the cucumber

Fruit weight (g)	Firmness (kg_f/cm^2)	Reducing sugar content (%)	Vitamin C content (mg/100 g)
101.46±0.11	3.63±0.05	1.70±0.02	4.50±0.10

Fig 1. Cucumber before storage treatment

Effect of Postharvest Treatments on Natural Weight Loss of Cucumber During Storage

The results presented in Figure 2 show that the natural weight loss of the cucumber after 7, 14, and 21 days of storage increased progressively in all three treatments and the control. However, the magnitude of increase differed significantly between the non-surface treatment and the surface treatments. Specifically, weight loss in the control (CT) group was the highest: after 21 days of storage, the loss rate reached 3.87%; weight loss in chemical treatments were moderate (3.50% for $KMnO_4$ and 3.55% for $NaHCO_3$); the lowest weight loss was observed in samples treated with water at 52 °C (3.15%); these differences were statistically significant (*$p<0.05$*). This indicates that surface treatment of fruits had a significant effect in limiting weight loss during storage, with hot water treatment of cucumber showing the most pronounced reduction in weight loss, followed by chemical treatments. These results are consistent with the findings of Nasef (2018) and Amer &

Azam (2019), where cucumber treated with water at 55 °C for 5 minutes exhibited the lowest weight loss among the treatments.

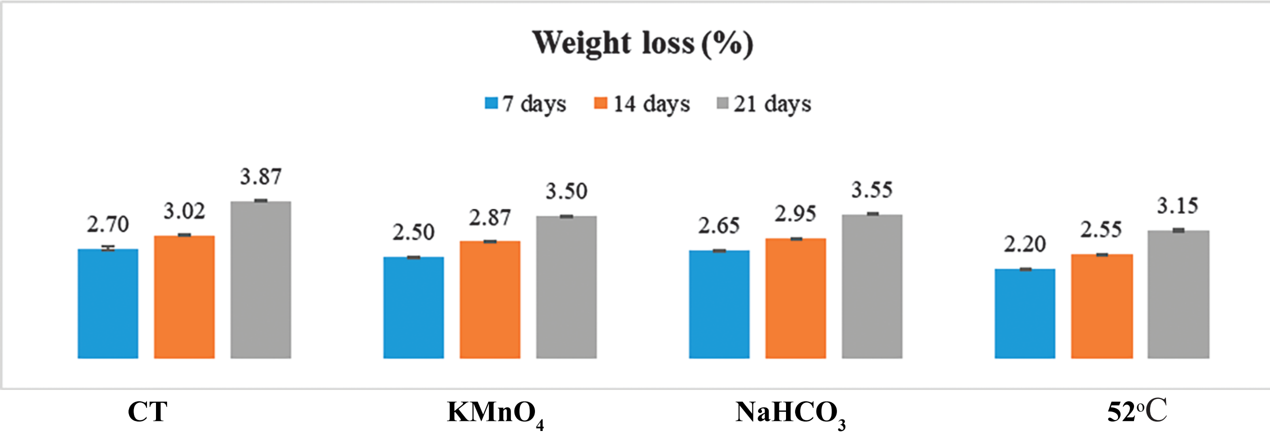

Fig 2. Weight loss (%) during storage for different treatments

Effect of Postharvest Treatments on Firmness of Cucumber During Storage

Firmness is one of the important physicochemical parameters of fruit, which is affected sensory quality and is influenced consumer purchasing decisions (Harker et al., 2003). The results of the cucumber fruit firmness analysis are presented in Figure 3.

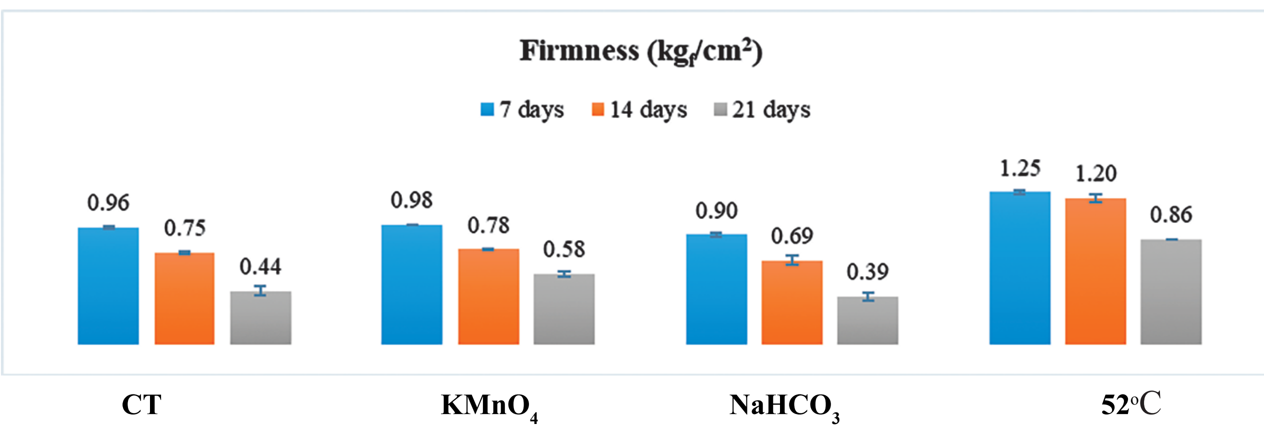

Fig 3. Firmness (kg_f/cm^2) during storage for different treatments

The results show that cucumber firmness in all treatments were decreased progressively during storage, with notable differences in the degree of reduction between the control sample and other treatments. After 21 days of storage from an initial firmness of 3.63 (kg_f/cm^2) in **Table 1**, samples treated with $NaHCO_3$ was shown the lowest value (0.39 kg_f/cm^2); the CT sample was decreased to 0.44 (kg_f/cm^2); was followed by $KMnO_4$ treatment (0.58 kg_f/cm^2), with the highest firmness recorded in hot water-treated samples at 0.86 kg_f/cm^2; these differences were statistically significant ($p<0.05$).

During postharvest storage, the decline in cucumber firmness is an important indicator reflecting the aging process and cellular structure degradation. The primary cause of this phenomenon is pectin hydrolysis in cell walls, which weakens intercellular bonds. The research results demonstrated that all three treatments ($KMnO_4$, $NaHCO_3$, and heat at 52 °C) were effective in maintaining firmness compared to the control. Among these, heat treatment at 52 °C showed superior performance, primarily through the mechanism of inactivating pectin-hydrolyzing enzymes such as pectin methyl esterase (PME) and polygalacturonase (PG), thereby significantly slowing structural degradation. Chemical methods also contributed through different mechanisms: $KMnO_4$ was acted as a strong surface antimicrobial agent, preventing microbial invasion and damage, while $NaHCO_3$ was inhibited the growth of spoilage microorganisms, limiting premature softening. Thus, although postharvest treatment methods were aimed to be maintain mechanical quality, each method was achieved effectiveness through different biochemical and microbiological mechanisms. Among these, heat treatment was shown distinct advantages, particularly for preserving cucumber firmness, due to its ability to simultaneously affect tissue structure and fruit physiological processes. Each method operates through a specific biochemical and microbial pathway, with heat treatment demonstrating optimal effectiveness for cucumber firmness parameters. These results were consistent with the findings of Amer & Azam (2019), where cucumber treated with water at 55 °C for 5 minutes showed the lowest firmness decline among treatment methods.

Effect of Postharvest Treatments on Reducing Sugar Content of Cucumber During Storage

Cucumber belongs to the non-climacteric fruit group; therefore, reducing sugar content tends to decrease linearly during storage as it is used as the main substrate for respiration (**Figure 4**). The research results were shown that all three treatments were effective in limiting the reduction of reducing sugar content compared to the CT after 7, 14, and 21 days of storage. Specifically, after 21 days, reducing sugar content in the CT decreased to 1.08%, while treated groups maintained higher levels: $KMnO_4$ (1.22%), $NaHCO_3$ (1.12%), and particularly the heat treatment at 52 °C (1.26%); these differences were statistically significant (*$p<0.05$*).

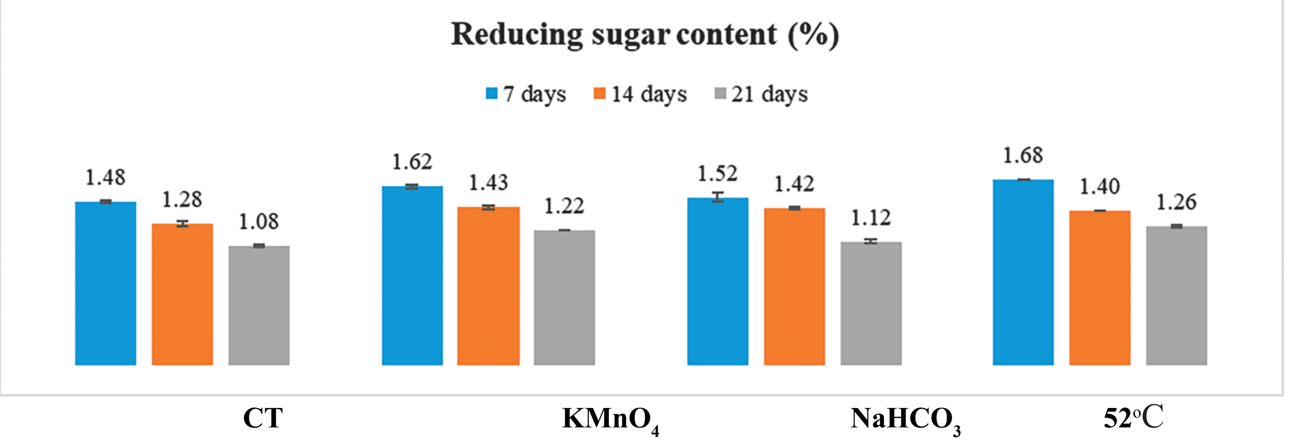

Fig 4. Reducing sugar content (%) during storage for different treatments

This difference stemmed from distinct action mechanisms. The highest preservation efficacy was shown by heat treatment at 52 °C, primarily through the mechanism in which fruit respiration intensity was directly reduced. By inhibiting the activity of enzymes involved in the respiratory cycle, the rate of sugar consumption was significantly slowed, thereby reducing sugar content, which was better preserved. Conversely, indirect mechanisms were acted upon by chemical methods. Treatment with $KMnO_4$, with its strong oxidative activity, functioned as an effective surface antibacterial and antifungal agent, by which microbial invasion and damage were prevented. Physiological injuries were limited, and a more stable metabolic status was maintained. Similarly, a mild alkaline environment on the fruit surface was created by $NaHCO_3$ solution, in which the germination and growth of mold spores and spoilage bacteria were inhibited. By effectively controlling the microbial system, biological stress was minimized, respiration intensity was maintained at lower levels, and sugar degradation processes were slowed. These results were found to be consistent with the findings of Nasef (2018), where the reduction sugar content loss was limited in cucumber treated with water at 55 °C for 5 minutes among treatments.

Effect of Postharvest Treatments on Vitamin C Content of Cucumber During Storage

The results from Figure 5 showed that vitamin C content in cucumber samples across all treatments exhibited a declining trend over storage, consistent with the oxidation-susceptible and degradable characteristics of this compound. However, the rate of decline in treated samples was significantly slower than in the control sample. Specifically, the initial vitamin C content was 4.50 (mg/100 g) in Table 1; after 21 days of storage, this content in the CT was decreased to 1.21 (mg/100 g); while higher levels were maintained in treated samples: $KMnO_4$ and $NaHCO_3$ yielded nearly similar results (2.36 mg/100 g and 2.32 mg/100 g, respectively), whereas the highest efficacy was achieved by heat treatment at 52 °C (2.72 mg/100 g); these differences were statistically significant ($p<0.05$).

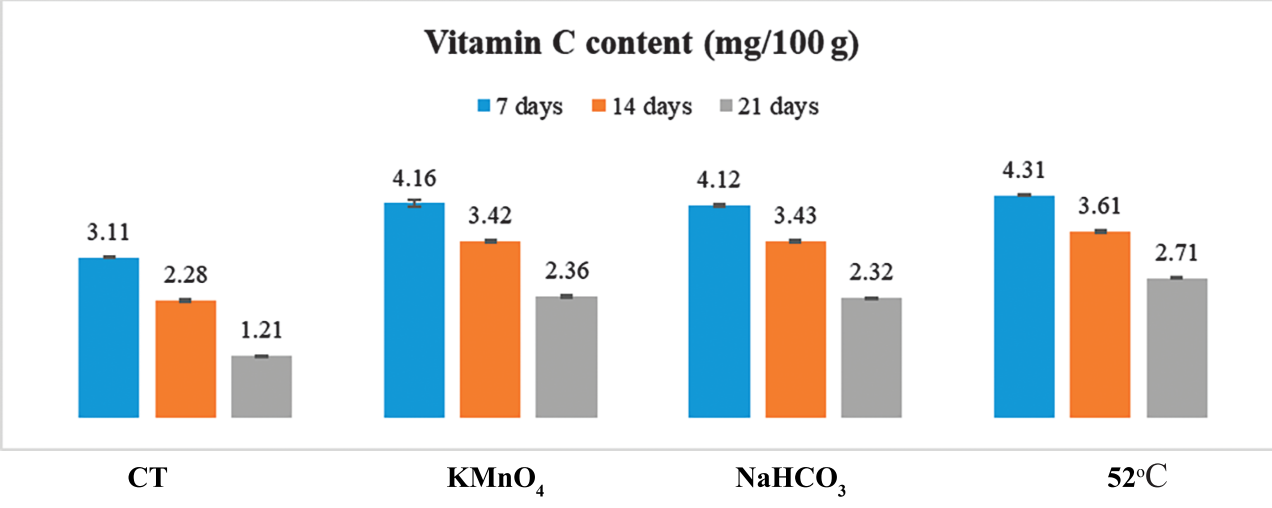

Fig 5. Vitamin C content (mg/100 g) during storage for different treatments

This difference stemmed from the distinct action mechanisms of each method: optimal efficacy was achieved by heat treatment (52 °C) through the mechanism in which respiration intensity was directly suppressed, thereby endogenous oxidation processes were slowed; treatment with $KMnO_4$ was primarily relied on strong surface antimicrobial properties by which microorganisms were controlled-the agents that accelerate vitamin C loss, while direct losses due to the oxidative nature of $KMnO_4$ were negligible during the short treatment period; while treatment with $NaHCO_3$ was operated by creating an alkaline surface environment in which the growth of mold and bacteria was inhibited, thereby quality deterioration was indirectly slowed. Thus, while endogenous physiological processes were directly affected by heat treatment, passive protection mechanisms were primarily relied on by the two chemical methods through control of external microbial agents. These results confirmed the effectiveness of surface treatment in preserving nutritional quality, consistent with the findings of Amer & Azam (2019), and indicated that heat treatment at 52 °C was the most effective method for maintaining vitamin C content in cucumber throughout the storage periods.

Conclusion

This study demonstrated that both physical and chemical postharvest treatments effectively improved the storage quality of cucumber at 10 °C. Among these, heat treatment at 52 °C exhibited the most comprehensive and superior efficacy across all four parameters: minimizing weight loss, maintaining firmness through inactivation of pectinase enzymes, preserving reducing sugar and vitamin C content via mechanisms that directly suppress respiration intensity. Chemical treatment methods, whose primary action mechanism is surface antimicrobial activity, also provided notable storage benefits, particularly in reducing water loss and quality deterioration caused by microorganisms. Therefore, heat treatment at 52°C is recommended as the optimal solution for extending storage life and maintaining the commercial quality of postharvest cucumber.

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