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Extending Cucumber Shelf Life: A Comparative Study of Low-Cost Drip Cooling Systems Using Different Fabric Coverings

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Authors' contributions

This work was carried out in collaboration between both authors. Author JPF conceptualization and design of the study, data collection, manuscript drafting. Author SMR data analysis and Interpretation. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Postharvest losses of cucumbers pose significant challenges for small-scale farmers in developing regions due to limited access to modern cold storage. This study investigated the effectiveness of low-cost indigenous drip coolers with different fabric coverings as an alternative preservation method.

Study Design: Completely Randomized Design (CRD) with five treatments and three replications.

Place and Duration of Study: Department of Crop Science, Surigao del Norte State University – Mainit Campus, Mainit, Surigao del Norte, Philippines on March 1-20, 2024.

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Methodology: Cucumber fruits were stored in indigenous drip coolers constructed with various recycled fabric coverings. Treatment combinations were: T1 - Control ambient temperature, T2 - Alpha Gina fabric, T3 - Silk satin bedsheets, T4 – Cotton comforter, and T5 - Cotton Blanket. The study evaluated color change, firmness, shriveling index, visual quality rating, weight loss, and damage rate over 20 days storage period.

Results: Significant differences in cucumber fruit quality emerged at different time points across various parameters. Differences in color change and firmness were observed on day 15 ($p = 0.023$), while shriveling and visual quality showed differences by day 20 of storage ($p = 0.042$ and $p = 0.042$, respectively). However, in terms of weight loss, the Alpha gina fabric significantly had the highest loss among fabric covers used ($p = 0.038$). Consistently, the control ambient group exhibited the poorest quality, while treatments like the cotton comforter and silk satin bedsheet were most effective in preserving cucumber quality.

Conclusion: This study demonstrates the effectiveness of indigenous drip coolers in preserving cucumber quality, with silk satin bedsheets and cotton comforter coverings consistently outperforming other materials and ambient conditions. These coolers were effective in slowing color change, maintaining firmness, reducing shriveling, and preserving overall visual quality. The study highlights the importance of fabric selection in drip cooler design, with cotton comforter and silk satin bedsheet coverings likely offering better air circulation, moisture retention, and insulation.

Keywords: Evaporative cooling; water drip; fabric cover; cloth cooler; cooling chamber.

1. INTRODUCTION

Postharvest handling of cucumbers (*Cucumis sativus* L.) presents significant challenges, particularly in rural areas of the Philippines and other developing regions with limited storage infrastructure, making this highly perishable vegetable crop prone to rapid quality deterioration after harvest. Evidence of this vulnerability is seen in cucumbers' susceptibility to moisture loss, ethylene sensitivity, chilling injury, mechanical damage, and pathogen infection [1]. The explanation for these challenges lies in the tropical climate of many developing regions, where high ambient temperatures accelerate spoilage, and the predominance of small-scale farmers who lack access to modern cold storage facilities due to cost and energy constraints [2]. As a result, cucumbers and other perishable produce frequently suffer significant postharvest losses. This issue directly reduced marketability and economic losses for farmers, highlighting the urgent need for affordable and practical storage solutions in these regions [3].

Traditional storage methods, such as ambient room storage "Kamalig" in the Philippines [4 - 6], have proven ineffective in preserving the quality of cucumbers. These methods fail to control critical factors like temperature and humidity, as studied by Liberty et al. [7]. Evaporative cooling systems have emerged as a promising low-cost, energy-efficient alternative for postharvest handling in resource-limited settings, facilitating water evaporation to lower temperature and increase relative humidity. Various designs of evaporative coolers have been implemented, including the Zero Energy Brick Cooler (ZEBC), Evaporative Charcoal Cooler (ECC), pot-in-pot structures, and charcoal cooling chambers. Research by Ambuko et al. [3], Mordi & Olorunda [8], and Odesola & Onyebuchi [9] has shown that these systems can effectively preserve fruit and vegetable quality, but this often requires specialized materials or construction techniques that may not be readily available or feasible for all small-scale farmers, potentially limiting their widespread adoption.

With this, indigenous drip cooler is a type of evaporative coolers that might address some of the limitations of previous systems is proposed. These coolers offer a more accessible and adaptable solution for small-scale farmers by utilizing locally available materials and simple construction methods. Their potential benefit lies in the use of various recycled fabric coverings as cooling absorbents, which provides an opportunity to optimize cooling efficiency and microclimate control within the storage environment. Indigenous drip coolers could be a viable alternative to more complex or expensive cooling systems. While these indigenous evaporative cooling systems show promise for preserving cucumber quality, more comprehensive research is needed to compare their effectiveness to other storage methods and understand their benefits for small-scale agriculture.

This study aims to fill this gap by evaluating the performance of indigenous drip coolers with different fabric coverings in maintaining the postharvest quality of cucumber fruits. We hypothesize that indigenous drip coolers, particularly those using fabric coverings with superior moisture retention and insulation properties, will significantly outperform ambient storage conditions in preserving cucumber quality. The findings of this study could have significant implications for postharvest management practices in resource-limited settings.

2. MATERIALS AND METHODS

2.1 Study Location and Indigenous Drip Coolers

The study was conducted on March 1-20, 2024 at Surigao del Norte State University (SNSU) Mainit Campus, Magpayang, Mainit, Surigao del Norte, Philippines, in an indigenous drip cooler that was constructed with dimensions of 1 x 1 x 2 meters (Fig. 1). The roof was made from nipa shingles, while the structural framework consisted of 2 x 2 x 2 wooden sticks for the posts and pillars and 1 x 2 x 4 wooden pieces for the flooring and floor joists. A ½ inch PVC pipe was used for water drips, connected to earthen jars that served as the water supply. The walls or coverings of the drip coolers were made from various fabrics, including recycled Alpha Gina fabric, cotton blankets, silk satin bedsheets, and cotton comforter sheets. The flooring was constructed from bamboo splits and divided into three layers: top, middle, and bottom. These indigenous drip coolers were positioned outdoors and fully exposed to sunlight. During the study, Surigao del Norte recorded an average temperature of 27.2°C and a relative humidity of 78%. Rainfall was lower compared to earlier months, contributing to drier conditions.

2.2 Cucumbers and Experimental Setup

The experiment utilized cucumber fruits of the Mega F1 cultivar, sourced from the student production project at Surigao del Norte State University (SNSU) Mainit Campus. Upon harvesting, the cucumbers underwent inspection for bruises, damage, and deformities, followed by cleaning with wet cloths and air drying for 15 minutes. The experimental design employed was a Completely Randomized Design (CRD) with five treatments, each replicated three times, resulting in a total of 180 cucumber samples. The treatments consisted of T1 (Control, ambient temperature), T2 (Alpha gina fabric covering), T3 (Silk satin bedsheet covering), T4 (Cotton comforter covering), and T5 (Cotton blanket covering). Each treatment included twelve cucumber samples, which were strategically divided among three layers (top, middle, and bottom) within the experimental units as shown in Fig. 1.

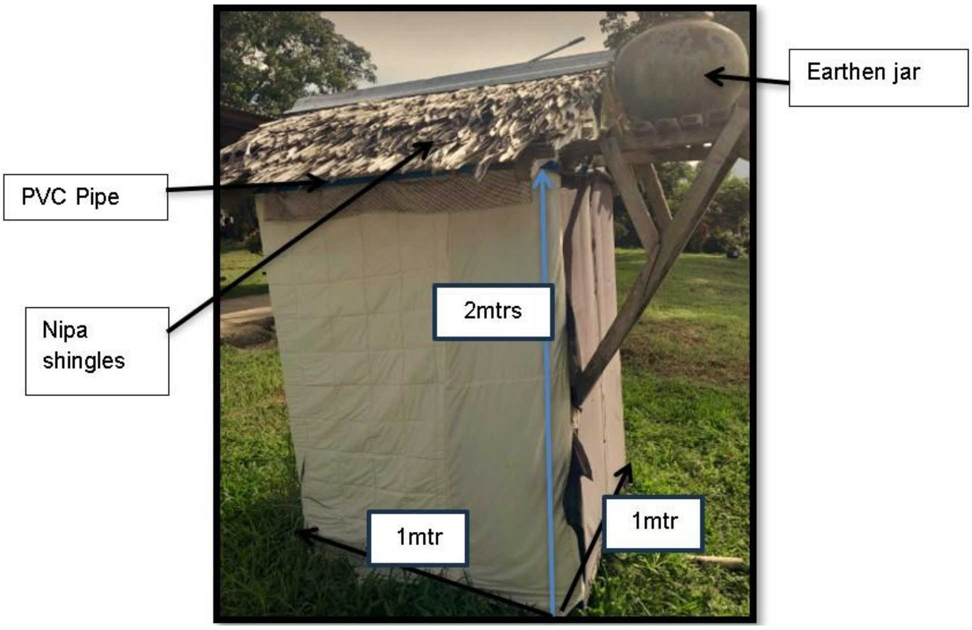

Fig. 1. Indigenous drip cooler

Fig. 2. Layers of cooling system

2.3 Data Gathering

2.3.1 Color change

Color change was assessed visually in triplicate using a 1-6 scale, where 1 represents green, 2 represents a definite break in color but <10% of surface, 3 represents turning (more green than yellow, pink, orange, or red), 4 represents more yellow, orange or red than green, 5 represents yellow, orange or red with a trace of green, and 6 represents full yellow, orange or red.

2.3.2 Firmness of fruit

Non-destructive firmness testing by mechanically applying very weak pressure against the surface of the fruit, also called micro-deformation, was used [10]. The scores ranged from 1 to 5: 1—Very firm, 2—Firm, 3—Moderately, 4—Soft, and 5—Very soft, with measurements done every five days for 20 days of preservation.

2.3.3 Shriveling Index

For the shriveling index, the degree of shriveling was quantified as a percentage of the fruit surface area affected at five-day intervals following the methods by Ponteras et al. [11]. The shriveling was categorized into five levels: 1 indicated no shriveling, and 2 represented slight shriveling affecting less than 10% of the surface. 3 signified moderate shriveling affecting 10-30% of the surface, 4 mostly shriveling affecting 40-50% of the surface. 5 denoted severe shriveling affecting more than 50% of the surface.

2.3.4 Visual quality rating

The overall physical appearance of cucumbers was evaluated using a 9-point scale, where 9 represented excellent quality with no defects, 7 indicated good quality with minor defects, 5 signified fair quality with moderate defects, 3 denoted poor quality with severe defects, and 1 represented extremely poor quality, making the produce inedible. Visual assessments were conducted at five-day intervals during the postharvest period to determine how different illumination treatments affected the overall visual quality.

2.3.5 Percentage weight loss

The initial weight was determined at the beginning of the study, and the weight of the fruits after five (5) days of storage was measured. Weight loss at each observation period was expressed as a percentage of initial weight. The percentage of weight loss was determined using the formula below.

$$\mathrm{WL}\ \% = \frac{Initial\ wt. of\ fruits - final\ weight\ of\ fruits}{Initial\ weight\ of\ fruits}\ x\ 100$$

2.3.6 Damage rate

Damage rate data was determined by counting the number of rotted cucumbers. The data collection was done every five (5) days after introduction in the coolers. The formula below was used to determine the damage rate.

$$\text{Damage rate} = \frac{Number\ of\ rotted\ fruit}{Total\ Number\ of\ fruits\ used}\ x\ 100$$

2.4 Statistical analysis

All gathered data was statistically analyzed using the Friedman Test of SPSS version 25 due to the non-normal distribution of the data, which prevented the use of ANOVA. Friedman's stepwise step-down procedure was applied to determine which specific treatments significantly differed from the others using the same SPSS package for Windows.

3. RESULTS AND DISCUSSION

3.1 Color Change

The color changes of cucumber fruits under various Indigenous drip cooler conditions were assessed over 20 days, with measurements taken at 5-day intervals. During the first 10 days, no statistically significant differences in color change were observed among the treatments. However, the control group (T1) consistently showed the highest mean color change, while the silk satin bedsheet (T3) and cotton comforter treatments (T4) maintained the lowest color change. Significant differences emerged among the treatments at day 15 ($p = 0.023$). The control group exhibited the highest color change (3.67), significantly different from the cotton comforter treatment, which maintained the lowest color change. By day 20, although not statistically significant, the trend continued, with the control group showing the highest color change and the silk satin bedsheet and cotton comforter treatments maintaining the lowest color change. Throughout the study, the control group consistently demonstrated the fastest color change, indicating more rapid ripening or senescence.

In contrast, the silk satin bedsheet and cotton comforter treatments were most effective in preserving the original green color of the cucumbers. These results suggest that Indigenous drip coolers, particularly those using silk satin bedsheets or cotton comforter coverings, can effectively slow down the color change process in cucumber fruits during storage, potentially extending their shelf life and maintaining quality longer compared to room temperature storage. This finding aligns with previous research on evaporative cooling systems' effectiveness in preserving fruit quality. For example, multiple studies have shown that these systems maintain lower temperatures (23-26.5°C) and higher relative humidity (65-99%) compared to ambient conditions [12 - 14]. The mechanism for this preservation effect lies in the cooler, more humid environment created by these systems, which effectively slows down quality deterioration, including color changes, weight loss, and firmness loss in stored produce. A concrete illustration of this effect comes from Kamaldeen et al. [15], who reported that tomatoes stored in an evaporative cooling system retained better color and experienced significantly less weight loss (32%) compared to those stored under ambient conditions (68% weight loss).

Similarly, Awafo et al. [14] found that tomatoes could be stored for more than 6 days with minimal changes in color, weight, and firmness, while those under ambient conditions deteriorated after 3 days. This preservation effect likely involves the reduction of respiratory activity and ethylene production. As suggested by Rosalie et al. [16], and Chopra et al. [17], lower temperatures achieved through evaporative cooling can slow down metabolic processes, including those responsible for chlorophyll breakdown and carotenoid synthesis. Our observations of delayed color change in the cooler treatments support this explanation. The superior performance of silk satin bedsheets and cotton comforter coverings in our study is particularly interesting. These materials may provide better insulation or moisture retention compared to other fabrics, leading to more stable microclimates around the fruits. The type of evaporative cooling material significantly influences cooling efficiency and production quality, as supported by research from Olosunde et al. [18] and Kapilan et al. [19]. Evaporative cooling is a broader term that refers to any cooling system that uses the evaporation of water to remove heat. It includes various types of systems, from large-scale industrial coolers to simple devices. In the context of our study, indigenous drip coolers are a specific type of low-tech evaporative cooling system. This simple, locally-made version uses a water drip system over fabric/cloth coverings to create a cooler microclimate. These systems work on the principle of cooling through water evaporation from the surface of the structure [2]. Various designs exist, including pot-in-pot, cabinet, static, and charcoal cooling chambers [9].

An active evaporative cooling device, incorporating features like inner and outer walls, suction fan, water pump, and trays, has been shown to effectively reduce ambient temperature and increase relative humidity, thereby improving the shelf life of produce [20]. The reports by Odesola and Onyebuchi [9] showed that porous evaporative coolers using materials like jute, damp cloth, or sand can create a cooler microclimate for the short-term preservation of fruits and vegetables. Eco-friendly nets and floating row covers can modify microclimate to improve tomato yield and quality for small-holder farmers [21]. Moreover, the gradual color change observed across all treatments aligns with the findings of Valero and Serrano [22], who described the progressive nature of pigment changes during fruit ripening. The slower rate of change in our cooler treatments suggests a potential extension of the climacteric rise phase, as described by Kader [23] and Ishangulyyev et al. [24] for various fruits. The control group's faster color change likely results from higher respiration rates and accelerated ethylene production at room temperature. This is consistent with the well-established relationship between temperature and ripening processes in fruits, as detailed by Althaus and Blanke [25].

3.2 Firmness

Firmness is a crucial quality attribute in cucumber fruits, directly influencing their texture and shelf life. Our study demonstrated that indigenous drip coolers, particularly those utilizing silk satin bedsheets or cotton comforter coverings, were effective in maintaining the firmness of cucumber fruits over 15 days of storage ($p = 0.023$). Table 2 shows that although not statistically significant, the trend persisted until 20 days of storage. These results indicate that indigenous drip coolers with silk satin bedsheets or cotton comforter coverings can effectively slow down the loss of firmness in cucumber fruits during storage. This preservation of firmness can be explained by the coolers' ability to maintain a favorable microclimate, potentially reducing the rate of cell wall degradation and water loss that typically led to softening in fruits. These findings align with several previous studies on the effects of cooling methods on fruit firmness. For instance, Odesola & Onyebuchi [9] implemented the pot-in-pot, cabinet, and charcoal cooling chambers that utilize materials such as jute, hessian, and cotton waste as cooling pads. Among these materials, jute demonstrated the highest cooling efficiency at 86.2%, although it was prone to mold formation [18]. The effectiveness of these materials is further exemplified by an active evaporative cooling device using a jute bag as a cooling pad material, which effectively reduces ambient temperature and increases relative humidity, resulting in less weight loss for stored produce [20]. These findings explain why such materials are commonly used in evaporative cooling systems, as they can significantly improve storage conditions for perishable produce.

Additionally, water drip cooling with CaCl2 and evaporative cooling have been shown to significantly preserve the firmness of peaches and pears [26] and tomatoes [14, 15]. This preservation effect likely involves the reduction of metabolic activities and enzyme actions responsible for cell wall degradation. Brummell [27] suggests that lower temperatures achieved through cooling can slow down the activity of cell wall-degrading enzymes such as polygalacturonase and pectin methylesterase. In our study, the silk satin bedsheet and cotton comforter coverings may provide better humidity control, reducing water loss from the fruits and maintaining cellular turgor pressure. This explanation is supported by research from Hussein et al. [28], who emphasized the importance of relative humidity in maintaining fruit firmness during storage. It is worth noting that while our study used a subjective scoring system for firmness, future investigations could benefit from quantitative measurements using texture analyzers or penetrometers, as employed by Valero et al. [22].

3.3 Shriveling Index

The effects of different storage treatments on cucumber shriveling became evident throughout the experiment. During the first 15 days of storage, no statistically significant differences in shriveling were observed among the treatments. However, by day 20, significant differences in the shriveling index emerged among the treatments ($p = 0.042$). The result reveals that the control group exhibited the highest degree of shriveling, significantly different from the silk satin bedsheet treatment, which showed the least shriveling (Table 3). The use of Indigenous drip coolers in storage, particularly those with silk satin bedsheet coverings, is able to maintain a more favorable microclimate for the cucumbers. The lower shriveling index in the silk satin bedsheet treatment suggests that this covering is more effective at preserving humidity and reducing water loss from the fruits. Ndukwuand Manuwa [1] demonstrated that these cooling systems maintain lower temperatures and higher relative humidity in Southwestern Nigeria, which reduces moisture loss. Liberty et al. [2] further confirm that evaporative cooling serves as an effective postharvest technology, preserving the quality of produce by minimizing dehydration. The effectiveness of these systems can be explained by the correlation between the physical properties of produce and the efficiency of evaporative cooling in reducing shriveling, as highlighted by Liberty et al. [7]. Tilahun [29] confirmed the feasibility and economic viability of low-cost evaporative cooling systems, particularly for small-scale farmers, emphasizing their role in reducing shriveling. This system is further supported by Ambuko et al. [3], who found that evaporative cooling significantly reduces shriveling, thus extending the marketable shelf life of leafy amaranth (*Amaranthus spp*.).

Evaporative cooling systems operate on the principle of heat absorption during water evaporation, effectively lowering temperature and increasing the relative humidity of the surrounding air. This process creates a microenvironment conducive to preserving fresh produce quality by minimizing moisture loss and reducing shriveling rate. This mechanism is provided by Liberty et al. [2], who explain that as water evaporates from produce surfaces, it absorbs heat, cooling the air and raising humidity, thereby slowing dehydration. Liberty et al. [7] further emphasize that cooling is most effective in low relative humidity environments, where higher evaporation rates lead to more significant cooling. This mechanism is particularly beneficial for fruits and vegetables stored in passive evaporative cooling structures, as highlighted by Ndukwu and Manuwa [1]. In our study, cooling is achieved through continuous water evaporation from fabric walls (Alpha gina, silk satin bedsheet, cotton comforter, and cotton blanket). As the water drips from the earthen jar to the PVC pipe onto fabric coverings, it creates a moist surface. Ambient air passing over this wetted surface causes evaporation, absorbing heat from the surrounding environment, including the structure's interior. This results in reduced air temperature and increased relative humidity within the cooler. The design allows for passive airflow, as temperature differences create natural convection currents, distributing cooled air around stored produce. The system's effectiveness relies on covering material properties, influencing water retention, evaporation rate, and air permeability. These characteristics affect cooling efficiency and the microclimate created within the structure, impacting cucumber preservation.

3.4 Visual Quality Rating

The visual quality of cucumber fruits followed a similar trend to the shriveling index throughout the storage period. By day 20 of storage, statistically significant differences in visual quality ratings (VQR) emerged among the treatments ($p = 0.042$), as evidenced in Table 4. The control group exhibited the lowest VQR, indicating the most deterioration in visual appearance. In contrast, the cotton comforter and cotton blanket treatments maintained higher VQRs, with no significant differences between them ($p > 0.05$). The ability of these treatments to maintain higher VQRs suggests that they created a more favorable microclimate for the cucumbers, potentially by regulating temperature and humidity more effectively than ambient conditions. Liberty et al. [2] found that evaporative cooling reduces storage temperature and enhances humidity levels, minimizing deteriorative reactions and maintaining produce freshness. Ndukwu and Manuwa [1] reported improved shelf life and higher moisture and vitamin C content but some decline in crispiness in stored fruits and vegetables. Using evaporative cooling is a viable alternative to conventional refrigeration, especially for crops like bananas and tomatoes prone to chilling injuries. The practicality of low-cost and passive evaporative cooling systems in developing countries has been emphasized by Tilahun [29] and Liberty et al. [7]. Further evidence of its effectiveness comes from visual quality assessments by Mordi and Olorunda [8], who found that tomatoes stored in evaporative coolers maintained superior visual quality, characterized by better color and reduced damage signs, especially when stored in perforated polyethylene bags. Similarly, Thiagu et al. [30] observed a more desirable color and higher ripeness index in tomatoes stored under evaporative cooling conditions. These findings corroborate this present study, suggesting that the observed improvements in visual quality and reduced shriveling are consistent with the broader literature on evaporative cooling systems and their benefits for the postharvest preservation of various fruits and vegetables. Our study employed a 9-point scale to assess the visual quality of cucumber fruits, a method widely used in postharvest research. This scale ranged from 9 (excellent quality with no defects) to 1 (extremely poor quality, inedible), with intermediate values representing varying degrees of quality and defects. This approach allowed for tracking the progression of visual quality changes over time, providing insights into the efficacy of different drip cooler treatments in maintaining fruit appearance. The 9-point scale offers a comprehensive assessment of visual quality, but it is inherently subjective and can be influenced by individual evaluator perceptions. To explain its limitations, we acknowledge that future studies could benefit from using multiple trained evaluators and incorporating inter-rater reliability measures.

Table 1. Mean color change scores of cucumber fruits stored under different indigenous drip cooler treatments over a 20-day preservation period

Treatment	Day 5	Day 10	Day 15	Day 20
Control	2.33	2.67	3.67^{b}	4.33
Alpha Gina Fabric	2.00	2.00	3.33^{ab}	3.67
Silk Satin Bedsheet	1.00	1.33	2.33^{ab}	2.67
Cotton Comforter	1.00	1.33	2.00^{a}	2.67
Cotton Blanket	1.33	1.67	2.33^{ab}	3.00
Chi-Square	7.75	7.294	11.347	9.388
Asymp. Sig.	0.101^{ns}	0.121^{ns}	0.023*	0.052^{ns}

Column means of the same superscript are not statistically different at the .05 level
**Significant*
^{ns} Not significant
Asymp. Sig. - Asymptotic significance

Table 2. Mean firmness scores of cucumber fruits stored under different indigenous drip cooler treatments over a 20-day preservation period

Treatment	Day 5	Day 10	Day 15	Day 20
Control	1.33	1.67	2.67^{b}	3.33
Alpha Gina Fabric	1.33	1.67	2.33^{ab}	2.67
Silk Satin Bedsheet	1.00	1.00	1.33^{ab}	1.67
Cotton Comforter	1.00	1.00	1.00^{a}	1.67
Cotton Blanket	1.00	1.33	1.33^{ab}	2.00
Chi-Square	3.000	6.667	11.347	9.388
Asymp. Sig.	0.558^{ns}	0.155^{ns}	0.023*	0.52^{ns}

Column means of the same superscript are not statistically different at the .05 level
**Significant*
^{ns} Not significant
Asymp. Sig. - Asymptotic significance

Table 3. Mean shriveling index scores of cucumber fruits stored under different indigenous drip cooler treatments over a 20-day preservation period

Treatment	Day 5	Day 10	Day 15	Day 20
Control	1.33	2.00	2.33	3.33^{b}
Alpha Gina Fabric	1.00	1.33	1.67	2.67
Silk Satin Bedsheet	1.00	1.00	1.00	1.67^{a}
Cotton Comforter	1.00	1.00	1.33	2.00^{ab}
Cotton Blanket	1.00	1.33	1.33	2.00^{ab}
Chi-Square	4.000	7.500	7.333	9.909
Asymp. Sig.	0.406^{ns}	0.112^{ns}	0.119^{ns}	0.042*

Column means of the same superscript are not statistically different at the .05 level
**Significant*
^{ns} Not significant
Asymp. Sig. - Asymptotic significance

Table 4. Mean visual quality rating of cucumber fruits stored under different indigenous drip cooler treatments over a 20-day preservation period

Treatment	Day 5	Day 10	Day 15	Day 20
Control	8.33	7.00	6.33	4.33^{a}
Alpha Gina Fabric	9.00	8.33	7.67	5.67^{ab}
Silk Satin Bedsheet	9.00	9.00	9.00	7.67^{ab}
Cotton Comforter	9.00	9.00	8.33	7.00^{b}
Cotton Blanket	9.00	8.33	8.33	7.00^{b}
Chi-Square	4.000	7.500	7.333	9.909
Asymp. Sig.	0.406^{ns}	0.112^{ns}	0.119^{ns}	0.042*

Column means of the same superscript are not statistically different at the .05 level
**Significant*
^{ns} *Not significant*
Asymp. Sig. - Asymptotic significance

3.5 Weight Loss

The weight loss differential of cucumber fruits became evident after a 20-day storage period, showing statistically significant differences between the treatments. The point of interest is that T1 (ambient) and T2 (Alpha gina fabric) exhibited higher weight loss compared to T4 (Cotton comforter), with $p > 0.05$, as shown in Table 5. This pattern can be explained by considering both environmental factors and material properties. The higher weight loss in ambient conditions (T1) is likely due to uncontrolled temperature and humidity, leading to increased transpiration and moisture loss from the cucumbers, as explained by studies of Kader [23]. The Alpha gina fabric (T2) may not have provided sufficient moisture retention or cooling effect, resulting in similar weight loss to ambient conditions.

The varying properties of these materials, particularly in terms of air permeability, moisture management, and drying rates, play a crucial role in their performance as evaporative cooling materials. The superior performance of the cotton comforter (T4) in preserving cucumber quality may be attributed to its unique structure and composition. Similar to Midha et al. [31] study on how cotton weft yarn in denim fabrics exhibits higher air and water vapor permeability, they found that cotton comforter likely provides better air circulation and moisture retention. This property could create a more stable and favorable microclimate for the cucumbers, effectively slowing down quality deterioration.

In contrast, the Alpha gina fabric (T2) showed less effectiveness in preserving cucumber quality. This difference might be explained by their potentially lower air permeability and moisture management capabilities. The study on denim fabrics revealed that different fiber compositions significantly affect moisture transport and drying rates [31]. It is possible that the Alpha gina fabric, which is polyester-based, have shown a high spreading rate but potentially lower moisture retention. This could lead to faster drying of the cooling system and less stable humidity levels around the cucumbers. To fully understand their effectiveness, further research could analyze the physical properties of each material, monitor microclimatic conditions within the drip coolers, and examine their effects on ethylene production and sensitivity.

Table 5. Weight loss value of cucumber fruits under indigenous drip coolers at five days interval for 20 days preservation period

Treatment	Day 5 (%)	Day 10 (%)	Day 15 (%)	Day 20 (%)
Control	6.57	14.54	21.79	29.02^{b}
Alpha Gina Fabric	3.47	15.82	24.27	29.72^{b}
Silk Satin Bedsheet	3.76	9.82	17.06	23.33^{ab}
Cotton Comforter	3.00	9.07	14.23	17.75^{a}
Cotton Blanket	3.77	12.28	19.69	23.40^{ab}
Chi-Square	8.533	4.000	7.733	10.133
Asymp. Sig.	0.074^{ns}	0.406^{ns}	0.122^{ns}	0.038*

Column means of the same superscript are not statistically different at the .05 level
**Significant*
^{ns} *Not significant*
Asymp. Sig. - Asymptotic significance

Table 6. Damage rate of cucumber fruits under indigenous drip coolers at five days interval for 20 days preservation period

Treatment	Day 5 (%)	Day 10 (%)	Day 15 (%)	Day 20 (%)
Control	-	0.33	0.67	1.33
Alpha Gina Fabric	-	0.67	1.33	1.67
Silk Satin Bedsheet	-	0	0.33	0.33
Cotton Comforter	-	0.33	0.67	0.67
Cotton Blanket	-	0.33	0.67	0.67
Chi-Square	-	1.857	4.976	6.51
Asymp. Sig.	-	0.762^{ns}	0.290^{ns}	0.164^{ns}

Column means of the same superscript are not statistically different at the .05 level
^{ns} Not significant
Asymp. Sig. - Asymptotic significance

3.6 Damage Rate

The preservation of cucumber fruits from damage varied across treatments throughout the storage period. Initially, no damage was observed in any treatment during the first 5 days of storage, while evidence of damage began to appear from day 10 to day 20 across all treatments (Table 6). However, statistical analysis showed no significant differences in damage rates among the treatments throughout the entire preservation period ($p < 0.05$). Despite the lack of statistical significance, some trends were observed. The control group and the Alpha Gina fabric treatment tended to show slightly higher damage rates by the end of the storage period.

In contrast, the silk satin bedsheet treatment consistently maintained the lowest damage rate throughout the study. These results explain the potential protective effects of the indigenous drip coolers, particularly the silk satin bedsheet covering, which may have provided a more suitable microclimate for cucumber preservation. However, the differences in effectiveness among the various treatments were not substantial enough to be statistically significant. This observation denotes the broader context of postharvest preservation research, suggesting that while indigenous drip coolers may offer some protection against damage tocucumber fruits during storage, further investigation is needed. Future studies with larger sample sizes or more extended storage periods might be necessary to determine if there are significant differences in damage prevention among these storage methods, potentially providing more conclusive evidence for the efficacy of these low-cost preservation techniques.

4. CONCLUSION

This study demonstrates the effectiveness of indigenous drip coolers in preserving cucumber quality, with silk satin bedsheets and cotton comforter coverings consistently outperforming other materials and ambient conditions. These coolers were effective in slowing color change, maintaining firmness, reducing shriveling, and preserving overall visual quality. The study highlights the importance of fabric selection in drip cooler design, with cotton comforter and silk satin bedsheet coverings likely offering better air circulation, moisture retention, and insulation. These low-cost, accessible solutions show promise for small-scale farmers and regions with limited cold storage, potentially reducing food waste and improving food security. While further research is needed to optimize these systems and explore their effectiveness with other produce types, this study provides valuable insights into sustainable, low-cost postharvest storage solutions with practical implications for resource-limited settings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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contributing to the field of postharvest technology.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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