

Research Article

TriCool Patch: A Sustainable Triple-Mechanism Hydrogel Cooling Patch Incorporating Cucumber, Aloe Vera, and Mint for Thermal Comfort

Nur Atiqah Zaharullil^{1*}, Shampazuraini Samsuri², and Atiqah Hanif³

¹ Faculty of Applied Sciences, Universiti Teknologi MARA Cawangan Melaka (Kampus Jasin);
atiqah0361@uitm.edu.my

² Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Cawangan Melaka (Kampus Jasin);
shampazuraini@uitm.edu.my

³ Sekolah Kebangsaan Ayer Merbau, Jasin, Melaka, g-64027528@moe-dl.edu.my

* Correspondence: atiqah0361@uitm.edu.my, +60197196901.

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Abstract: Extreme of heat and incresilng unpredictable weather conditions which occur globally have led to thermal discomfort and increasing in body temperatures, particularly children and the elderly. Today, existing of cooling patches sold in the market as a solution to this issues are expensive, utilise synthetic chemicals and contribute to environmental problems. To address these disadvantages, the innovation idea name as TriCool Patch was developed which provide natural, cost-effective, and eco-friendly cooling solution. This innovation integrates three natural ingredients incorporating with biodegradable hydrogel matrix to achieve a triple cooling mechanism. These three ingredients, aloe vera, cucumber, and mint, provide their own function in this cooling patch as a moisture-retaining hydrogel, enhance cooling through evaporation, and provide a refreshing sensation, respectively. The preparation involves three steps, which are extraction, mixing the ingredient with specific ratios, solidify to form a flexible patch. The results demonstrated that the TriCool Patch effectively reduces skin surface temperature by approximately 3.1°C, improving thermal comfort during heat exposure. Beside its function to reduce our body temperature for thermal comfort, it also promotes green chemistry and sustainable product development.



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1. INTRODUCTION

Recently, climate change has significantly had an impact on us, as increasing of heat exposure, heat stress, and associated health risks, particularly in Malaysia climate. The increasing of temperatures today has an impact on our health, such as heat exhaustion, heat stroke, fever or dehydration. The outdoor workers, especially kids, elderly, are particularly at risk due to heat exposure and limited adaptive capacity (Ebi et al., 2021; Muslim & Susami, 2026). The development activities or urbanisation increased the exposure to extreme heat, however, reducing natural cooling mechanisms, such as green forest vegetation (Lundgren & Kjellstrom, 2013; Zou et al., 2025). On the other hand, there is research particularly in Malaysia highlight the significant effects of this phenomena toward public health and productivity (Kjellstrom & Crowe, 2011; Muhamad et al., 2024). Hence, the water-based cooling

method, such as dousing, gives promise as a low-cost, sustainable strategy for vulnerable individuals. It effectively reduced core body temperature and prevented the health risks, particularly in extreme heat conditions. Yet, its effectiveness depends on water temperature, body surface area, and environmental conditions (Bhuvad et al., 2025). Consequently, it is essential to address these limitations, enhancing the performance of cooling technologies (Zhu et al., 2025).

Cooling patches sold in the market today have several limitations, including high cost, using synthetic chemicals, and leading to environmental waste due to non-biodegradable materials. This creates a clear gap for a more sustainable alternative. From the bird's eye view, very few natural cooling patches that effectively combine natural ingredients such as cucumber, aloe vera, and mint within a biodegradable hydrogel matrix. Each of these components offers distinct cooling properties, yet their integration into a single system remains underexplored. Therefore, the development of the TriCool Patch addresses this gap by providing a cost-effective, eco-friendly, and multifunctional solution to reduce body temperature and body discomfort specifically for kids and the elderly when they have been exposed to high temperatures.

TriCool Patch possesses its unique integration of natural and cooling mechanisms. It utilises natural ingredients to deliver a triple-cooling mechanism. Cucumber juice is good for hydration and evaporative cooling, aloe vera gel for soothing effects and mint extract for a refreshing sensation via menthol activation of cooling receptors. Its natural formulation supports sustainability by minimizing the dependency on synthetic chemicals make is as one of the green alternative. Innovation TriCool Patch combines scientific concept, environmental awareness, and practical application into a single innovative product.

2. LITERATURE REVIEW

Natural ingredients such as aloe vera have common functions for treating burns, wounds, and inflammatory skin. The bioactive compounds in aloe vera, including polysaccharides, enzymes, and vitamins, are good for anti-inflammatory, moisturising, and antioxidant effects. Proven studies showed that aloe vera gel enhances skin hydration by increasing the water content on the outermost layer of human skin, hence making it effective for dry skin management (Dal'Belo et al., 2006; Sharma & Kaur, 2026). Thus, it makes aloe vera one of the natural ingredients for soothing and rejuvenating the skin. On the other hand, cucumbers provide cooling and soothing effects on the skin as they possess high water content and bioactive compounds, such as cucurbitacin and flavonoids, which help alleviate skin irritation, reduce swelling, and provide relief from sunburn pain (Mukherjee et al., 2013). The cucumber juice is used to nourish the skin, offering a refreshing and calming effect, particularly for inflamed or sensitive skin. A chemical compound, namely menthol, which is derived from peppermint leaves widely recognized as cooling sensation and ability to reduce discomfort. The combination of these natural ingredients, incorporating hydrogel based provides a triple cooling mechanism for cooling, soothing, and improving skin health in hot or discomfort conditions.

Hydrogel-based materials functions to reduce body temperature and discomfort in skin-contact cooling applications through evaporative cooling and thermal conduction mechanisms. It has a high-water content able to absorb heat from the skin and dissipate it via water evaporation, which imitate the natural sweating process. A study showed hydrogel-based materials can achieve significant cooling effects by releasing absorbed moisture during evaporation (Ji et al., 2022). These properties make hydrogels ideal for wearable cooling devices, offering both comfort and efficient thermal regulation.

The innovative idea of hydrogel patches incorporating natural extracts like cucumber and aloe vera for a cooling sensation presents both advantages and disadvantages, including variability in the composition of natural extracts, which can affect the stability and consistency of bioactive compounds (Kawee-ai, 2025). In addition, long-term durability and water retention under low-humidity conditions remains a significant challenge for hydrogel-based systems (Hu et al., 2026). Nevertheless, it lies in the multifunctional properties of these patches, such as their ability to provide cooling, UV protection, and therapeutic benefits, making them suitable for both medical and cosmetic applications (Nam et al., 2025). By addressing these disadvantages, natural ingredients extraction can play a main role in thermal comfort applications.

3. METHODOLOGY



Figure 1. Materials used in the preparation of the TriCool Patch

Figure 1 shows the materials used in the preparation of the TriCool Patch. Its formulation consisted of aloe vera gel, cucumber extract, and mint leaf extract. These three natural ingredients act as natural cooling and soothing agents. Gelatin was used as the hydrogel matrix-forming material, and glycerol was mixed in the formulation to improve the flexibility and durability of the patch. A small amount of distilled water was used as the solvent to mix all the ingredients and produce the homogenous solution. These materials were selected due to their availability, safety, biodegradability, and potential to provide a natural cooling effect.

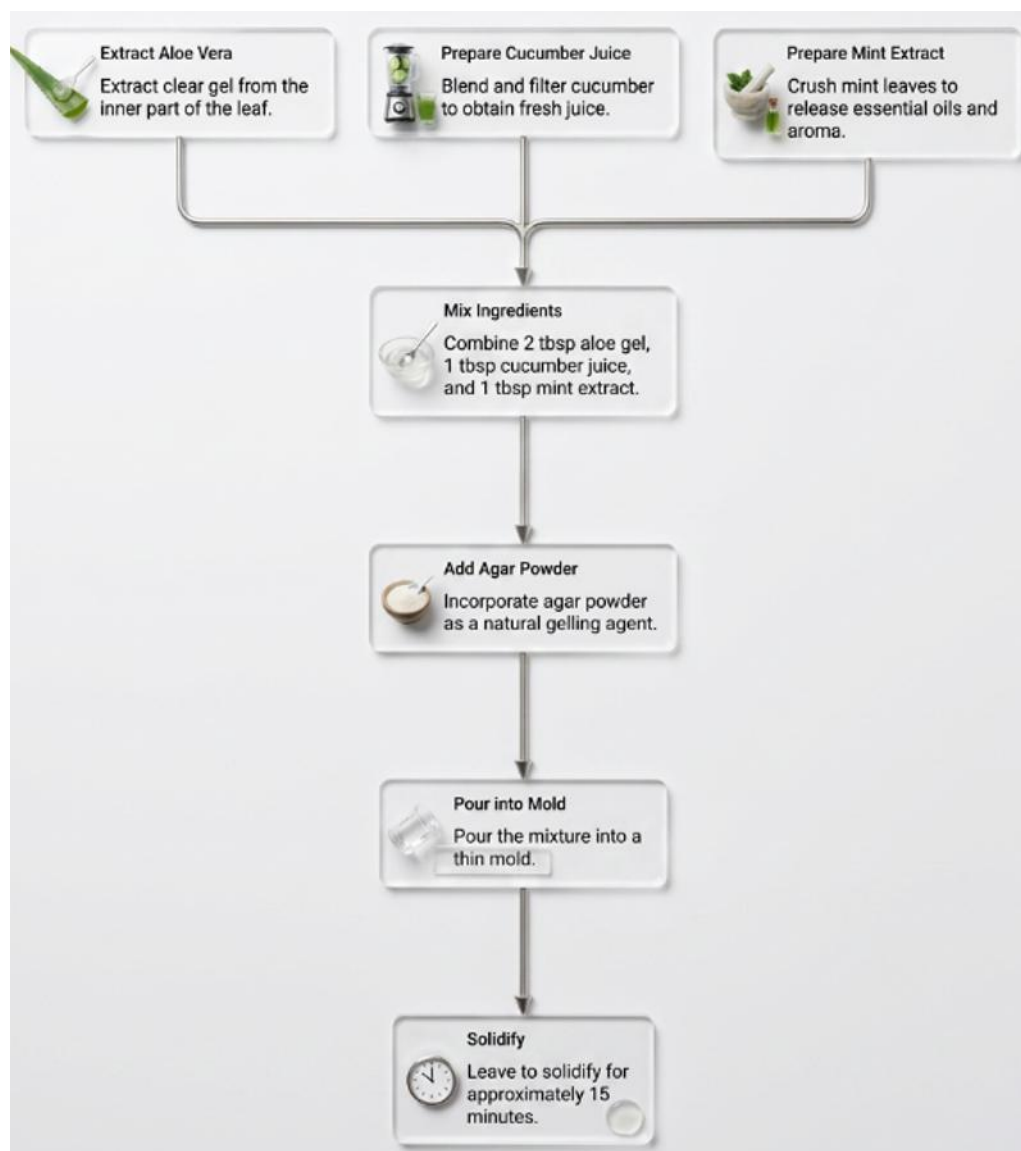


Figure 2. Flowchart illustrating the formulation process of the TriCool Patch

Figure 2 shows the process of the TriCool Patch. At the first step, all the natural ingredients: fresh aloe vera gel was extracted from the inner leaf, cucumber and peppermint leaves were cut into pieces, blended with a small amount of water and filtered to get the fresh cucumber juice and mint extract respectively. Next, the three natural ingredients were then combined and mixed thoroughly to form a homogeneous solution. Subsequently, gelatine (agar powder) and glycerol were added as a natural gelling agent to form the hydrogel matrix. The homogenous mixture was poured into a thin mould and allowed to solidify for approximately 15 minutes, producing a flexible hydrogel cooling patch suitable for temporary thermal comfort applications. To enhance the cooling sensation, this patch was stored in the freezer before use.

4. FINDINGS

4.1 Physical Characteristics



Figure 3. Final prototype of the TriCool Patch

The TriCool Patch exhibited a dark green appearance, indicating the presence of natural plant-based ingredients such as aloe vera, cucumber, and mint, with the addition of one drop of green colouring to enhance the appearance. It demonstrated a soft hydrogel texture, a moist and glossy surface, which indicates an effective water retention within the gel matrix. A minty odour was detected, indicating the presence of mint extract from peppermint extract, a refreshing sensory experience. It also showed good flexibility, not easy to break, allowing it to easily curve skin surfaces. However, the application on the skin surface showed that the skin adhesion was moderate, signify for further enhancement to improve its adherence for prolonged use.

4.2 Cooling Performance

Table 1. Cooling performance of the TriCool Patch as indicated by the reduction in surface temperature over time.

Time (min)	Surface Temperature (°C)
0	38.0 ± 0.2
10	36.9 ± 0.2
30	35.4 ± 0.3
60	34.9 ± 0.3

To test the performance of TriCool Patch, the temperature changes for 60 minutes. In this study, temperature measurements were taken at the skin surface using an infrared thermometer, specifically at the forehead where the TriCool Patch was applied. As shown in Table 1, the initial skin surface temperature was recorded as $38.0 \pm 0.2^{\circ}\text{C}$, representing a condition of heat exposure or body discomfort. 10 minutes after the application of the patch, the temperature gradually decreased to $36.9 \pm 0.2^{\circ}\text{C}$, signalling an immediate cooling effect. The temperature continued to decline to $35.4 \pm 0.3^{\circ}\text{C}$ after 30 minutes, and after 60 minutes, the skin temperature reached $34.9 \pm 0.3^{\circ}\text{C}$, corresponding to an overall reduction of approximately 3.1°C .

5. DISCUSSION

The decrease in body skin temperature proved that the TriCool Patch provided sustained cooling and was more realistic for a natural hydrogel-based formulation. This cooling effect is influenced by the high water content of the hydrogel matrix, which promotes the cooling process upon application to the skin. The cucumber extract contributes moisture and hydration, aloe vera provides soothing and moisture-retaining properties, while mint extract contains menthol, which activates cold-sensitive receptors in the skin. All natural ingredients and hydrogel matrix prolonged the cooling effect observed throughout the study.

TriCool Patch demonstrated the potential to provide temporary heat comfort in our body and provide a low-cost, eco-friendly alternative to conventional cooling patches. Its ability to maintain a cooling effect for 60 minutes is suitable for individuals that been exposed to hot environmental conditions or are experiencing mild heat-related discomfort.

This innovation gives significant impact on education, society, environment, and economy. It also aligns closely with Sustainable Development Goals (SDGs). It introduced green chemistry principles by utilising natural, biodegradable materials as an alternative to reduce body temperature and body discomfort during hot weather conditions and serves as an affordable alternative cooling aid accessible to a wide community. The use of natural ingredients such as aloe vera, cucumber, and mint reduces dependency on synthetic chemicals and promotes safer and more sustainable practices. Hence, it provides the low production cost and availability of raw materials contribute to its strong potential for commercialisation and scalability. This innovation aligns with several SDGs, namely SDG 3 (Good Health and Well-Being) by improving comfort during heat exposure, SDG 12 (Responsible Consumption and Production) using natural ingredients in its formulation, and SDG 13 (Climate Action) by addressing challenges associated with rising climate temperatures.

6. CONCLUSION

TriCool Patch successfully demonstrated a triple cooling mechanism through the integration of aloe vera, cucumber, and mint. This idea offers a practical solution for improving thermal comfort, particularly in hot weather conditions. It also highlights its potential as a sustainable and environmentally friendly alternative to conventional cooling aids. As recommendations, further research and development in terms of formulation, appearance, mechanical strength and its cooling performance are required to enhance its shelf-life stability, optimise cooling duration, and evaluate its feasibility for large-scale production and commercialisation in the future.

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