

(Research Article)

Effectiveness of Simple Cooling Devices Based on Fans and Ice to Improve Thermal Comfort in Islamic Boarding School Dormitories

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Abstract: This study aims to analyze the performance of a simple cooling device based on a fan and ice to improve thermal comfort in the female dormitory rooms of Pondok Pesantren Darunnaja, Bengkulu. The research used an experimental quantitative approach involving temperature and humidity measurements as well as perception data collected through Likert-scale questionnaires. The experiment was conducted in six dormitory rooms measuring 3 × 3 meters. The results indicated that the device was capable of reducing room temperature by approximately 3–5°C and increasing relative humidity to a moderate level. About 70% of respondents reported an improvement in thermal comfort after using the device. Although the cooling effect was not optimal, the fan-and-ice-based system proved effective in creating a more comfortable indoor thermal environment. This simple cooling technology is cost-efficient, energy-saving, and environmentally friendly, making it suitable for application in dormitory or low-cost housing environments.

Keywords: Dormitory; Fan; Ice; Simple Cooling Device; Thermal Comfort

1. Introduction

Thermal comfort plays a vital role in maintaining productivity, health, and well-being in enclosed environments such as boarding schools. According to ASHRAE Standard 55 (2017), thermal comfort is influenced by air temperature, humidity, airflow, and personal factors including metabolic rate and clothing. In tropical countries like Indonesia, where average temperatures range between 25–33°C, thermal discomfort is common, particularly in densely populated buildings with limited ventilation. Prolonged exposure to hot and humid conditions can negatively affect concentration, sleep quality, and learning performance (Sukri et al., 2021; Al-Sanea & Zedan, 2012). Therefore, affordable and environmentally friendly cooling solutions are urgently needed to enhance comfort in such settings.

The use of conventional air conditioners (AC) is often limited by high installation costs and energy consumption (Cengel & Boles, 2015; Chen et al., 2020). As a practical alternative, evaporative cooling systems utilize the principle of water evaporation to absorb heat and reduce air temperature (Jamaluddin, 2018; Khan & Kumar, 2018). Previous studies have demonstrated that ice-based cooling devices can lower indoor air temperatures by 3–5°C while maintaining relative humidity within the comfort range (Prasetyo et al., 2020; Iskandar & Sudiadi, 2019). Furthermore, innovations such as portable freon-free air conditioners have been shown to provide effective and environmentally sustainable cooling solutions (Kalsi et al., 2019).

In Islamic boarding schools, limited ventilation and high occupancy levels often exacerbate indoor heat conditions (Mahmud, 2021; Indrawan & Puspita, 2022). Simple cooling devices utilizing fans and ice offer a practical and sustainable solution, as they are easy to assemble, low-cost, energy-efficient, and emission-free (Kindangen, 2017). This study examines the performance of a fan-and-ice-based cooling device in improving thermal comfort at the Darunnaja Islamic Boarding School for Girls in Bengkulu, focusing on

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variations in temperature, humidity, and occupants' comfort perception. The findings are expected to support the advancement of energy-efficient and environmentally friendly cooling technologies (Fanger, 1970).

2. Theoretical Foundation

Basic Concepts of Cooling

Cooling refers to the process of removing or absorbing heat from a system to reduce its temperature to a desired level. In the context of thermal comfort, the primary objective of cooling is to maintain indoor air temperature within a range that supports human comfort and well-being (Cengel & Boles, 2015). The cooling process can be achieved through either natural or mechanical means. Natural cooling relies on air ventilation and free convection, whereas mechanical cooling employs external energy sources, such as vapor compression systems used in conventional air conditioners (AC).

Another effective alternative is the evaporative cooling system, which operates based on the principle of water evaporation. When water or ice evaporates, a portion of the air's heat energy is absorbed to change the water phase into vapor, thereby reducing the air temperature (Jamaluddin, 2018; Budiyanto, 2021). This method is recognized for its energy efficiency and environmental sustainability, as it eliminates the use of chemical refrigerants that can harm the ozone layer (Hamdan & Rahardjo, 2019).

In this process, hot air flowing over the surface of ice or a wet medium experiences a temperature drop due to evaporation, which utilizes the latent heat of vaporization. The effectiveness of evaporative cooling depends on several parameters, including airflow velocity, relative humidity, and the surface area available for evaporation (Khan & Kumar, 2018). Because of these characteristics, evaporative cooling technology is widely adopted in tropical regions as an environmentally friendly and cost-effective approach to achieving thermal comfort (Sopian & Alghoul, 2015).

Principles of Thermodynamics in Cooling Systems

The fundamental concept of cooling can be understood through the principles of thermodynamics. According to the first law of thermodynamics, energy cannot be created or destroyed; it can only be transformed from one form to another. In the context of cooling systems, this law implies that the heat energy (Q) absorbed from the surrounding environment is converted into other forms of energy, such as latent heat during the phase change process. When ice is used as a cooling medium, the heat absorbed from the air is utilized to melt the ice. This process can be expressed by the following equation:

$$Q = m \times L_f$$

where m is the mass of ice (kg) and L_f is the latent heat of fusion (kJ/kg). The second law of thermodynamics states that heat transfer always occurs spontaneously from a region of higher temperature to one of lower temperature. In the context of a simple fan-and-ice-based cooling system, warm air from the room comes into contact with the ice surface, which has a lower temperature. This interaction facilitates the transfer of heat from the air to the ice, leading to a reduction in air temperature as the ice absorbs the heat energy and undergoes melting (Cengel & Boles, 2015).

Heat Transfer Mechanisms

Heat transfer within cooling systems occurs through three primary mechanisms: conduction, convection, and radiation (Holm, 2020).

- a. Conduction refers to the transfer of heat energy between particles or objects through direct physical contact. The rate of conduction depends on the temperature gradient and the thermal conductivity of the materials involved.

- b. Convection involves the transfer of heat through the movement of a fluid medium, such as air, driven by differences in density or external forces. In simple cooling devices, the use of a fan enhances forced convection, thereby accelerating the transfer of heat from the surrounding air to the ice surface (Jamaluddin, 2018; Marwah & Hidayat, 2020).
- c. Radiation is the transfer of heat energy through electromagnetic waves without requiring a physical medium. Although its contribution in small-scale cooling systems is relatively minor, it still plays a role in the overall heat exchange process.

The overall effectiveness of a cooling system is strongly influenced by factors such as airflow velocity, the contact surface area between air and ice, and the total air volume within the enclosed space (Kindangen, 2017). Optimizing these parameters enhances the system's cooling performance and contributes to improved thermal comfort.

Thermal Comfort

Thermal comfort refers to a state in which an individual experiences satisfaction with the thermal conditions of their surrounding environment (ASHRAE, 2017). The key parameters influencing thermal comfort include air temperature, relative humidity, air velocity, and thermal radiation. According to ASHRAE standards, the optimal thermal comfort range is between 22–27°C for air temperature and 40–60% for relative humidity.

Kindangen (2017) emphasized that increasing air velocity can reduce the perception of heat by enhancing sweat evaporation. However, when relative humidity exceeds 70%, the evaporation process becomes inhibited, leading to decreased comfort. Therefore, fan-and-ice-based cooling systems must achieve a balance between temperature reduction and humidity control to maintain conditions within the thermal comfort zone (Rijal & Humphreys, 2020).

Beyond physical parameters, thermal comfort is also influenced by user adaptation to local climatic conditions and tropical building design strategies (Wijaya & Santoso, 2020). In dormitory settings characterized by high occupancy and limited ventilation, the application of simple active cooling systems becomes essential to meet international thermal comfort standards effectively.

Efficiency of Simple Cooling Systems

The efficiency of a cooling system is commonly evaluated using the Coefficient of Performance (COP), which represents the ratio between the amount of heat absorbed from the conditioned space (Q_{out}) and the energy input required to perform the cooling process (W). This relationship can be expressed by the following equation:

$$COP = \frac{Q_{out}}{W}$$

In a fan-and-ice-based cooling system, the Coefficient of Performance (COP) is influenced by factors such as fan speed, ice mass, and cooling duration (Baek & Kim, 2021). Although its performance is lower than that of conventional mechanical systems such as air conditioners, this simple device offers significant advantages in terms of low energy consumption, minimal operating costs, and environmental sustainability, as it operates without chemical refrigerants (Megantara & Nurrahman, 2023).

Beyond energy efficiency, the effectiveness of the cooling system is also affected by the thermal characteristics of the building and the direction of air circulation (Lim & Chua, 2016). Incorporating thermodynamic considerations and optimizing air convection in the device design can further enhance cooling performance without increasing electricity demand.

3. Research Metode

Research Design

This study employs a quantitative experimental approach aimed at evaluating the effectiveness of a simple fan-and-ice-based cooling device in reducing air temperature and

enhancing thermal comfort within dormitory rooms. The research design adopted is a pre-test and post-test model, in which measurements of air temperature and relative humidity are conducted both before and after the operation of the cooling device.

This design allows for the direct comparison of environmental conditions prior to and following the intervention, thereby providing a clear assessment of the device's performance and its impact on the thermal comfort of dormitory residents. Two conditions were tested for comparison:

- a. Initial condition (without cooling device) – measurement of room temperature and humidity under normal conditions.
- b. Treatment condition (with simple cooling device) – measurements were taken after the fan and ice had been used for one hour.

This approach aligns with the principles of thermal comfort evaluation outlined in ASHRAE Standard 55 and established thermal comfort testing methodologies (ASHRAE, 2020; Olesen, 2015). Such an experimental design is widely adopted in evaporative cooling studies because it effectively illustrates the direct relationship between changes in physical parameters such as temperature and humidity and subjective perceptions of comfort (Lim & Chua, 2016).

Location and Time of Research

The research was conducted at the Darunnaja Islamic Boarding School Girls' Dormitory, North Bengkulu, Bengkulu, which has a humid tropical environment with limited natural ventilation. The rooms used were 3 × 3 meters in size with 6–7 students per room. The experiment was conducted during June to July 2025 at noon between 11:00 a.m. and 1:00 p.m. Western Indonesian Time, because during this time period the ambient temperature reached its highest point.

Research Variables

There were three types of variables in this study:

- a. Independent variable: the use of a simple cooling device based on a fan and ice.
- b. Dependent variables: changes in temperature (°C), changes in humidity (% RH), and thermal comfort perception.
- c. Control variables: room size, number of occupants, air ventilation, and room heat sources were kept constant during the experiment.

Tools and Materials

The simple cooling device used in this study consists of several main components, including a 12-volt DC fan, a plastic container, a 4-inch PVC pipe, and a 12-volt adapter serving as the power source. These components function collectively to circulate air through a container filled with ice cubes, allowing the air passing through to absorb coolness from the ice. As a result, the air that exits the device has a lower temperature, contributing to improved thermal comfort within the room.

Table 1. Research Tools and Materials.

Tools/Materials	Main Functions
12V DC fan	Circulating air through cooling media
Plastic container	Storing ice cubes as a cooling source
4-inch PVC pipe	Cold air distribution ducts
12V adapter	Power source for fans
Digital thermometer	Measuring room air temperature
Hygrometer	Measuring relative air humidity

Research Procedure

The research procedure was carried out through several systematic stages to ensure the accuracy and reliability of data collection, as follows:

- a. Preparation – The simple cooling device was inspected to confirm proper functionality, and all measuring instruments, including the thermometer and hygrometer, were calibrated to ensure measurement accuracy.
- b. Initial Measurement (Pre-test) – Baseline measurements of air temperature and relative humidity were taken prior to operating the cooling device to establish initial environmental conditions.
- c. Experiment – The cooling device was operated for a duration of 60 minutes, during which air temperature and humidity data were recorded at 15-minute intervals to observe progressive changes.
- d. Final Measurement (Post-test) – After the device was turned off, a final set of measurements was conducted to determine variations in thermal parameters resulting from the cooling process.
- e. Comfort Questionnaire – A perception survey was administered to dormitory residents using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) to evaluate subjective comfort levels before and after the experiment.

Data Analysis Methods

Quantitative data obtained from temperature and humidity measurements were analyzed descriptively and comparatively by calculating the average changes in air temperature and relative humidity before and after the application of the cooling device. The perception data collected through questionnaires were processed using percentage analysis to determine the respondents' level of acceptance and perceived effectiveness of the simple cooling system.

The criteria for evaluating the success of the cooling device were established as follows:

- a. A minimum decrease in air temperature of 3°C after the operation of the device.
- b. Relative humidity maintained within the range of 40–70% RH to ensure thermal comfort.
- c. At least 70% of respondents reporting an improvement in perceived thermal comfort following the use of the cooling device.

The collected data were analyzed and compared against the thermal comfort criteria outlined in ASHRAE Standard 55 (2020) to provide a scientific assessment of the cooling device's effectiveness.

4. Results And Discussion

Initial Room Conditions

Initial observations revealed that the average air temperature in the dormitory rooms prior to the use of the cooling device ranged from 31–33°C, with relative humidity levels of approximately 56–60% RH. According to ASHRAE (2017) standards, these conditions are classified as thermally uncomfortable, as they exceed the optimal comfort range of 22–27°C. The relatively high humidity also inhibits the evaporation of sweat, thereby intensifying the sensation of heat and discomfort among occupants.

Limited air ventilation in dormitory rooms accommodating 6–7 occupants leads to an increase in indoor temperature due to the accumulation of body heat and restricted natural air circulation. This observation aligns with the findings of Fatkhurrohman (2022), who reported that small, densely occupied spaces exhibit a faster cooling response but also experience a greater rise in humidity compared to rooms with open ventilation.

The dormitory environment exhibited limited air ventilation and high occupancy density, averaging six to seven residents per room. Such conditions promote the accumulation of body heat and restrict natural airflow, resulting in elevated indoor temperatures and a decline in overall thermal comfort.

Performance of Simple Cooling Devices

After operating the simple fan-and-ice-based cooling device for a duration of 60 minutes, a noticeable decrease in air temperature and a corresponding increase in relative humidity were observed within the dormitory room. These changes indicate the effectiveness of the device in modifying the indoor thermal environment toward more comfortable conditions. The average measurement results of air temperature and humidity before and after the use of the cooling device are presented in Table 2. below.

Table 2. Changes in Temperature and Air Humidity.

Time (Minutes)	Temperature Before (°C)	Temperature After (°C)	Temperature Change (°C)	Humidity Before (%)	Humidity After (%)
0	32.5	32.5	0.0	58.0	58.0
15	32.3	30.8	1.5	58.2	63.5
30	32.4	29.7	2.7	57.8	65.1
45	32.6	28.9	3.7	58.1	66.0
60	32.4	28.5	3.9	58.0	67.2

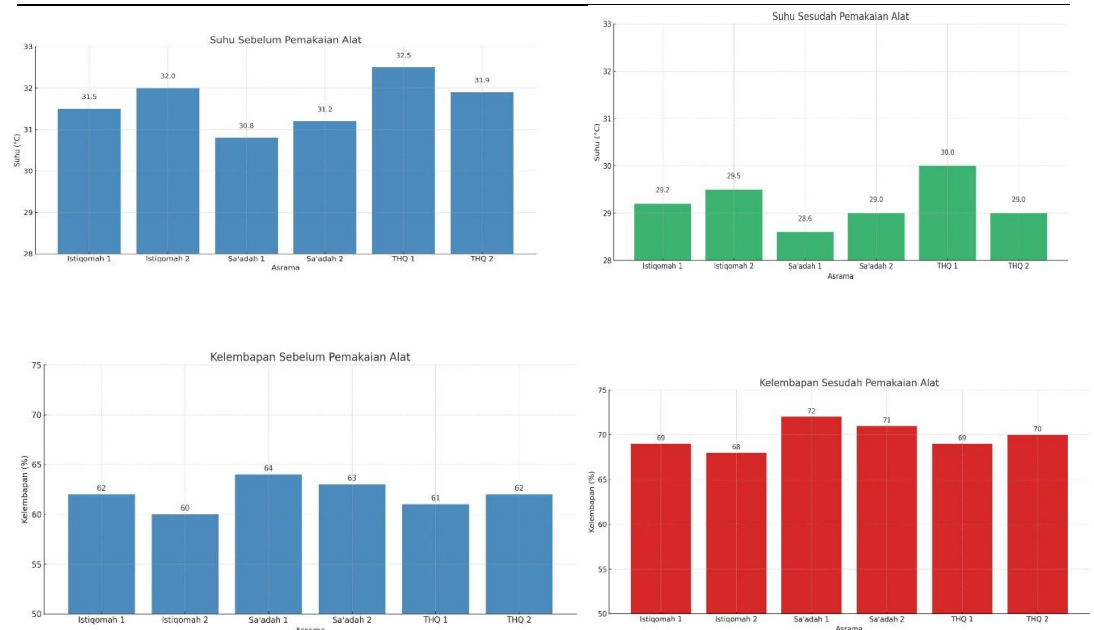


Figure 1. Graph of Temperature and Humidity Changes.

The average temperature reduction achieved was 3.5–4°C, accompanied by an increase in relative humidity of approximately 8–10%. These results indicate that the simple cooling system is effective in significantly lowering indoor temperatures without causing excessive humidity (Sutanto & Arifin, 2021). Similar findings were reported by Fatkhurrohman (2022), who observed an average temperature decrease of 3°C and an improvement in thermal comfort among 75% of respondents when using a portable evaporative cooling system in dormitory settings.

These findings demonstrate that the simple fan-and-ice-based cooling system was sufficiently effective in lowering room temperature to a more comfortable level. Moreover, the increase in humidity remained within an acceptable range, indicating that the cooling process did not result in excessive moisture accumulation that could negatively impact indoor comfort.

Perception of Thermal Comfort

The results of the questionnaire distributed to 30 respondents indicated that 73% of students reported feeling more comfortable after the use of the simple cooling device, 20%

expressed a neutral response, and 7% stated that they did not experience any significant change in comfort levels. Overall, most respondents noted that the room temperature felt cooler and the air was fresher, contributing to a more pleasant indoor environment. However, a few participants mentioned a slight increase in humidity, particularly in areas located near the cooling device.

Table 3. Summary of Comfort Perception Questionnaire Results.

Response Category	Number of Respondents	Percentage (%)
Very Comfortable	6	20
Comfortable	16	53
Neutral	6	20
Less Comfortable	2	7

These findings indicate that the simple cooling device positively influences users' perception of thermal comfort. This aligns with the adaptive thermal comfort model proposed by Luo et al. (2020), which suggests that psychological adaptation and individual perception can enhance comfort levels even when physical changes in the environment are relatively minor.

Discussion

The findings of this study indicate that the simple fan-and-ice-based cooling device is considerably effective in improving the thermal conditions of dormitory rooms. The observed average temperature reduction of 3–4°C is sufficient to shift the indoor environment from the “hot” category to the “moderately comfortable” range, in accordance with ASHRAE (2017) thermal comfort standards.

The recorded increase in relative humidity by 8–10% remained within the acceptable comfort range of 40–70% RH, suggesting that the cooling process did not result in excessive dampness. This balance reflects the combined effect of ice melting, which absorbs heat through latent heat transfer, and air circulation generated by the fan, which enhances ventilation and promotes uniform temperature distribution within the room.

The effectiveness of the cooling device is influenced by several interrelated factors, including:

- Room air volume – Smaller rooms (approximately 3×3 m) allow for faster and more uniform cooling due to reduced air mass.
- Ice cube capacity – A larger mass of ice extends the duration of the cooling effect by sustaining the heat absorption process.
- Fan airflow velocity – Higher airflow speeds enhance forced convection, which accelerates heat exchange between air and ice, thereby increasing cooling efficiency (Jamaluddin, 2018).

Compared to mechanical cooling systems such as air conditioners, this device exhibits a lower Coefficient of Performance (COP) but offers significantly higher energy efficiency, requiring only about 12 watts of power (Cengel & Boles, 2015). Moreover, it is environmentally friendly as it does not utilize refrigerants such as R-22 or R-410A, which contribute to the greenhouse effect (Kalsi et al., 2019; Zhang & Wang, 2021).

From the user perspective, the questionnaire results demonstrate a noticeable increase in perceived comfort. This finding supports the adaptive thermal comfort theory, which suggests that subjective comfort can improve through enhanced air movement and moderate temperature reduction (Luo et al., 2020; Givoni, 1998).

Overall, the simple fan-and-ice-based cooling device presents an economical, energy-efficient, and sustainable alternative for indoor cooling. Its design philosophy aligns with Givoni's (1998) principle emphasizing simple, locally adaptable technologies to promote thermal comfort in densely populated tropical environments.

5. Conclusion

Based on the results of research and analysis that has been conducted, it can be concluded that a simple cooling device based on a fan and ice is quite effective in improving thermal comfort in boarding school dormitories. An average temperature reduction of 3–4°C and an increase in relative humidity of 8–10% indicate that this system is capable of creating cooler thermal conditions without causing excessive humidity (ASHRAE, 2020). Most respondents (73%) reported an increase in comfort after using the device, which means that this simple cooling system not only has a physical effect on thermal conditions but also impacts the psychological perception of occupants regarding room comfort.

In terms of energy efficiency, this device is considerably more economical than conventional cooling systems, as it operates with only about 12 watts of electrical power and does not use chemical refrigerants that are harmful to the environment (McMullan, 2018). Its simple and practical design makes it particularly relevant for boarding schools, dormitories, and densely populated residential areas in tropical climates.

Moreover, the use of simple cooling systems such as this supports the implementation of sustainable building technologies. This aligns with Al-Sanea and Zedan (2012), who emphasize the importance of enhancing a building's thermal performance through simple yet efficient innovations that improve occupant comfort without increasing energy consumption.

Therefore, the fan-and-ice-based cooling device can be recommended as a low-cost, energy-efficient, and environmentally friendly alternative with strong potential for integration into energy conservation initiatives and microclimate management strategies in tropical high-density buildings.

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