Development of a cooling system without electricity

Abstract

In order to solve problems such as the inability to use refrigerators in poor areas with high temperatures, a refrigerator that does not use electricity was developed. This study explored conditions that would make the pot-in-pot system, which uses evaporative heat to cool the inside of the container, more efficient and lower the temperature. Three experiments were conducted in this paper to investigate these conditions. The first experiment confirmed the effect of container density on temperature change. The second experiment examined temperature changes when using materials with high water absorption inside the container. The third experiment observed temperature changes when changing the material of the container. Data was collected using a digital thermometer in all experiments. The results revealed that efficient air convection is crucial for cooling the interior of the container. These findings suggest that a pottery container with high air permeability, combined with cotton that offers both breathability and water absorption, is the optimal choice.

Introduction

Background

Some regions has not have electricity supply and house hold which those not have refigure.In fact, as of 2020, approximately 760 million in the world people do not have access to electricity. In addition to this situation, food poisoning and food loss due to poor food conditions are particularly problematic in regions with high temperatures.

In Japan, natural disasters such as earthquakes and typhoons occur frequently, and power outages often occur as a result of these disasters. One of the problems that arises when a power outage occurs is the storage of food. Generally, food in the refrigerator will lose its freshness and deteriorate after about four hours of power outage. As a result, a large amount of food is discarded at supermarkets, farms, fishing ports, and general households. In the 2018 Hokkaido Eastern Iburi Earthquake, which caused power outages across the entire prefecture, I witnessed measures being taken such as distributing meltable ice cream and frozen foods that could not be sold for free at convenience stores, or selling them at reduced prices. According to Zaikei Sapporo (September 8, 2022), the amount of collected garbage reached 1,408 tons, which is 2.4 times the usual amount, due to the large amount of food waste, including dairy products. My family also had to dispose of a large amount of food due to the power outage. Such situations where refrigerators cannot be used lead to significant food loss.

In addition, according to the Greenhouse Gas Imperito Office, electricity accounts for 47.6% of carbon dioxide emissions from households, and refrigerators consume 14.3% of the electricity used in households. Carbon dioxide is one of the greenhouse gases that cause global warming. Japan aims to reduce greenhouse gas emissions by 46% by 2030 compared to 2013 levels, but as of 2022, emissions have decreased by only 22.9% compared to 2013 levels.

Given these issues, a cooling system capable of

Figure 1: 2020 Carbon Dioxide Emissions from Households – Breakdown by Fuel Type –

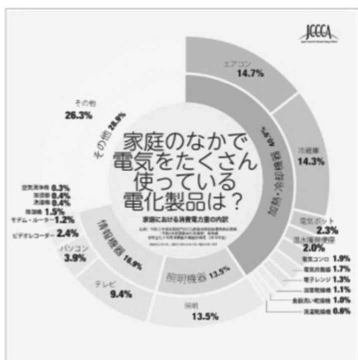

Figure 2: Breakdown of household electricity consumption

operating without electricity could be regarded as a potential lifeline during disasters, while also offering benefits such as reducing food waste and carbon dioxide emissions.

Hypothesis

It was confirmed in a preliminary experiment that the temperature inside the container would decrease due to the heat of vaporization. Therefore, three methods of accelerating vaporization were researched.

Firstly, regarding the density of the container (polystyrene), it is expected that the greater the density, the greater the temperature decline. According to the properties of polystyrene, low-density polystyrene traps air inside, and air is not good at conducting heat; therefore, it is conceivable that high-density polystyrene is better than low-density polystyrene.

Secondly, when comparing polymer and cotton, which play a role as water-absorbent materials, it is conceivable that polymer is better because polymer evaporates more easily due to the water staying on the surface.

Thirdly, regarding the material of the container, it is expected that a clay container is better than a polystyrene one because clay is a porous material, so the area in which water can evaporate is larger than that of a polystyrene container.

Overview of experiments

Overall, the method of enhancing vaporization was investigated.In addition,The experiment was conducted using the pot-in-pot method. The pot-in-pot method involves stacking two containers of different sizes. A highly absorbent material is placed between them, and water is added to cause evaporation heat, thereby lowering the temperature inside the inner container.

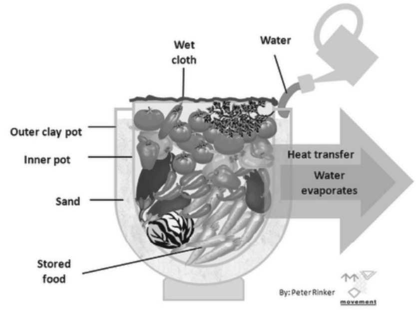

Figure 3:method of pot-in-pot

Experiment 1

An experiment was conducted to confirm temperature differences in container density affect temperature changes inside the container. Polystyrene was used as the container material because, like the pottery pots used in previous pot-in-pot studies, polystyrene has high thermal insulation properties that prevent the internal temperature from being affected by the external temperature.

Experiment 2

An experiment was conducted to confirm whether the temperature inside the container would decrease depending on the material placed between the containers. The materials compared were polymer and cotton. Both are known to be highly absorbent materials. The purpose of placing highly absorbent materials inside is to retain water for as long as possible and to sustain the heat of vaporization.

Experiment 3

Whether the material of the container influences the internal temperature was examined. This is because the pottery used in the pot-in-pot method is a porous material, which increases the surface area available for water evaporation and promotes evaporation heat. Therefore, handmade pottery made from clay were used to conduct experiments following the pot-in-pot method, and the resulting temperatures were compared with those of polystyrene containers.

Materials

Experiment 1

- 1 High density polystyrene container
- 1 low density polystyrene container
- 2 small container
- polymer 960g
- water 300ml×2
- 3 iPad
- 2 digital thermometer

Experiment 2

- 2 large container
- 2 small container
- 3 cotton cloth
- polymer 960g
- water 300ml ×2
- 3 iPad
- 2 digital thermometer

Experiment 3

・1 large pottery container

・1 small pottery container

・3 cotton cloth

・water 300ml

・2 iPad

・1 digital thermometer

Procedure

Experiment 1

1. Place the polymer in the high-density container and the low-density container, respectively.
2. Stack the small container on top of them.
3. Pour 300 ml of water into the space between the small and large containers.
4. Place a digital thermometer in the small container and measure the temperature change for one hour.

Experiment 2

5. Place cotton cloth and polymer in a large container.
6. Place a small container on top.
7. Pour 300 ml of water into each of the small and large containers.

8. Place a digital thermometer in the small container and measure the temperature change for one hour.

Experiment 3

9. Put cotton in the large pottery container.

10. Place the small pottery container on top of it.

11. Pour 300 ml of water into each of the small and large pottery containers.

12. Place a digital thermometer in the small pottery container and measure the temperature change for one hour.

Results

Experiment 1

The temperature inside the high-density container dropped by 1.4°C from the temperature before the experiment. In contrast, the temperature inside the low-density container dropped by 3.3°C.

Density	Temperature
High	-1.4°C
Low	-3.3°C

Figure 4:Table of experiment 1 results

Experiment 2

When cotton was placed in a low-density container, the temperature inside the container dropped by 4.0°C from the temperature before the experiment.

Experiment 3

When pottery was used, the temperature inside the container dropped by 5°C from the temperature before the experiment.

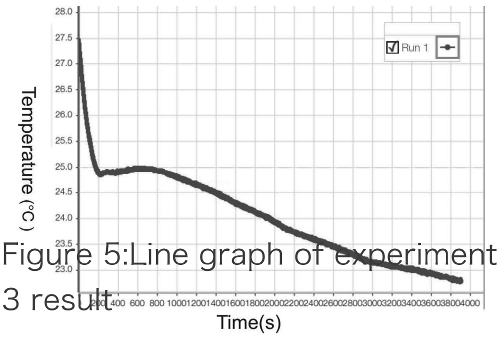

Figure 5:Line graph of experiment 3 result

Discussion

Experiment 1

The temperature dropped more in the less dense container than in the more dense container. This is thought to be due to the effect of air convection. The less dense container is less airtight, making it easier for heat exchange with the outside air to occur, causing the temperature to drop. In this way, it is thought that the temperature dropped as a result of heat exchange.

Experiment 2

When comparing the results of Experiment 1 (when polymer was placed in a container with low density) with those of Experiment 2, the temperature decreased more when cotton was placed in Experiment 2. The reason for this is that cotton has fine fibers, high water absorption due to capillary action, and high breathability. Since air can pass through easily, water evaporates more readily, allowing for efficient evaporation heat transfer. Furthermore, cotton has many gaps between its fibers and a large surface area for evaporation, which is believed to have further accelerated evaporation heat transfer.

However, neither Experiment 1 nor Experiment 2 showed significant temperature changes. This is thought to be due to the material of the container. As seen from the experimental results, air convection is crucial for efficiently lowering temperature. However, the polystyrene containers used in Experiments 1 and 2 do not allow air to pass through easily. In contrast, the pottery containers used in prior research are porous materials that allow air to pass through well and have a large evaporative surface area. Therefore, it is considered that porous materials should be used.

Experiment 3

When pottery were used, the temperature dropped more than in experiments 1 and 2. The reason for this is that, as mentioned above, pottery are a porous material, allowing more air to pass through and increasing the area available for evaporation.

Conclusion

This study found that the combination of pottery and cotton is the most suitable for a cooling system. However, the temperature decrease observed in the experiment was not sufficient for practical use. Therefore, it is necessary to explore methods that can increase the temperature drop, such as enlarging the size of the container.

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