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Design of Tissue-Transfer Container Using Thermoelectric Element Module

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The internal temperature of human-tissue transfers must be steadily maintained regardless of the external environmental changes. An ice pack and dry ice are the coolants for the transfer containers for which heat-insulating materials such as EPP (expended polypeopylene and EPS (expended polystrene) are used; however, changes of the external temperature/pressure and the melting of the coolants that is due to a long carriage result in changes of the internal temperature, and this makes it difficult to maintain the temperature. Accordingly, the thermoelectric element was used to design/manufacture a transfer container to maintain the internal temperature regardless of the external environmental changes. As a result of the measurement of the changes of the internal temperatures of the manufactured thermoelectric-element container and the EPS container over time, the internal temperature of the EPS container was increased, whereas the internal temperature of the thermoelectric-element container was maintained. The temperature of the distilled water that was poured into the containers indicated a pattern identical to that of the internal temperature.

Keywords: Thermoelectric element, Peltier effect, Transfer container, Heat insulation

1. INTRODUCTION

The human tissues used in Korea are collected from carcasses or living bodies, and they are then processed and distributed in accordance with the statements specified in the “The Act on safety and management of human tissues.” Since such human tissues are transplanted into human beings, a number of research studies have been conducted on the maintenance conditions during storage and the distribution, not only to secure safety but also to maintain the histological/physical characteristics [1]. However, the weakness is that the thickness and the size of the heatinsulating materials that are used during the distribution of such human tissues vary, and it is therefore difficult to equally maintain the temperature due to the different thicknesses/sizes of the heat-insulating materials that are used during the distribution of such human tissues, and the changes of the temperature that are due to different seasons and altitudes. Accordingly, it is necessary to conduct research to design a transfer container in which the temperature can be equally maintained regardless of the changes of the temperature that are due to different seasons and altitudes.

The thermoelectric element used in this research contains the Seeback Effect, Peltier Effect, and Thomson Effect [2,3]. The Peltier Effect that releases heat through the shifting of the heat absorbed from one contact point to another was used for cooling.

The thermoelectric element for which the Peltier Effect is used electrically forms a serial connection and thermally forms a parallel connection [4,5]. Since such a thermoelectric element on a simple structure is highly reliable, it is widely applied to industrial cooling devices and domestic appliances. In addition, a number of studies have been conducted on the application of the thermoelectric element for the designs of cooling/heating cabinets, as well as the use of the cooling characteristics for the controlling of the heat temperature of LEDs [8].

In this thesis, the thermoelectric element was used to manufacture the cooling section of the tissue-transfer container so that the container receives no influence from the surrounding environments, and the temperature characteristics were subsequently analyzed.

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2. EXPERIMENTS

Human tissues can be classified into freeze-dried tissue, refrigerated tissue, deep-frozen tissue, and ultra-low-freezing tissue. Such tissues are stored and carried within diverse temperature ranges. Table 1 shows the storing-temperature range for each tissue.

The EPS (expended polystrene) container can be easily found in the actual lives of humans, as it is frequently used as the container for carrying groceries and particular materials while the refrigeration temperature is maintained. An EPS container is used for carrying human tissues while the temperature is maintained. To maintain the refrigeration temperature within such EPS containers, an ice pack or dry ice is used as the refrigerant; however, when dry ice is used to maintain the temperature within an airtight space for a long time, the dry ice may evaporate and increase the internal pressure. Such an increased internal pressure may decrease the airtightness within the container and exert an unnecessary influence on the tissue stored within the container. To minimize the factors from this pressure that may cause internal changes, an ice pack was used as the refrigerant in this research. The changes of the internal temperature of such EPS containers was analyzed over time.

As for the EPS container used in this research, the size is 250 mm × 250 mm × 250 mm, and the thickness is 20 mm, and the two ice packs weighed 680 g. As for the temperature measurement, a data logger (GL220; Graphtec Corp. Japan) and a K-type temperature sensor (TT-K-36-SLE; Omega Corp. USA) were used. To analyze the changes of the internal temperature based on the external environmental changes, the EPS container was installed outdoors, and the temperature was measured for 1 hr. For the measuring, distilled water (500 ml) that was cooled down to 7℃ was poured into the EPS container to measure the changes of the temperature of the distilled water, in addition to the changes of the internal temperature. Figure 1 shows the changes of the internal temperature of the EPS container that was exposed to the external environment, as well as the changes of the temperature of the distilled water that was poured into the EPS container.

The external temperature is approximately 32.8℃ prior to the initiation of the experiment, and the highest temperature throughout the entire hour is approximately 35.3℃. The internal temperature of the EPS container is approximately 17.6℃. Upon the initiation of the experiment, the ice pack and the distilled water (500 ml) that had been cooled down to approximately 7℃ were put into the EPS container. As a result, the internal temperature of the EPS container was instantaneously decreased to 13.1℃ however, the external temperature continued to increase over time, the ice pack within the EPS container started to melt, and the internal temperature continued to increase. The temperature of the distilled water that was cooled down to 7℃ reached 10 after 27 min of the experiment.

These data signify that the external environment is considerably influential on the changes of the internal temperature. Such conditions do not cause any problems in the carrying of freezedried tissue, but they may cause major problems in the carrying of refrigerated tissue, which requires a temperature of between 110. It would take more than 4 hr to carry human tissues from Seoul to Busan or Jeju. The longer the time that it takes to carry such human tissues, the greater the changes of the internal temperature. Accordingly, it is necessary to design a new type of transfer container that will not be influenced by the external environmental changes.

In this research, the thermoelectric element was used to design/manufacture a container to eliminate the influence of external environmental changes.

Table 1. Temperature range per tissue.

Division	Storage temperature
Freeze-dried tissue	< 48℃
Refrigerated tissue	1~10℃
Deep frozen tissue	< - 40℃
Ultra-low-freezing tissue	< - 120℃

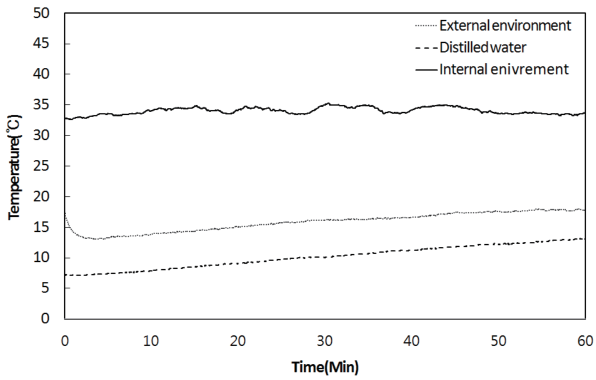

Fig. 1. Changes of the internal temperature and distilled water of the EPS container exposed to the external environment.

3. RESULTS AND DISCUSSION

In this research, the thermoelectric element (Tec1-12706, HB Electronic Components, China) was used to design/manufacture a cooling system. Such a designed/manufactured cooling system consists of a control section for the controlling of the internal temperature of the container, a sensor for measuring the temperature, and a battery for supplying the power. Table 2 shows the characteristics of the thermoelectric element that was used in this research.

The characteristics of the thermoelectric element were used to design/manufacture a tissue-transfer container. The display LCD was attached to the front section of the thermoelectric element container for the control. The thermoelectric element was attached to the three sections besides the front section. Considering the sizes of the thermoelectric element and the heat sink for cooling, two thermoelectric elements were respectively attached to each section, and therefore a total of six thermoelectric elements were attached to the three sections. Figure 2 shows a 3D rendering of the tissue-transfer container that was designed/manufactured in this research.

The size of the heat sink was considered in the setting of the internal-space dimensions of the container as 260 mm × 260 mm × 125 mm. Since it is necessary to minimize the power consumption of the container that is used to carry human tissues, the transistor was used to control the thermoelectric element through the turning on/off of the FET. In addition, the heat sink and cooling fan were installed to promptly cool down the heat being released to the outside so that the internal space of the container can be smoothly cooled down. Due to the characteristics of the thermoelectric element, one side cools down when the other side heats up, and

Table 2. Performance specification of thermoelectric element.

Internal resistance (r)	2.1 ~ 2.5 Ω
Max temperature difference (ΔT_{max})	60℃
Operating current (I_{max})	5.8 A
Rated voltage (V_{max})	15 V
Cool down capability (Qc_{max})	58 W
Waking condition (ΔT)	- 55℃ ~ 83℃

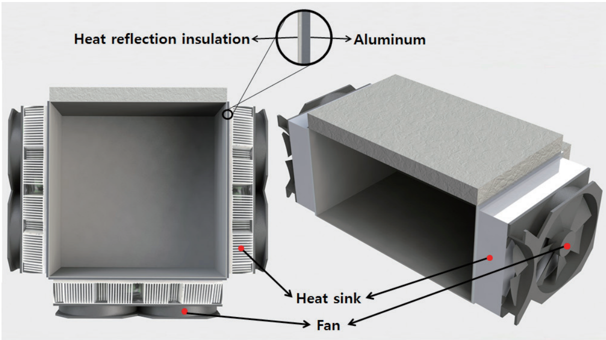

Fig. 2. 3D rendering of tissue-transfer container.

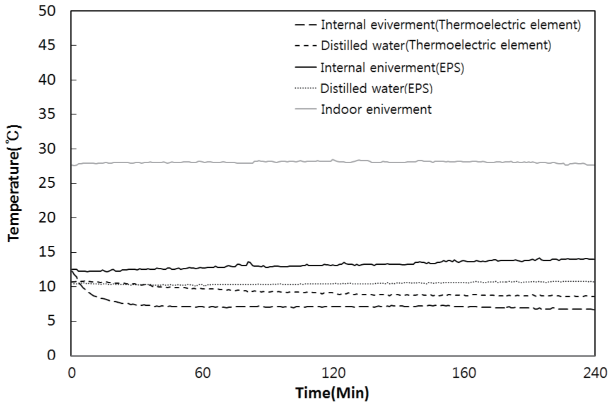

Fig. 3. Temperature changes of the thermoelectric-element container and the EPS container in the indoor environment.

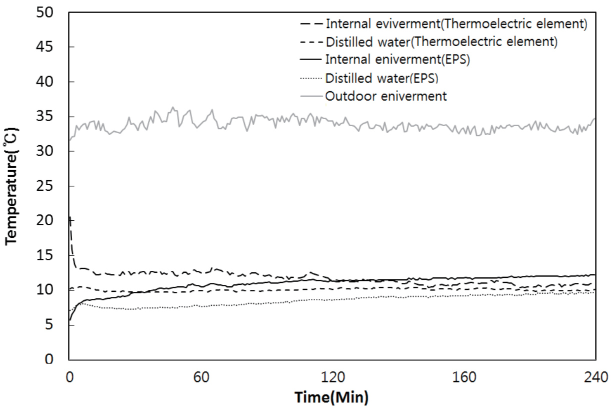

Fig. 4. Temperature changes of the thermoelectric element container and the EPS container in the outdoor environment.

this expands the temperature difference between the internal-wall board and the heat sink. Accordingly, heat-reflection insulation was inserted between the heat sink and the internal-wall board to maintain an efficient temperature difference. In addition, an aluminum board with an outstanding thermal conductivity was used as the material for the internal wall to maintain the cold air within the container.

It is necessary to maintain the temperature between 1 and 10℃ regardless of the external environmental changes to carry refrigerated tissue; accordingly, prompt cooling is essential. Six thermoelectric elements were attached to the manufactured carrier and the cooling experiment was conducted. In the experiment, the thermoelectric-element container and the EPS-based container were compared in terms of the cooling performance. The size of the EPS container is 250 mm × 250 mm × 135 mm to match the internal volume of the thermoelectric-element container. The two ice packs weighing 680 g were used as the coolant for the EPS container. As for the temperature measurement, the data logger (GL220; Graphtec Corp. Japan) and the K-type temperature sensor (TT-K-36-SLE; Omega Corp., USA) were used. In the experiment, the cooled-down distilled water (500 ml) was poured into the container to measure the temperature of the distilled water as well.

Through this process, the change of the internal temperature of the container based on the changes of the external environmental temperature was measured, and the change of the temperature of the distilled water that was poured into the transfer container was measured as well. To analyze the externaltemperature changes, the experiment was conducted in indoor-/outdoor-environment settings. For the indoor environment, the temperature was measured within the building. For the outdoor environment, the containers were placed outside the building to facilitate natural temperature changes. Figure 3 shows the characteristics of the temperatures of the thermoelectric-element container and the EPS container in the indoor environment.

For the temperature measurement, the following temperatures were measured: the external temperature, the internal temperature of the thermoelectric-element container, the temperature of the distilled water poured into the thermoelectric-element container, the internal temperature of the EPS container, and the temperature of the distilled water poured into the EPS container. Normally, human tissues are carried on vehicles, trains, and airplanes; accordingly, the temperature changes were measured for 4 hr.

The external temperature was maintained within the range of 27.6℃ and 28.5℃, and this signifies that the temperature change is approximately 1℃. Accordingly, it was determined that the changes of the external temperature are not considerably influential on the changes of the internal temperature. The internal temperature of the thermoelectric-element container is 12.3℃, and the internal temperature of the EPS container is 12.5℃ prior to the initiation of the experiment. The temperature of the distilled water poured into the thermoelectric-element container and the EPS container is 10.7℃, which is a bit higher than the refrigeration temperature. An ideal container should be capable of maintaining the refrigeration temperature even though a sample at a temperature that is a bit higher than the refrigeration temperature is poured in.

The internal temperature of the thermoelectric-element container is 6.8℃ upon the completion of the experiment. The temperature was decreased by 5.5℃ from the initiation to the completion of the experiment, and the refrigeration temperature was well-maintained. As for the EPS container, the temperature was slightly decreased due to the cold air of the ice pack that was immediately put into the carrier upon the initiation of the experiment, but the temperature was gradually increased from then onward. The temperature was increased to 14.3℃ upon the completion of the experiment, and a maintenance of the refrigeration temperature did not occur. It was determined that the internal temperature of the EPS container started to increase as the ice pack that was put into the carrier to maintain the refrigeration started to melt.

The temperature of the saline solution within the thermoelectric element container was decreased from 10.7℃ to 8.6℃, and the refrigeration was maintained. As for the EPS container, the temperature was decreased from 10.7℃ to 10.1℃ due to the cooled ice pack, but the temperature was then increased. This signifies that the refrigeration temperature cannot be maintained unless a sufficient amount of cold air is contained in the ice pack.

Figure 4 shows the characteristics of the temperatures of the thermoelectric-element container and the EPS container in the outdoor environment.

The method that was used for measuring the indoor temperatures was used for measuring the outdoor temperatures as well. The external temperature of the outdoor environment was maintained within the range of 31℃ and 36.5℃ throughout the 4 hr, and this signifies that the temperature changes are considerable. Accordingly, it was determined that the changes of the internal temperature that are based on the changes of the outdoor temperature would be considerable as well. The internal temperature of the transfer container must be well-maintained despite the considerable changes of the temperature of the outdoor environment. To confirm whether or not the outdoor environment leads to a result that is identical to that of the indoor environment, the internal temperature of the EPS container was cooled down to 5.7, and the internal temperature of the thermoelectric-element container was cooled down to 20.5℃ for the experiment.

The distilled water poured into the EPS container was cooled down to 7.1℃, and the coolant at 10.2℃ was poured into the thermoelectric element container. As for the thermoelectric element container, the temperature was gradually decreased throughout the 4 hr, and the refrigeration temperature was maintained at slightly above 10. As for the EPS container, the temperature was continuously increased until it was maintained at approximately 12. The temperature of the distilled water that was poured into the carriers maintained the refrigeration temperature at approximately 10℃ for both the thermoelectric-element container and the EPS container. As for the distilled water poured into the EPS container, it was determined that the temperature was maintained because the cooled distilled water was poured into the EPS container after the cooling of the EPS container itself.

In the indoor experiment, the temperature was not maintained because the EPS container itself was not cooled; however, in the outdoor experiment, the refrigeration temperature was maintained because the EPS container was sufficiently cooled. The EPS container would be influenced by diverse environmental changes. Accordingly, it was determined that it would be more safe to use the thermoelectric-element container than the EPS container.

4. CONCLUSIONS

In this research, a thermoelectric-element container is designed/ manufactured for a safer carriage of human tissues. In consideration of the installation of the control section, the container was designed so that the thermoelectric elements can be attached to the three sections for cooling. Considering the sizes of the thermoelectric element and the heat sink, a total of six thermoelectric elements were used to manufacture the container. Accordingly, the thermoelectric-element container was manufactured to compare its temperature characteristics to those of the EPS container. In addition, the temperature characteristics of the indoor/outdoor environments were compared to compare the temperature characteristics based on the environmental changes.

In the indoor experiment, the internal temperature of the EPS container started to slightly decrease as the cooled ice pack started to melt, but it was then again increased to 14.3℃. The distilled water poured into the EPS container failed to maintain the refrigeration temperature due to the increase of the internal temperature. However, the internal temperature of the thermoelectric element container was decreased by 5.5℃ from its initial internal temperature, whereby it reached 6.8℃, and the distilled water within the thermoelectric-element container effectively maintained the refrigeration temperature at 8.6℃.

Since the EPS container failed to maintain the refrigeration temperature in the indoor environment, the temperature comparison in the outdoor environment was conducted after the cooling of the EPS container. As a result of supplying the ice pack and the cooled distilled water after the temperature of the EPS container was reduced to 5.7℃, the refrigeration temperature was maintained; however, since such EPS containers are almost never purposefully cooled and are almost never cooled during the carriage process, it seems like it would be difficult to maintain the temperature in actual applications. As for the thermoelectric element container, the carrier was cooled after it was exposed to the external environment, and the internal temperature as well as the temperature of the distilled water was decreased to a value near the refrigeration temperature. It is essential to maintain the temperature to prevent the human tissues from decaying.

Since the thermoelectric-element container can be easily controlled to not only maintain the refrigeration temperature, but to also set and maintain the preferred temperature, it is expected that it will be used as the next-generation container.

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