POSSIBILITY OF PERSONAL STORING OF CEREALS

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ABSTRACT
Farming is very popular in Tohoku Region. Especially the yield of rice in this region is more than 10% of that in Japan. However, farmers have a problem with its storage in winter and summer. In general, rice should be harvested in autumn, and be stored until the harvest next year. To store it in summer, electric refrigerators are generally used and they cost a couple of million yen every year. This is not good in view of the promotion of Kyoto Protocol concerning global warming.

In this study, the authors propose a passive storing model that makes the best use of the thermal insulation ability and the thermal capacity of the soil. Although an old tunnel has been used as a passive storehouse for several years in Iwate Prefecture, it has not been known yet to farmers in general. The authors started the investigations of actual conditions of Tohoku Region, and examined the possibility of a personal storing by experiments and calculations. The results of this review will show the possibility of a passive and personal model for storing cereals.

KEYWORDS
Passive storing, snow, personal model, energy conservation

INTRODUCTION
Rice is generally stored in electric refrigerators and the cost reaches a couple of million yen in average every year. Furthermore, its energy consumption leads to global warming, so some countermeasures have to be taken. In this study, the authors analyze how a passive storage system using snow works in heavy snowfall areas and propose the possibility of a personal storage, using computer simulation.

HOW STOREHOUSES REALLY ARE IN IWATE PREFECTURE
1) Natural Refrigerators in Koiwai Farm
A natural refrigerator in Koiwai Farm has long been known. The storehouse built in 1905 keeps its indoor temperature low in summer using the heat stored in the ground and was used for the preservation of butter but it is not used now from the viewpoint of hygiene. The authors measured its temperature, humidity and ventilation rates, regarding its structure as a basic storehouse. Figure 1 shows the plan of the natural refrigerator. It is about 9 meters deep and about 6.3 meters wide at longest. A ventilation stack is installed. Figure 2 shows the temperature and humidity both outside and inside of the refrigerator. Inside temperature varies according to the measurement place but is constant at about 11°C. Humidity stayed more than 99% and the walls always had vapor condensation Ventilation rates were measured from December 1 to December 2, 2003 by the constant tracer gas injection method. Since indoor humidity is high and there can be moisture on the walls, SF6 was used instead of carbon dioxide, which is easy to be absorbed in water.

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The gas was supplied from a cylinder to each room via a regulator at the constant flow amount of 5 ml/min controlled by a mass flow controller. Then, air samples were collected at the places far from the generation point in each room, mixed and sent to a multi-gas monitor, where the density of SF6 and the humidity were measured every minute. Figure 3 shows the measurement results. The ventilation rates varied from 60 to 110 m$^3$/h.

The ventilation rates at night were high. This is because of the temperature difference between indoors and outdoors and the influence of the wind outside.

In the natural refrigerator, a ventilation stack is installed but it is not useful for drying, which is an original function of ventilation or rather it allows moist summer air to come in as we can see from the measurement results shown in the figure. Koiwai natural refrigerator was built many years before, so its insulation depends on only the soil. The temperature stays low indeed but more effect might not be expected. Since it keeps its indoor temperature low even without insulation systems, it can be changed into an energy-saving refrigerator by the use of a small freezer.
The ventilation of Koiwai natural refrigerator depends on the airflow from the openings of the entrance and from the ventilation stack. The outdoor temperatures when measured were 4 to 9 °C and almost the same as its indoor temperatures, so the refrigerator was ventilated not by the temperature difference but by the wind. Here, the entrance has a double door and its insulation is high, so the airflow from the stack by a pressure change is thought to be prominent.

These results suggest a method of measuring ventilation characteristics in the space with several stacks. This will lead to a further examination of natural ventilation methods by the use of stacks in well-insulated houses.

2) Yukkiko Tunnel in Sawauchi

A former tunnel in Sawauchi Village has been used as a storehouse since 2001. The inside of the tunnel is 200m long and 5.2m wide: It is divided into a 75m snow storing area on Shizukuishi side, a 20m × 3.1m bulb storing area in the middle, a 45m × 3.1m unpolished rice storing area on Sawauchi side, a passage for cars, a machinery room in which are fans for stirring the air, and ducts. At the entrance, insulation shutters are equipped considering inside air-tightness. Insulation foam covers the walls to get effective insulation and storage of heat.

Figure 4 shows the measurement results of temperature and humidity in summer.
The temperature in the unpolished rice storing area stays about 9℃ and the humidity there stayed at about 80% after snow was put in and shutters were closed to prevent the outside air in. However, immediately after the preparation for rice storing started in September, the humidity reached nearly 100%. This is thought to result from the frequent openings of the shutters. The humidity after September reached over 99%. The temperature stays 8.9℃ till November, and from 5℃ to 7℃ in a snow storing area. Therefore, this former tunnel storehouse is very effective in keeping its inside temperature low and is good for storing vegetables in summer.

The above results suggest that unnecessary snow in winter and heat in the ground can be useful as an energy-saving method for storing crops. However, in large farmland, the energy used for conveying crops or snow to a storehouse might become a big problem, and personal storage of crops with a snow storing system should be recommended.

EXAMINATION OF PERSONAL STORAGE

1) Calculation Model

In this calculation model, the storehouse is in Morioka City. Its floor area is 100 m²(10m wide × 10m deep) and its height from the bottom is 7m. The storehouse was buried into the ground and the depth is 1m, 3m, and 5m from the ground level (see Figure 5). Table 1 shows the patterns for calculation and Table 2 shows building materials and their characteristics. Its capacity for storing snow is estimated 8m × 8m × 6m=384m³ (one meter from each wall or ceiling is left open as a space for working).

![Figure 5 Calculation Model](image)

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<tr>
<th>Model Number</th>
<th>Space thermal insulation</th>
<th>Foundation insulation</th>
<th>Depth of Insulation</th>
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</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>Concrete 150mm (no insulation)</td>
<td>Insulation from outside of foundation XPS 3b 50mm</td>
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<tr>
<td>No. 2</td>
<td></td>
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<td>3 m</td>
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<tr>
<td>No. 3</td>
<td>Concrete 150mm + XPS 3b 100mm (insulation from outside)</td>
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<td>No. 4</td>
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<td>No. 6</td>
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Table 2 Building materials and its characteristics

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2) Calculated Results

Figure 5 shows the monthly amount of melting snow in six patterns. In all the patterns the amount of melting snow becomes largest in summer (July and August). The amount is especially large in No.1, No.2 and No.3 with no insulation on the roof. The amount of melting snow is more than ten times of No.4, No.5 and 6 with insulation from outside. The amount of melting snow in No.3 is about half of No.1 and the effect of burying into the ground is large in the case of no insulation models. On the other hand, concerning insulation models (No.4,5 and 6), the amount in No.6 is about 85% of that in No.4; only 15% reduction.

The deeper the model is buried into the ground, the smaller the area of the walls facing outside air is. The roofs need to be well insulated especially in summer because the solar altitude is high.

Figure 6 shows the calculated rates of the remaining snow when snow is put in the whole capacity except for a space for working (384m³). Considering its role as a cooling energy source, it is necessary to keep as much snow as possible until summer (July and August).

Figure 7 shows the investigation of the case of storing snow in high density. The cooling energy that can be stored in the same capacity increases if its density is high, so in no insulation models, the time snow melted away was June 7 in No.1, June 24 in No.2, and July 16 in No.3, but it cannot be used as a cooling energy source.

In insulation models, on July 1, snow remained 88.8% (No.4), 90.1% (No.5), 91.5% (No.6) and the higher snow density is the less the difference in the depth in the ground becomes. This shows that insulation of the upper part is more important than that of the ground level and at the same time, it suggests if a model is well insulated, a model buried in the ground is not necessarily effective, taking into consideration the cost of digging and dealing with the soil left.
CONCLUSIONS
The researches in the buildings for snow storage and the results of calculation lead the following conclusions.
1) In Iwate Prefecture there is an experimental energy-saving storage system in a conventional storehouse but it is not easily accessible.
2) In regions with large farmland there is a possibility of using snow in a personal storehouse.
3) The effect of burying in the ground is large if the space is not well insulated.
4) The depth of burying in the ground has few differences if the space is well insulated.
5) The snow storage space in the size reviewed this time is not available as a cooling energy source in summer under the weather condition of Morioka City unless the space is insulated.
6) If the snow is stored in high density, the amount of stored snow increases and there is no difference in the depth of burying in the ground. Therefore the possibility that it is used as a cooling energy source in summer will be strong, especially in view of the construction fees.

DISCUSSION
In cold regions, cellars in the ground have been conventionally used. In Russia and Hokkaido, there still remain cellars in the mounded soil and cellars in the ground. Such energy saving storing systems in a large scale are seen in Tohoku Region, too, but personal storing systems are not popular yet. The authors think users’ understanding is essential for the spread of personal energy-saving storing systems.

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REFERENCES