Freshness-Keeping Technology with Ambient Humidity Control

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ABSTRACT

In recent years, food being discarded even though it is still edible (food loss) has become a social problem. Taking note of how freshness is lost as food becomes dry, Fuji Electric has developed technology that controls ambient humidity to keep food fresher for longer. This method applies Fuji Electric's polymer electrolyte fuel cell technology. Using no liquid water significantly reduce the risk of bacterial and fungal growth that causes food poisoning. The technology allows users to determine appropriate humidity conditions for specific food materials, store them with little loss of fresh texture, and increase sales opportunities, reducing food loss.

1. Introduction

In recent years, food being discarded even though it is still edible (food loss) in the food distribution industry has become a social problem. Reducing food waste to half in terms of retail and consumption levels by 2030 is one of the Sustainable Development Goals (SDGs) adopted by the United Nations and must be recognized as a global problem.

From a micro perspective, food loss puts pressure on the profits of convenience stores and supermarkets and reducing it has become a big challenge for them. Convenience stores have counter fixtures around their counters (see Fig. 1). In these fixtures, cooked foods or sweets that emphasize freshness and deliciousness are exhibited in an unwrapped state. Although they have a strong product appeal, their fresh texture and taste are greatly affected by the storage environment because they are exposed. This leads to the problem that they have to be discarded after several hours. In conventional counter fixtures, temperature control such as cooling or heating was used as an effort to maintain the texture and taste. This paper describes a technology for keeping freshness by focusing new attention on the drying of food and by controlling humidity as well as temperature through the use of an element to which the principle of fuel cells was applied.

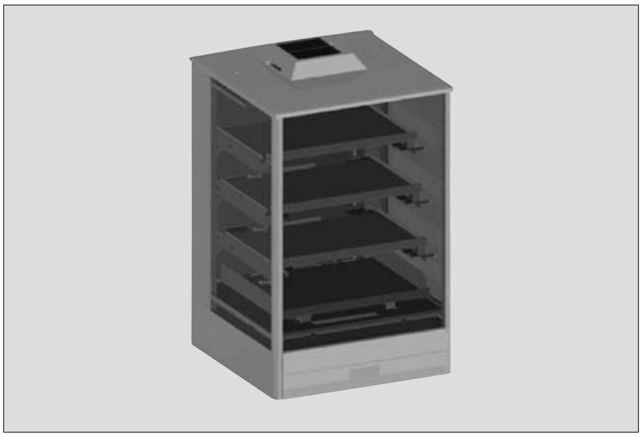

Fig.1 Counter fixture

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2. Characteristics of Freshness-Keeping Technology

A typical and known humidifying method uses heat or ultrasonic waves to vaporize water and release it into a space. Unfortunately, with this method there is a high risk of bacterial and fungal growth in the stored water. Fuji Electric decided not to select this method for counter fixtures because it might lead to the risk of fatality from factors such as food poisoning.

As a new method, we developed a technology for controlling humidity without using liquid water by applying Fuji Electric's polymer electrolyte fuel cell technology.

Figure 2 shows the external appearance and structure of the developed element. It has catalysts with different compositions applied on each surface of an electrolyte membrane that selectively allows protons to pass. The membrane is sandwiched between electricity collecting metal plates (electrodes) and resin covers from both sides.

Figure 3 shows a schematic diagram of the reaction of the element. When a voltage is applied to the electricity collecting metal plates, a reaction occurs on the catalyst surface. On the dehumidifying side, water is decomposed into protons and oxygens. The protons

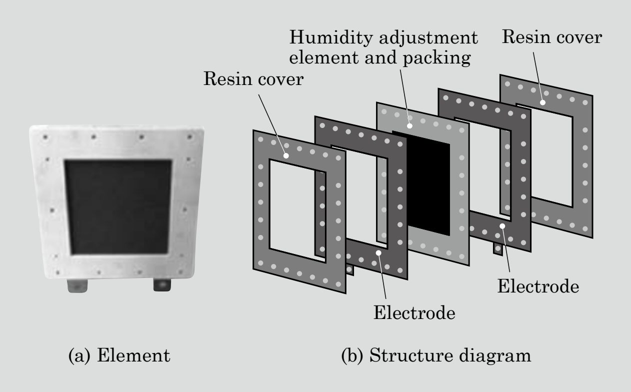

Fig.2 External appearance and structure of the element

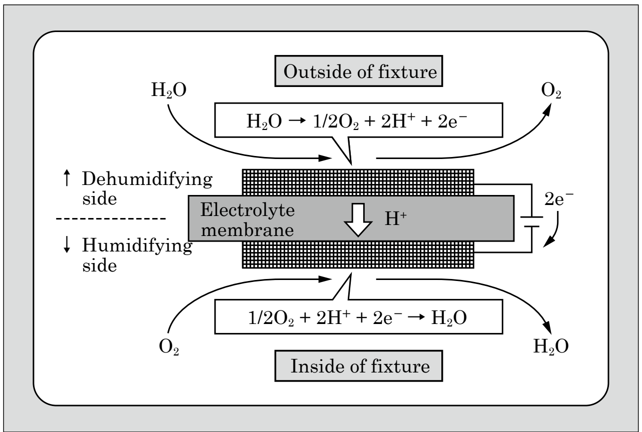

Fig.3 Reaction schematic diagram

pass through the electrolyte membrane and bond with oxygen on the humidifying side to form water and be released. This is a reaction of decomposition and release at the level of water molecules in the air. It is characterized by there being no need to replenish water during humidification and no drain water being generated during dehumidification.

Another characteristic is that the target container can have both humidification and dehumidification functions and they can be switched depending on whether it is the front or back surface of the element to be attached to the container.

3. Element Technology Development

3.1 Technology to improve moisture treatment ability

At the start of developing the element, we set a target value for the moisture treatment speed required for humidification and dehumidification based on the capacity and airtightness of the counter fixture. To satisfy the requirement for moisture treatment speed, we can increase the treatment speed easily by enlarging the surface area of the element. When, however, the element becomes larger, the necessary amount of the electrolyte membrane and catalyst also increases, and this directly affects cost. Consequently, the key point of the development is to determine how to use a small element to improve the dehumidification and humidification performances to ensure the necessary functions.

To satisfy the necessary element performance, we first studied the electrolyte membrane. There are a wide variety of proton-exchange membranes from those used for fuel cells to those for water electrolysis. Figure 4 shows the transition of the internal humidity change and current value when an element with an electrolyte membrane having a thickness of 30 µm (T30) and an element with a membrane having a thickness of 180 µm (T180) are used to humidify containers of the same capacity.

In general, the number of protons passing through the electrolyte membrane is proportional to the electric current. Therefore, the more electrolytic current that flows, the more protons that pass through the electrolyte membrane. When the element performances of T30 and T180 are compared, it is found that T180 can increase the humidity inside the container faster than T30 despite its lower electrolytic current value.

As shown in Fig. 5, water back-diffuses through the electrolyte membrane from the humidification side with higher humidity to the dehumidification side with lower humidity. T180 has a higher water diffusion resistance, which may be the reason for its higher humidification and dehumidification performance. Increasing the humidification and dehumidification per-

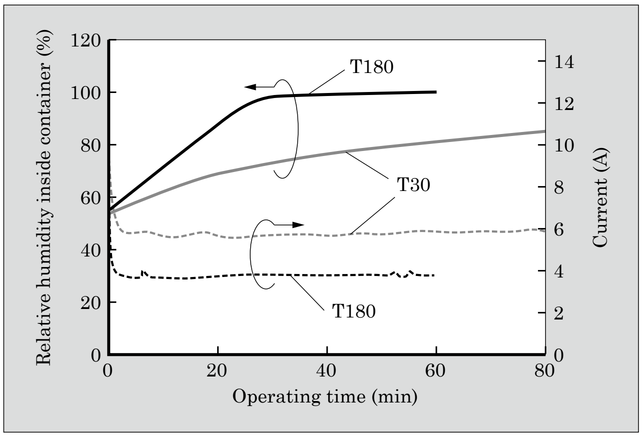

Fig.4 Transition result of humidifying amount and electric current

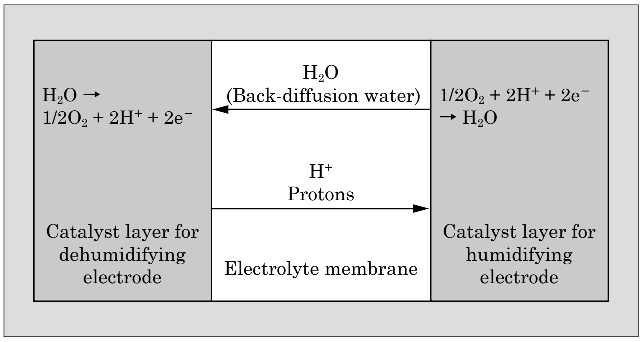

Fig.5 Schematic diagram of water movement in the element

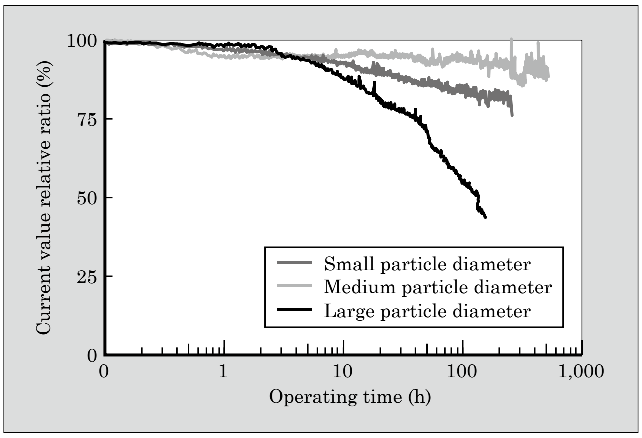

Fig.6 Durability test result

formance of the element requires two factors to be optimally controlled: Ensuring the electrolytic current value and suppressing the back-diffusion. Based on these study results, we optimized the electrolyte membrane thickness and catalyst layer to develop an element that can achieve the specified target value with less power consumption.

3.2 Durability performance-enhancing technology

Elements mounted on food distribution equipment need durability so that they stably maintain their functionality for a long period of time. For fuel cells, which have a similar structure, aggregation of the electrode catalyst is one of the important degradation modes. We thus studied the durability of the developed element. We looked at the initial particle diameter of the catalyst and built elements by using catalysts having three different particle diameters, small, medium and large. We then conducted an accelerated durability test on each element for 1,000 hours under an elevated temperature environment.

As shown in Fig. 6, we found that the initial particle diameter greatly affected the durability performance and there was an optimal particle diameter. By clearly specifying the control range of the initial particle diameter, we now can stably build elements that satisfy the required durability.

4. Effect Verification

4.1 Effect verification through mounting on counter fixture

We mounted the developed element on a counter fixture and verified the effect. The fixture had specifications of a capacity of 50 liters and cooling function (two settings of 10 °C or less and 18 °C). Use at room temperature was assumed. We selected sandwiches and stuffed rolls for the products to be stored and evaluated the influence of humidity changes inside the case on those sandwiches and stuffed rolls that were exhibited in an unwrapped state. Table 1 shows the details of the test conditions.

Table 1 Test conditions for effect verification

Item	Condition
Fixture capacity	50 L
Cooling unit	Off (room temperature)
Outside air environment	25°C, 50%RH
Product	Sandwiches and stuffed rolls
Measurement timing	Immediately after opening
	After 12 hours
	After 24 hours
Measured items	Mass
	External appearance inspection
	Sensory evaluation

We placed the counter fixture in a constant temperature and humidity bath set at 25 °C and 50%RH and stored sandwiches and stuffed rolls inside the case. When the element was not activated, the humidity naturally stayed at 50%. After 12 hours of storage, the mass of the products in the fixture reduced by 2%. After 24 hours of storage, the reduction in mass doubled to 4%. We found there was a tendency for moisture to decrease and the products to get dry over time.

We then activated the element to maintain the humidity inside the counter fixture at 80%. The decrease in mass was 1% after 12 hours and 2% after 24 hours. As shown in Fig. 7, we found that keeping a high humidity inside the fixture was an effective way to reduce the drying out of the products.

Next, we conducted a simple sensory test by actually eating the samples. Ten Fuji Electric male design engineers in their 20s to 50s were selected as evaluators. After eating the samples, they answered a questionnaire asking if they thought it would be worthwhile to buy the products without telling them the condition of each sample (see Table 2). The figures in the table show those evaluators who answered “I don’t think I would buy it” after evaluating the texture and taste of the samples they ate.

As a result, it can be considered that a reduction in mass of 2% is the limit in terms of product value and product value would be lost if the mass decreased by 4%. This indicates that sandwiches and stuffed rolls

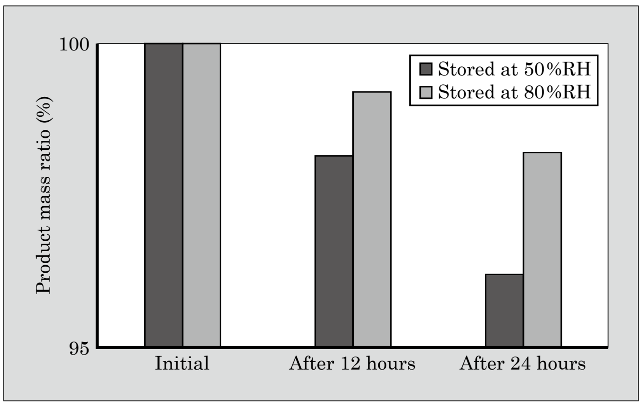

Fig.7 Mass change rate

Table 2 Sensory test questionnaire result

	Storage period	Mass change rate	Number of answers*
Initial state	—	—	0/10
Storage at 50% humidity	12 hours	−2%	5/10
	24 hours	−4%	9/10
Storage at 80% humidity	12 hours	−1%	1/10
	24 hours	−2%	4/10

* Number of evaluators who answered "I don't think I would buy it" / Number of evaluators

will need to be discarded after approximately 12 hours in a storage environment of 50% humidity, whereas the products can be stored with product value maintained up to 24 hours when the humidity is kept at 80%.

4.2 Verification of changes in texture due to storage conditions

As described above, we found that food preservation is greatly affected by the parameter of humidity as well as temperature. To confirm the influence of the storage environment on food, we studied the texture of sweet rolls and fried chicken to examine the parameter of humidity.

We used a constant temperature and humidity bath and prepared food samples by storing them for a certain period of time at a constant temperature while changing the parameter of humidity. We conducted a sensory evaluation to evaluate the texture of the food. For the evaluation, we set texture terms to indicate contrary textures: "crusty" and "fluffy" for sweet rolls, and "crispy" and "tender" for fried chicken. Evaluators made a judgment by using the rating scale method based on JIS Z 9080. Figure 8 shows the evaluation result.

As for the sweet rolls shown in Fig. 8(a), samples were stored at three levels of humidity for 6 hours in a 28 °C environment. After the verification, we confirmed there was a tendency for the contradictory textures of "crusty" and "fluffy" to swap over when the humidity changed from low to high. This indicates that controlling humidity allows food to be preserved while keeping a specific texture.

As for the fried chicken shown in Fig. 8(b), samples were stored at three levels of humidity for 6 hours in a 60 °C environment. We verified the contradictory texture strengths, "crispy" and "tender." Unlike the case of the sweet rolls, we confirmed the same decreasing tendency even for the contradictory textures while the humidity changed from low to high. The tendency varies depending on the composition or moisture content of the food. In terms of food preservation, each food has its appropriate humidity condition and it is important to determine it.

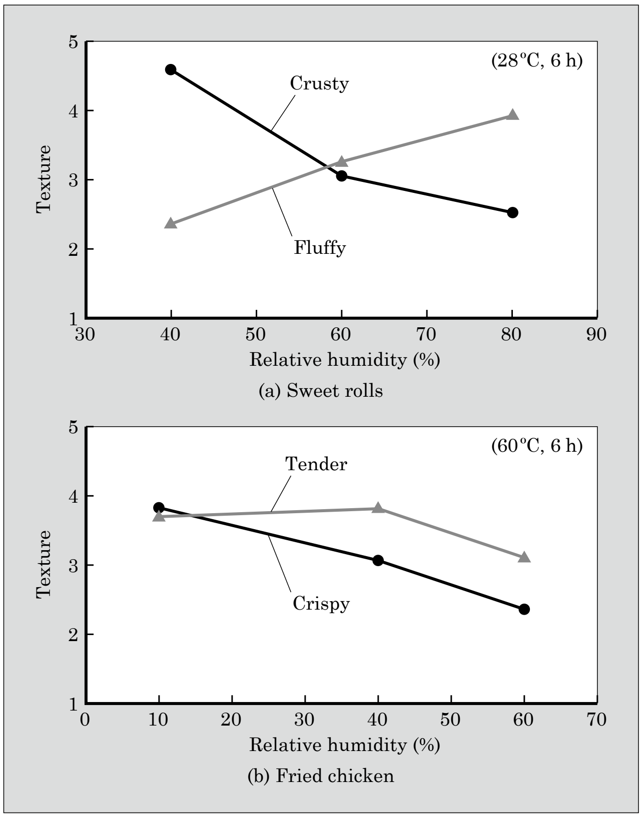

Fig.8 Taste evaluation by sensory test

We found that, by changing the storage humidity in accordance with the product concept, we can store food while maintaining the product value such as the texture to be emphasized.

We are still continuing our verification in these sensory evaluations and trying to accumulate data concerning the environmental factors required for the preservation of each food and to improve the evaluation technology.

5. Postscript

This paper described a technology for keeping food freshness with humidity control. Controlling the humidity makes it possible to extend the storage period while maintaining product value. This offers an advantage of extending sales opportunities at stores while increasing expectations for the effect of reducing food loss. Humidity control without using water can also greatly decrease the risk of fatality in the food industry due to factors such as bacteria and fungi.

As a manufacturer of food distribution equipment, Fuji Electric will continue to develop ways to improve food preservation environments and help to overcome the challenge of reducing food loss.