Featured Articles

Development of the “Vacuum Compartment” Series of Large-capacity Refrigerators
—Adding Photocatalyst Preservation for Vegetable Compartment to Environmentally Conscious Features—

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OVERVIEW: Refrigerators consume the most electrical energy in the home, and the need for improved energy savings is great. With the rise of health consciousness, more attention is being focused on vegetables, leading to higher demand for refrigerator functions that preserve vegetable freshness. The new “Vacuum Compartment” series released by Hitachi in FY2014 improved the unique “Frost Recycle Cooling” technology developed in FY2009 and increased its energy-saving performance. Furthermore, the newly developed “Photocatalyst Preservation for Vegetable Compartment” function helps keep vegetables fresh while advances in the unique “Vacuum Compartment” function inhibit the oxidation of food items, thereby slowing the loss of nutrients and satisfying the consumer’s need for preserved freshness.

INTRODUCTION

ACCORDING to data from the Agency for Natural Resources and Energy, electric refrigerators consume more power than any other device in the home (approximately 14%*1). Consumers are paying close attention to the shift toward energy-saving in refrigerators, and Hitachi has been developing its own unique energy-saving technologies over the years as this trend has grown in importance. These technologies are being highly praised, and the products released in FY2013 were awarded the FY2013 Grand Prize for Excellence in Energy Efficiency and Conservation (Product Category & Business Model Category, Reviewer’s Prize)*2. Furthermore, technologies originally developed for large-capacity refrigerators (see Fig. 1) were incorporated into medium-capacity refrigerators in FY2014 products, and Hitachi continues to lead the industry in the promotion of energy-saving capabilities.

Because the increasing number of small-family households and the aging of the population are changing the structure of demand, Hitachi conducted a survey regarding consumer priorities when purchasing refrigerators by household size and age range to help inform considerations of how to respond to these changes. The survey results indicated that regardless of household size and age range, many consumers give priority to the basic performance of a refrigerator, including high capacity and energy savings, as well as preserving vegetable freshness.

In particular, although it was hypothesized that the need for capacity would be reduced due to the shift

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*1 Based on “Breakdown of Energy Consumption by Device in the Home” from the 2009 Civilian Sector Energy Consumption Survey conducted by the Agency for Natural Resources and Energy (in Japanese).

*2 Award-winning models: “Vacuum Compartment FS” refrigerator series model R-G6700D and others, including 11 models total.

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Fig. 1—Large-capacity Refrigerator (R-X6700E).
In spite of its high capacity (rated capacity: 670 L), annual power consumption is only 200 kWh/year (JIS C 9801-2006).
toward smaller households requiring less storage space, in actuality the survey results indicated that the demand for large-capacity refrigerators remains as strong as ever. Also, due to a high level of health consciousness, preserving vegetable freshness is a high priority among both seniors and members of the child-raising generation (see Fig. 2).

To satisfy the high-priority need for preserving vegetable freshness, Hitachi took the unique “Photocatalyst Preservation” technology used to preserve food items stored in the “Vacuum Compartment” and applied it to the vegetable compartment as well.

The unique, highly praised “Vacuum Compartment” function has been used to successfully improve food item preservation performance even further by utilizing an antioxidant and a pungent component described hereinafter in combination with “Photocatalyst Preservation” technology to achieve a synergistic effect.

Hitachi will continue working to apply these advanced food preservation technologies to the development of products that satisfy consumer needs while inhibiting the loss of freshness and reducing food waste.

**ENERGY-SAVING TECHNOLOGY**

The increase of storing capacity and the improvement of energy-saving performance, both of which are major consumer needs, presents key technological challenges in the development of products.

Fig. 3 shows how annual power consumption has changed among the refrigerators Hitachi has released each year that have the largest rated capacity. The annual energy consumption of its FY2014 product (200 kWh/year) was reduced by approximately 71% compared to its FY2005 product (690 kWh/year), while rated capacity increased from 535 L to 670 L. These improvements in refrigerator energy-saving performance were achieved by using vacuum insulation panels to reduce the amount of heat conduction through the insulation walls, and by reducing input energy through the use of high-efficiency compressors. Furthermore, Hitachi also began applying energy-saving technology to its products by incorporating a view of system-wide optimization starting in FY2009.

One example of system-wide optimization technology is Hitachi’s unique “Frost Recycle Cooling” technology, which takes advantage of the frost that forms on the evaporator to help cool the refrigerator and vegetable compartments while the compressor is stopped. In the past, frost on the evaporator would be merely periodically defrosted with a heater to melt it, and then discarded it because it deteriorates the evaporator’s performance. Starting with the FY2009 products, however, “Frost Recycle Cooling” has been applied to save energy by focusing...
the cooling potential of the frost and diverting it for use in cooling the compartments of the refrigerator (see Fig. 4)(1).

A new “Hybrid Defrosting System”, which evolved from “Frost Recycle Cooling”, was also developed for use in products released in FY2014.

The defrosting operation based on the Hybrid Defrosting System first runs a fan, then it cools the refrigerator compartment with the frost that forms on the evaporator, thereby increasing the temperature of the frost (fan defrosting). Next, a glass tube heater and a cord heater directly attached to the cooler are both used to heat the evaporator (dual heater defrosting). This system makes it possible to efficiently increase the temperature of the evaporator during defrosting so that energy consumption can be reduced (see Fig. 5).

DEVELOPMENT OF VEGETABLE/CHILLED ROOM HIGH-FRESHNESS PRESERVATION TECHNOLOGY

To satisfy the need for “preserving vegetable freshness,” which is a high priority for both the senior generation and child-raising generation due to health consciousness, Hitachi adopted unique “Photocatalyst Preservation” technology in FY2014 for use in the vegetable compartment to preserve vegetables by putting them in to a dormant state. Hitachi also worked to improve freshness preservation technology with its unique “Vacuum Compartment.”

Photocatalyst Preservation Technology

Controlled atmosphere (CA) preservation (2) is a commercial preservation technology used to store fruits, vegetables, and other such products long-term in an extremely airtight refrigerating chamber with a gas composition adjusted to have a higher concentration of carbon dioxide (CO₂) and a lower concentration of oxygen than the outside air. Hitachi turned to CA while developing its “Photocatalyst Preservation” technology for adoption starting in FY2012, whereby Hitachi’s unique “Vacuum Compartment” system uses “Photocatalyst Preservation” to break down the ethylene gas and odor components that emanate from food items into water and CO₂ using a light-emitting diode (LED) and photocatalyst.

Furthermore, in FY2014, a “Photocatalyst Preservation Space for Vegetables” was included that adopted the “Photocatalyst Preservation” function was included with an improved sealing in back of the lower case in the vegetable compartment.

Structure of Photocatalyst Preservation Space for Vegetables

The “Photocatalyst Preservation Space for Vegetables” was achieved through the application of the following three technologies:

1. CO₂ generation

By placing the photocatalyst on the left side of the lower vegetable container, and the LED light source on the opposite surface of the photocatalyst, the ethylene gas and odor components that emanate from vegetables come into contact with the photocatalyst and CO₂ is generated as a gas and components are broken down by the light. Furthermore, the CO₂ concentration around the vegetables increases due to vegetable respiration, which in turn suppresses this respiration (see Fig. 6).

2. Condensation control and a high-humidity environment
The strong seal maintains the high CO₂ concentration, while preserving moisture in the space, resulting in a high-humidity environment. However, this sealing also causes the moisture from the vegetables to condense and stick to the walls of the compartment. A “moisture unit” is used to evaporate this condensation outside the back of the lower case using cooling air, thereby achieving a high-humidity environment while controlling condensation (see Fig. 7).

(3) Strong sealing

The “lock lever” on the front of the upper case is locked in order to tighten the seal within the “Photocatalyst Preservation Space for Vegetables”, which makes up the area between the upper and lower cases, thereby suppressing the leakage of CO₂ and moisture from within this space (see Fig. 7).

Preservative Effect of the Photocatalyst Preservation for Vegetable Compartment

The same amounts and types of vegetables were stored in a conventional vegetable compartment and in a “Photocatalyst Preservation Space for Vegetables” for 7 days, and changes in weights were used to compute and compare residual moisture ratios. The results showed differences of approximately 13% for bok choy and approximately 4% for Japanese mustard spinach, indicating that drying had been inhibited. In this way, the “Photocatalyst Preservation for Vegetable Compartment” technology maintains the firmness and juiciness of vegetables, which is apparent in the external appearance of the vegetables (see Fig. 8). Similarly, when the nutritional content in the vegetables was compared after preservation, the loss of vegetable nutrients was reduced by approximately 17% for vitamin C in bok choy, by approximately 21% for vitamin C in broccoli, and by approximately 3% for vitamin B₁ in podded peas, providing evidence that vegetable nutrients are protected (see Fig. 9).

The strong seal maintains the high CO₂ concentration, while preserving moisture in the space, resulting in a high-humidity environment.
Improving Preservation Performance in the Vacuum Compartment

The highly praised "Vacuum Compartment" is a unique function that uses "Vacuum Preservation" and "Photocatalyst Preservation" technologies to suppress the oxidation of food items, while utilizing an antioxidant and a pungent component in the antioxidant cartridge for a synergistic effect that improves food preservation performance even further. When the interior of the “Vacuum Compartment” is decompressed, the antioxidant cartridge emits an antioxidant component (vitamin E), commonly added to butter and other food items along with a pungent component (allyl isothiocyanate), which is contained in food items such as wasabi (see Fig. 10). The suction of the air in the “Vacuum Compartment” lowers the air pressure outside the aluminum external cover enclosing the antioxidants and pungent components, thereby causing the external cover to swell. The external cover then shrinks once the pressure in the compartment stabilizes, and the antioxidants and pungent components are emitted through pulpwood and into the interior of the compartment (see Fig. 11).

This causes the antioxidant component to be oxidized instead of the nutrients in the food items. Oxidation in the food items is suppressed because the pungent component suppresses the action of enzymes while preventing protein degradation.
When this method is compared with preservation in the refrigerator compartment, the K value\(^3\), which is used to represent freshness, is suppressed by approximately 4.9% for chicken breast meat, and in the case of docosahexaenoic acid (DHA), a nutrient contained in mackerel, increased by approximately 57% (see Fig. 12).

**USABILITY IMPROVEMENT TECHNOLOGY**

In response to the increase in food storage space provided by higher-capacity refrigerators, Hitachi has been working on developing technology to improve usability so that doors can be opened and closed easily even when the refrigerator is full of food.

The drawers used for the freezer and vegetable compartments require a great deal of force in the initial action to open them. Hitachi developed its own unique power-assisted drawers and started implementing them in products in FY2006 to reduce this burden.

The user lightly presses a button on the front of the power-assisted drawer to activate a power-assisted drawer, which then pushes out the drawer. Furthermore, consideration is given to how using the function feels to the consumer by ensuring that the drawer opens at the same speed regardless of how much food is in the refrigerator (see Fig. 13).

The storage capacity of the pockets in the refrigerator compartment doors is also increasing along with the shift to higher capacities. In response, Hitachi developed power-assisted doors for refrigerator compartments with motorized opening mechanisms for use in refrigerator compartment doors on both the left and right sides, and included them in the FY2013 version of its products.

The motorized opening mechanism pushes the door open when the user lightly touches the operating part of the refrigerator compartment’s power-assisted door, located on the door’s glass surface, thereby activating the refrigerator compartment power-assisted door unit mounted on the ceiling of the refrigerator. Both left and right doors can also be opened with a single operation by touching the operating part and sliding the finger. This functionality supports needs such as inserting large food items into the refrigerator,
A variety of design considerations have been implemented to ensure that not only can the drawer be easily and comfortably opened, they can also be used safely.

CONCLUSIONS

This article discussed energy-saving technologies for refrigerators, preservation technologies including “Photocatalyst Preservation for Vegetable Compartment” and the “Vacuum Compartment,” as well as the Power-assisted drawer and the power-assisted door for refrigerator compartment functions, which improve the usability of large-capacity refrigerators.

Hitachi will continue to develop unique technologies with the goal of creating industry-leading products that earn the consumer’s satisfaction.

REFERENCES


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