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 cosumer’s need for preserved freshenss.

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]). Comsumers 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 comsumer 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 comsumers 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

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).

*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.

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

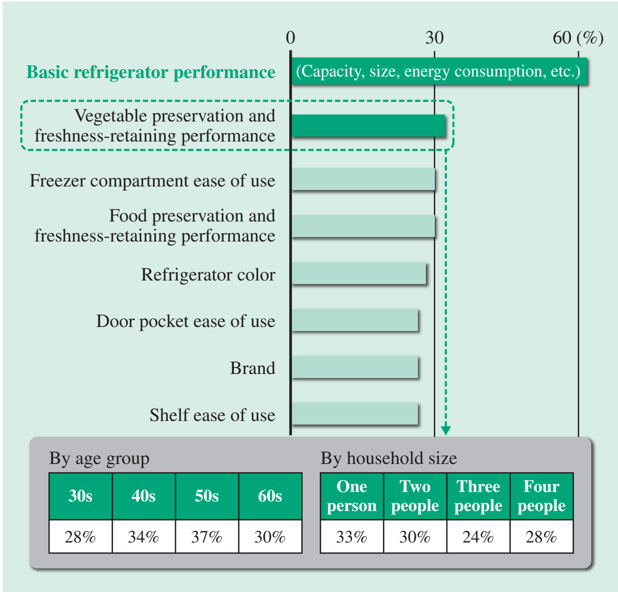


Fig. 2—Priorities in Purchasing (Multiple Responses) (Research by Hitachi in December 2013, Users of 401 L or Larger Refrigerators: n=418).
Vegetable preservation and freshness-retaining performance are given priority regardless of age or household size.

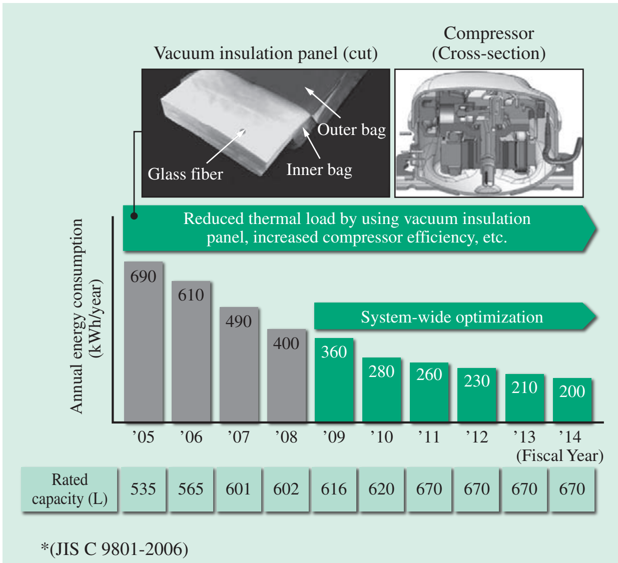


Fig. 3—History of Annual Power Consumption in Hitachi Refrigerators and Energy-saving Technologies.
Hitachi has achieved both high capacity and energy-savings through the use of unique energy-saving technologies.

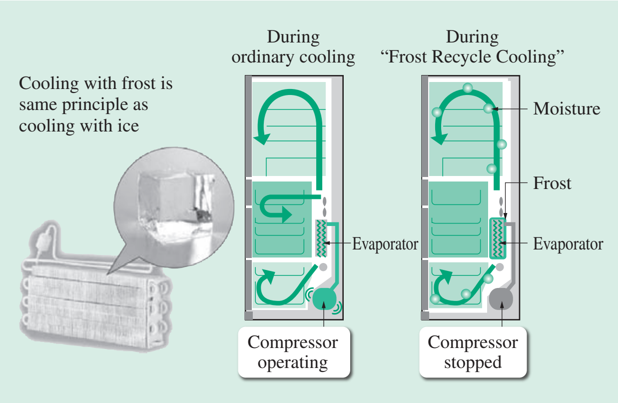


Fig. 4—"Frost Recycle Cooling."
Frost that forms on the evaporator is used to cool the refrigerator and vegetable compartments to save energy.

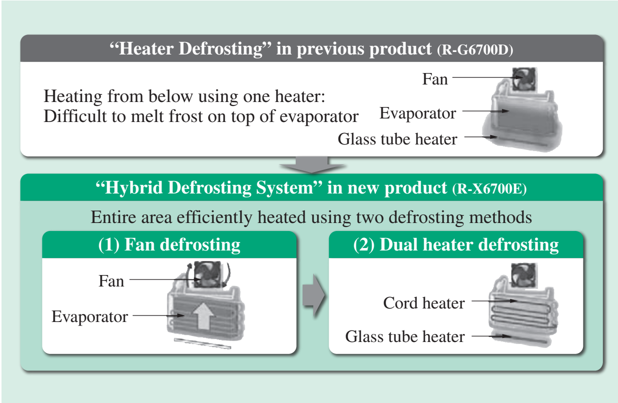


Fig. 5—"Hybrid Defrosting System."
Efficient defrosting is implemented through the use of two methods: "Fan Defrosting" and "Dual Heater Defrosting."

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 (CO_2) 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 CO_2 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) CO_2 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 CO_2 is generated as a gas and components are broken down by the light. Furthermore, the CO_2 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

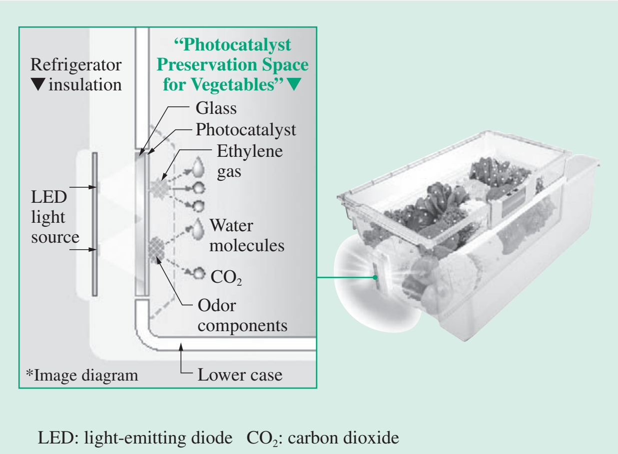


Fig. 6—CO_2 Generation Principle Used in “Photocatalyst Preservation Space for Vegetables.”
An LED light source and a photocatalyst are used to break down ethylene gas and odor components, thereby generating CO_2.

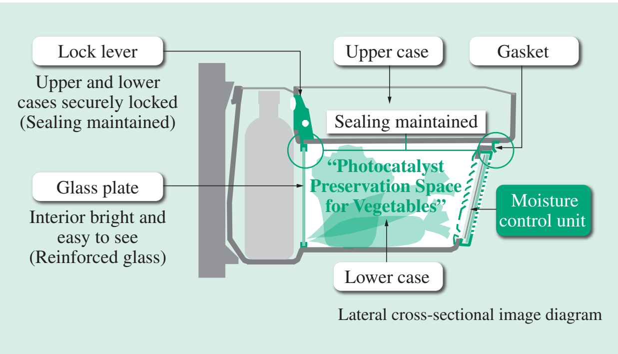


Fig. 7—Structure of Vegetable Compartment.
The seal is tightened using a “lock handle” and a “glass divider,” and condensation is suppressed using a “moisture unit,” achieving a high-humidity environment.

The strong seal maintains the high CO_2 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 CO_2 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 B_1 in podded peas, providing evidence that vegetable nutrients are protected (see Fig. 9).

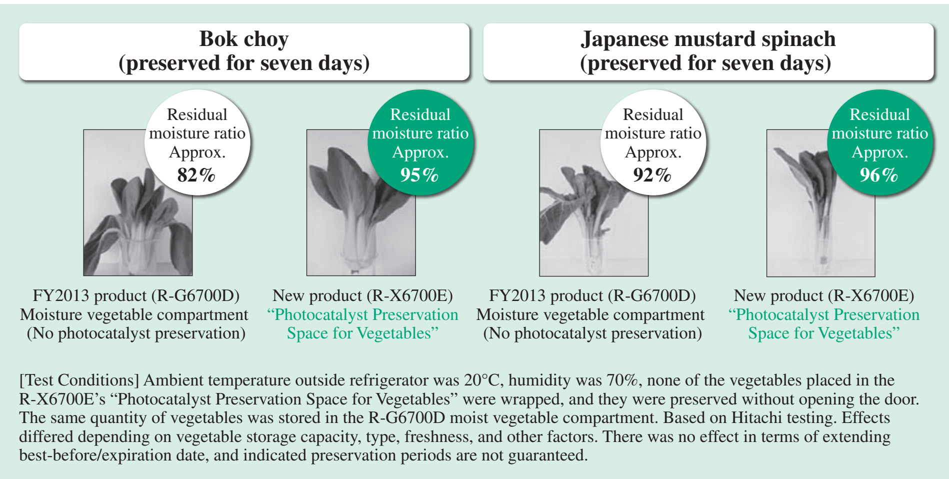
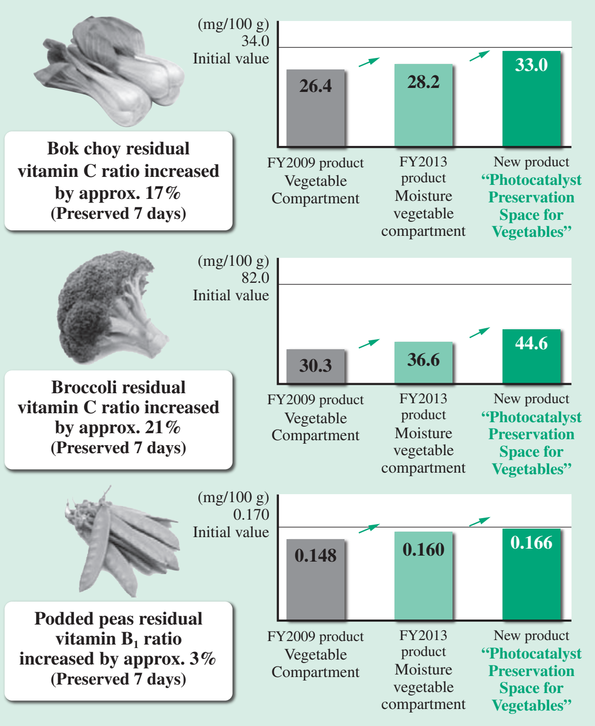


Fig. 8—Effect of “Photocatalyst Preservation Space for Vegetables” (Comparison of Exterior Appearance and Residual Moisture Ratio).
Drying is inhibited through “Photocatalyst Preservation for Vegetables” technology, and the firmness and juiciness of vegetables is maintained.



[Test Conditions] Ambient temperature outside refrigerator was 20°C, humidity was 70%, none of the vegetables placed in the R-X6700E's "Photocatalyst Preservation Space for Vegetables" were wrapped, and they were preserved without opening or closing the door. The same quantity of vegetables was stored in the R-G6700D moist vegetable compartment. Residual ratios were compared between the new R-X6700E product's "Photocatalyst Preservation Space for Vegetable," the previous year's R-G6700D product with moist vegetable compartment (without photocatalyst preservation, and with moisture preservation), and there was no nutrient increase or similar effect with respect to initial values. Graphs show a comparison between the new R-X6700E product's "Photocatalyst Preservation Space for Vegetables," the previous year's R-G6700D product with moist vegetable compartment (without photocatalyst preservation, and with moisture preservation), and the R-Z6200 product from five years ago with vegetable compartment (without photocatalyst preservation, and without moist preservation). Based on Hitachi testing.

Fig. 9—Effect of the "Photocatalyst Preservation Space for Vegetables" (Nutrient Comparison).
In addition to the residual moisture ratio, vitamin C, and other nutrients were also protected.

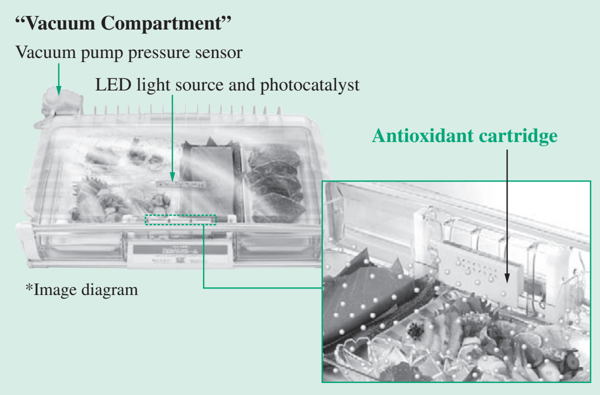


Fig. 10—Antioxidant Cartridge
An antioxidant and a pungent component are utilized in the antioxidant cartridge in order to improve preservation performance.

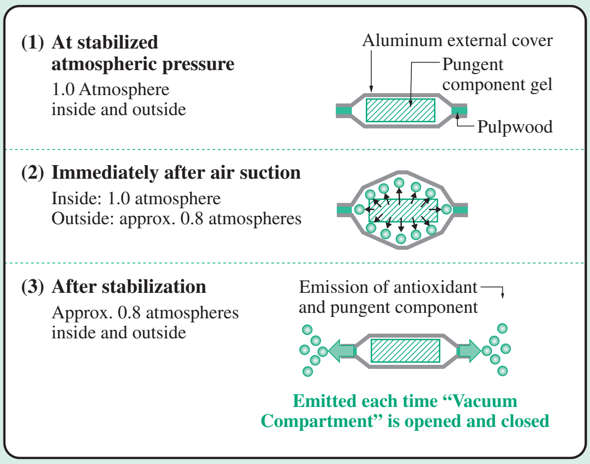
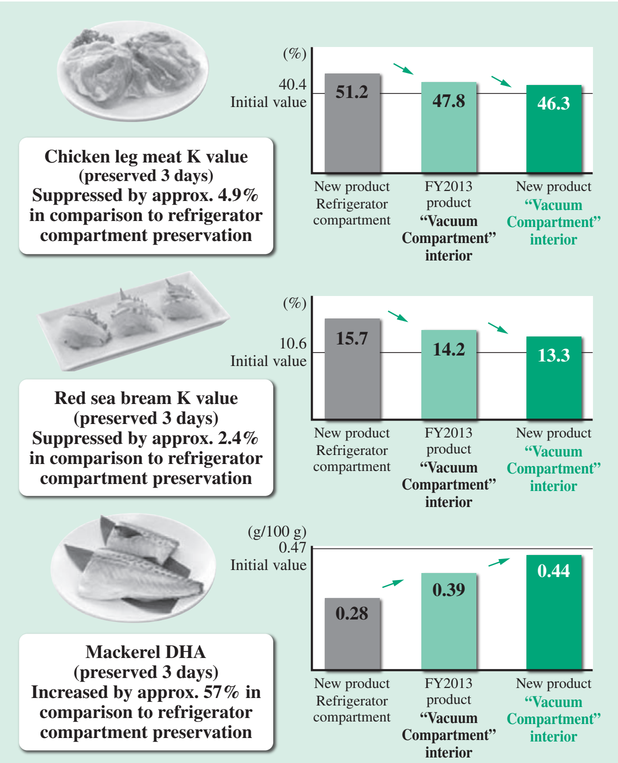


Fig. 11—Antioxidant and Pungent Component Emission Principle.
Vacuum suction in the "Vacuum Compartment" is used to emit the antioxidant and pungent component.

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.



Comparison between refrigerator compartment in new R-X6700E product, “Vacuum Compartment” interior (set to the lower temperature mode), and “Vacuum Compartment” interior of previous year’s RG6700D product (set to the lower ice temperature mode). Ambient temperature outside refrigerator was 20°C, polyvinyl chloride wrapping was used, door was not opened or closed, and food items were preserved for 3 days. Based on Hitachi testing.
Since polyvinyl chloride wrap is permeable to moisture and gas, use/non-use of wrap does not affect vacuum preservation or photocatalyst preservation. Effects differ depending on food ingredient type, freshness, and other factors. There was no effect in terms of extending best-before/expiration date, and indicated preservation periods are not guaranteed.

DHA: docosahexaenoic acid

Fig. 12—“Vacuum Compartment” and Refrigerator Compartment Preservation Performance Comparison.
Nutrient loss in food items is suppressed through preservation in “Vacuum Compartment.”

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).

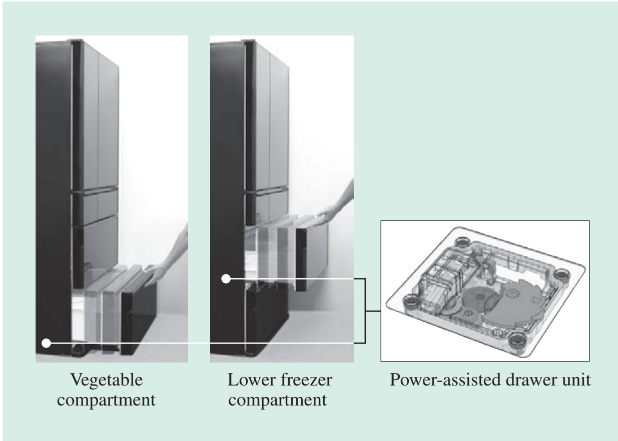


Fig. 13—Power-assisted Drawer and Power-assisted Drawer Unit.
A motorized opening mechanism was used to reduce the burden of opening and closing each drawer due to the shift towards high capacity.

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,

*3 K value is an index that represents freshness, and is based on the ratios (%) of inosine and hypoxanthine, which are the final by-products of adenosine triphosphate with respect to the total amount of adenosine triphosphate-associated compounds. The lower the K value, the better the freshness level.

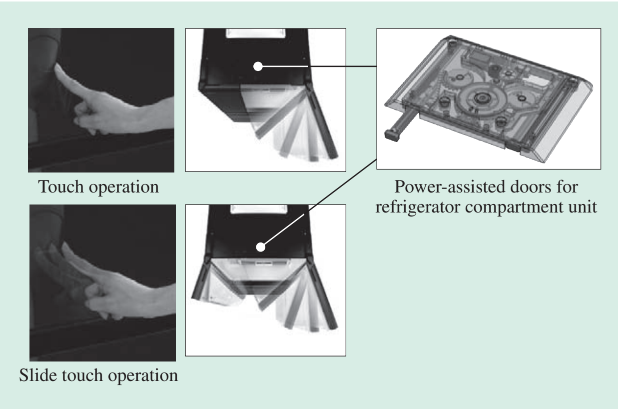


Fig. 14—Power-assisted Doors for Refrigerator Compartment and Power-assisted Doors for Refrigerator Compartment Unit.
A motorized opening mechanism is also used for the refrigerator compartment doors, and the door can be easily opened by just touching the door glass surface.

or verifying the contents of both door pockets (see Fig. 14).

Furthermore, for the sake of safety, when the user inserts a hand or accidentally touches the door over a wide area, such as with the palm of the hand or the elbow, the door does not open (the door only opens when touched with fingertips or otherwise over a small area). The design also incorporates considerations that prevent the user's hand from getting stuck in the door.

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.

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