

DESCRIPTION

Title of Invention

REFRIGERATOR

Technical Field

5 [0001]

The present invention relates to a refrigerator having a function of supercooling a cooling target object.

Background Art

[0002]

10 Typically, when food is stored in a refrigerator while the quality thereof is maintained, the food is desirably maintained in an unfrozen state at a possible lowest temperature. Some proposed methods achieve such storage by storing the food in a supercooled state. The supercooled state refers to a state in which the food has not started freezing or is in an unfrozen state at a temperature equal to or lower than the
15 freezing point thereof. However, when the food is stored at a temperature equal to or lower than the freezing point (for example, 0 degrees C), the supercooled state is potentially canceled due to impact or some causes, and ice crystals are generated in the food. Then, as the food is left to stand while the supercooled state is canceled, the freezing of the food proceeds, and the quality of the food degrades due to cell
20 damage through the freezing.

[0003]

To avoid such a problem, some disclosed methods periodically change temperature to melt ice crystals generated due to cancellation of the supercooled state. For example, Patent Literature 1 discloses a refrigerator configured to, when
25 activation and stop of a cooling unit with temperature setting for a refrigeration operation are repeated at least once after a supercooling operation start the supercooling operation of supercooling food again. In the refrigerator of Patent Literature 1, when the food starts freezing by the supercooling operation, the refrigeration operation is performed at a setting temperature higher than the setting
30 temperature of the supercooling operation, thereby preventing complete freezing of

the food.

[0004]

Patent Literature 2 discloses a refrigerator configured to repeatedly perform a low temperature process of setting a preset compartment temperature to be lower than the freezing point of food, and a temperature increasing process of setting the preset compartment temperature to be higher than the freezing point. In the refrigerator of Patent Literature 2, when the supercooled state of the food is canceled in the low temperature process and the food has started freezing with generation of ice crystals in the food, the ice crystals generated at the supercooling cancellation can be melted by starting the temperature increasing process at a predetermined timing. The supercooled state can be achieved thereafter by performing the low temperature process again, thereby stably maintaining the supercooled state of the food.

[0005]

Like the refrigerator disclosed in Patent Literature 3, a vegetable compartment, which is frequently used, is desirably disposed below a refrigerator compartment disposed in an upper region of the refrigerator, thereby allowing a user to take out vegetables or the like while standing. When the vegetable compartment is provided in a lower region of the refrigerator, the user needs to bend lower to take out vegetables, which causes a large load when a heavy vegetable is taken out, and degrades usability. Thus, the vegetable compartment is adjacent to a supercooling controlled region when the function of supercooling a cooling target object, which is disclosed in Patent Literatures 1 and 2, is additionally provided in a lower part of the refrigerator compartment in the refrigerator of Patent Literature 3.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Patent No. 4647047

Patent Literature 2: Japanese Patent No. 4948562

Patent Literature 3: Japanese Unexamined Patent Application Publication No.

2000-186883

Summary of Invention

Technical Problem

5 [0007]

In the refrigerator of Patent Literature 1, the refrigeration operation is performed in a duration in which a cycle of the normal refrigeration operation is repeated at least once, and no consideration is made to a duration in which the supercooling operation is performed and the relation between heat amounts at both operations. Thus, for example, when the duration in which the refrigeration operation is performed is too short as compared to the duration in which the supercooling operation is performed, ice crystals in food cannot be sufficiently melted, and freezing of the food proceeds. When the duration in which the refrigeration operation is performed is too long as compared to the duration in which the supercooling operation is performed, the average temperature of food over a duration in which the food is stored increases, which potentially leads to degradation of the quality of the food.

[0008]

In the refrigerator of Patent Literature 2, for example, the duration of the low temperature process is set to completely melt ice crystals generated in the low temperature process. Specifically, in the refrigerator of Patent Literature 2, the duration of the low temperature process is set so that latent heat Q_1 radiated when water changes to ice, latent heat Q_2 taken away from water through the progress of freezing, and heat Q_3 provided to ice through the progress of defrosting satisfy the relation of $Q_3 \geq Q_1 + Q_2$. Accordingly, ice crystals generated in the low temperature process can be completely melt, but the duration of the temperature increasing process becomes longer, and as a result, the average temperature of food over a duration in which the food is stored is higher than the freezing temperature, which potentially leads to quality degradation.

[0009]

30 In the refrigerator of Patent Literature 3, when the function of supercooling a

cooling target object is additionally provided in the lower part of the refrigerator compartment, the vegetable compartment is adjacent to the supercooling controlled region and thus potentially cooled too much. Thus, in this refrigerator, a heat insulation structure needs to be formed between the supercooling controlled region and the vegetable compartment by using an appropriate heat insulation material, which adds a structural restriction.

[0010]

The present invention is intended to overcome the above-described problem and provide a refrigerator capable of maintaining a cooling target object in a state equivalent to a supercooled state and decreasing the average temperature of the cooling target object over a duration in which the cooling target object is stored, thereby preventing completion of freezing of the cooling target object without adversely affecting the cooling target object.

Solution to Problem

[0011]

A refrigerator according to an embodiment of the present invention includes: a heat insulation box having a storage space therein, the storage space being partitioned into a plurality of storage compartments by a partition member; a low-temperature compartment provided as one of the storage compartments and configured to store a cooling target object at a temperature equal to or lower than a freezing point of the cooling target object without freezing the cooling target object; a cooling device configured to cool the storage space; and a controller configured to control the cooling device to repeatedly perform a first process of decreasing a compartment temperature of the low-temperature compartment, to a first temperature lower than the freezing point of the cooling target object, from a second temperature higher than the freezing point in a duration set in advance, and a second process of increasing the compartment temperature from the first temperature to the second temperature and maintaining the second temperature for a duration set in advance. The controller performs control so that a time integral value of a difference between the freezing point and the compartment temperature of the low-temperature

compartment while the compartment temperature of the low-temperature compartment is lower than the freezing point balances with a time integral value of the difference between the freezing point and the compartment temperature of the low-temperature compartment while the compartment temperature of the low-temperature compartment is higher than the freezing point.

Advantageous Effects of Invention

[0012]

In the refrigerator according to an embodiment of the present invention, since control is performed so that the time integral value of the difference between the freezing point and the compartment temperature of the low-temperature compartment when the compartment temperature of the low-temperature compartment is lower than the freezing point balances with the time integral value of the difference between the freezing point and the compartment temperature of the low-temperature compartment when the compartment temperature of the low-temperature compartment is higher than the freezing point, a duration in which freezing of the cooling target object is recognized and heat amount can balance with each other between the first process and the second process. Accordingly, the refrigerator according to the embodiment of the present invention can maintain the cooling target object in a state equivalent to a supercooled state and decrease the average temperature of the cooling target object over a duration in which the cooling target object is stored, thereby preventing completion of freezing of the cooling target object without adversely affecting the cooling target object.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a front view schematically illustrating appearance of a refrigerator according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is an internal configuration diagram schematically illustrating an internal configuration of the refrigerator according to the embodiment of the present invention.

[Fig. 3] Fig. 3 is an internal configuration diagram schematically illustrating an

internal configuration of a refrigerator compartment of the refrigerator according to the embodiment of the present invention.

[Fig. 4] Fig. 4 is a block diagram illustrating a control configuration of the refrigerator according to the embodiment of the present invention.

5 [Fig. 5] Fig. 5 is a functional block diagram related to temperature control of a low-temperature compartment by a controller in the refrigerator according to the embodiment of the present invention.

[Fig. 6] Fig. 6 is a graph illustrating temporal change of the setting temperature and compartment temperature of the low-temperature compartment when the
10 temperature control is performed in the refrigerator according to the embodiment of the present invention.

[Fig. 7] Fig. 7 is a flowchart illustrating temperature control processing on the low-temperature compartment in the refrigerator according to the embodiment of the present invention.

15 [Fig. 8] Fig. 8 is a graph illustrating temporal change of the setting temperature and compartment temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, a heat amount q_1 radiated from the cooling target object, and a heat amount q_2 supplied to the cooling target object.

20 [Fig. 9] Fig. 9 is a graph illustrating, when a low-temperature setting temperature θ_L is set to be -3 degrees C, the relation between a duration (freezing duration) in which freezing of the cooling target object has proceeded after supercooling cancellation, and a break peak number when the cooling target object is cut.

25 [Fig. 10] Fig. 10 illustrates temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, and is a graph illustrating an example in which supercooling of the cooling target object is not canceled.

30 [Fig. 11] Fig. 11 illustrates temporal change of the setting temperature,

compartment temperature, and food temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, and is a graph illustrating an example in which supercooling of the cooling target object is canceled.

5 [Fig. 12] Fig. 12 illustrates temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment when temperature control is performed in a comparative example, and is a graph illustrating an example in which a temperature increasing process duration is set so that the heat amount $q_1 >$ the heat amount q_2 is satisfied.

10 [Fig. 13] Fig. 13 illustrates temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment when the temperature control is performed in the comparative example, and is a graph illustrating an example in which the temperature increasing process duration is set so that the heat amount $q_1 <$ the heat amount q_2 is satisfied.

15 Description of Embodiments
 [0014]

 The following describes an embodiment of the present invention with reference to the accompanying drawings. Parts same as or equivalent to each other in the drawings are denoted by a same reference sign, and duplicate description thereof will
20 be omitted or simplified as appropriate. The shapes, sizes, disposition, and the like of components illustrated in the drawings may be changed as appropriate within the scope of the present invention. The positional relation (such as upper-lower relation) between components in the specification is that when a refrigerator 1 is installed in a usable state, in principle.

25 [0015]

Embodiment

 Fig. 1 is a front view schematically illustrating external appearance of a refrigerator according to the embodiment of the present invention. Fig. 2 is an internal configuration diagram schematically illustrating an internal configuration of the
30 refrigerator according to the embodiment of the present invention. Fig. 3 is an

internal configuration diagram schematically illustrating an internal configuration of a refrigerator compartment of the refrigerator according to the embodiment of the present invention. Fig. 4 is a block diagram illustrating a control configuration of the refrigerator according to the embodiment of the present invention. The dimensional relation, shapes, and the like of components in the following drawings including Figs. 1 to 4 are different from those in reality in some cases. The positional relation (such as upper-lower relation) between components in the specification is that when the refrigerator 1 is installed in a usable state, in principle.

[0016]

(Configuration of refrigerator 1)

As illustrated in Figs. 1 and 2, the refrigerator 1 includes a heat insulation box 90 that has an opening in the front and in which a storage space is formed. Although not illustrated in detail, the heat insulation box 90 includes a steel outer box, a resin inner box, and a heat insulation material filling a space between the outer box and the inner box. However, no heat insulation material exists between a refrigerator compartment 100 and a vegetable compartment 200. The storage space formed inside the heat insulation box 90 is partitioned, by a plurality of partition members 50, into a plurality of storage compartments in each of which a cooling target object such as food is stored. As illustrated in Figs. 1 and 2, the refrigerator 1 of the present embodiment includes, as the plurality of storage compartments, the refrigerator compartment 100 disposed at an uppermost part, the vegetable compartment 200 disposed below the refrigerator compartment 100, and a freezer compartment 300 disposed at a lowermost part. In a structure in which the vegetable compartment 200 is disposed below the refrigerator compartment 100, the kind and number of storage compartments included in the refrigerator 1 are not limited to these described above.

[0017]

A pivotable door 8 is provided at an opening formed at a front surface of the refrigerator compartment 100 to open and close the opening. The door 8 of the refrigerator 1 of the present embodiment is a single swing door. As illustrated in Fig.

3, the refrigerator compartment 100 includes a built-in input panel 6. As illustrated in Fig. 4, the input panel 6 includes an input unit 61 for adjusting, for example, the setting temperature of each storage compartment, and a display unit 62 configured to display, for example, the temperature of each storage compartment and information on stock in the storage compartment. The input unit 61 includes, for example, an operation switch. The display unit 62 includes, for example, a liquid crystal display. The input panel 6 may be a touch panel in which the input unit 61 is integrated into the display unit 62.

[0018]

As illustrated in Fig. 2, the vegetable compartment 200 and the freezer compartment 300 are opened and closed through drawer doors 80 and 81, respectively. These drawer doors 80 and 81 can be each opened and closed in the depth direction (front-back direction) of the refrigerator 1 when a frame fixed to the door slides on rails horizontally formed in right and left inner wall surfaces of the corresponding storage compartment. The vegetable compartment 200 stores, in a drawable manner, a housing case 201 in which a cooling target object can be housed. The housing case 201 is supported by the frame of the door, and slides in the front-back direction along with opening and closing of the door. Similarly, the freezer compartment 300 stores, in a drawable manner, a housing case 301 in which food and the like can be housed. One housing case 201 is provided to one storage compartment and one housing case 301 is provided to another storage compartment, but two or more housing cases may be provided for each storage compartment when, for example, a housing characteristic and organization easiness are improved with the entire capacity of the refrigerator 1 taken into consideration.

[0019]

A compressor 2, a cooler (evaporator) 3, an air-sending fan 4, and an air path 5 are provided on the back side of the refrigerator 1, and serve as a cooling device 19 configured to supply cool air to each storage compartment. The compressor 2 and the cooler 3 together with a condenser (not illustrated) and an expansion device (not illustrated) are included in a refrigeration cycle, and generate cool air supplied to each

storage compartment. The cool air generated by the compressor 2 and the cooler 3 is sent to the air path 5 by the air-sending fan 4 and supplied from the air path 5 to the freezer compartment 300 and the refrigerator compartment 100 through a damper. The vegetable compartment 200 is supplied and cooled with returning cool air from the refrigerator compartment 100 through a refrigerator-compartment returning air path (not illustrated). The cool air supplied to the vegetable compartment 200 is returned to the cooler 3 through a vegetable-compartment returning air path (not illustrated).

[0020]

As illustrated in Fig. 3, the refrigerator compartment 100 includes a door pocket 10 provided on the compartment inner side of the door 8, and shelves 11 dividing the refrigerator compartment 100 into a plurality of spaces. The numbers of door pockets 10 and shelves 11 are not limited to those illustrated in Fig. 3, but any numbers, equal to or larger than one, of door pockets 10 and shelves 11 may be provided. A lower part of the refrigerator compartment 100 is divided into upper and lower parts: the upper part includes a chilled compartment 12 maintained at a temperature equal to or higher than 0 degrees C; and the lower part includes a low-temperature compartment 13 as a supercooling controlled region in which a cooling target object is stored at a temperature equal to or lower than the freezing point of the cooling target object without freezing the cooling target object.

[0021]

As illustrated in Fig. 3, the air path 5 on the back side of the refrigerator compartment 100 is divided into an air path 5a through which cool air is sent to the refrigerator compartment 100 and the chilled compartment 12, and an air path 5b through which cool air is sent to the low-temperature compartment 13. A damper 16 is provided at air path 5a, and a damper 17 is provided at the air path 5b. The damper 16 and the damper 17 are used to adjust the air volume of cool air supplied to the refrigerator compartment 100 and the low-temperature compartment 13. A temperature sensor 14 is provided on the back portion of the refrigerator compartment 100 to detect temperature in the refrigerator compartment 100, and a

temperature sensor 15 is provided on the back portion of the low-temperature compartment 13 to detect temperature in the low-temperature compartment 13. The temperature sensor 14 and the temperature sensor 15 are, for example, thermistors.

[0022]

5 A heater 18 as a heating unit is disposed on the front side of a lower region of the low-temperature compartment 13 to perform supercooling control or increase the compartment temperature of the vegetable compartment 200. Specifically, in the refrigerator 1, a partition plate 40 is provided in parallel with the partition members 50 between the low-temperature compartment 13 and the vegetable compartment 200
10 positioned below the low-temperature compartment 13. The heater 18 is provided in a region surrounded by the partition plate 40 and the partition members 50. To increase the heat generation density of the heater 18, the region surrounded by the partition plate 40 and the partition members 50 is partitioned, by a rib region 20 made of one or a plurality of ribs protruding from the partition plate 40 or the partition
15 members 50, into a heater area in which the heater 18 is disposed and a still air region 30. The number of spaces into which the surrounded region is partitioned by the rib region 20 are not limited to the above-described two regions, but may be three regions or more.

[0023]

20 A controller 7 configured to control operation of the refrigerator 1 is provided at an upper part of the refrigerator compartment 100. The controller 7 may include a computing device such as a microcomputer or a CPU, and software executed thereon. The controller 7 may comprise hardware such as a circuit device configured to achieve the function thereof.

25 [0024]

 As illustrated in Fig. 4, the controller 7 receives input of detection signals from temperature sensors configured to detect the temperature of each of storage compartments, including the temperature sensors 14 and 15, and an operation signal from the input unit 61 of the input panel 6. The controller 7 controls, based on each
30 input signal, the cooling device 19 and the heater 18 in accordance with an operation

program stored in advance so that insides of the refrigerator compartment 100, the chilled compartment 12, the low-temperature compartment 13, the freezer compartment 300, and the vegetable compartment 200 are maintained at respective setting temperatures set therefor. The cooling device 19 includes, for example, the compressor 2, the air-sending fan 4, and dampers such as the dampers 16 and 17 disposed in the storage compartments. The controller 7 controls the output of the compressor 2, the air-sending volume of the air-sending fan 4, and the opening degree of each damper. The controller 7 controls the display unit 62 of the input panel 6 based on each input signal to output the temperature of each storage compartment, and a display signal related to information on stock in the storage compartment.

[0025]

(Temperature control of low-temperature compartment 13)

The following describes temperature control of the low-temperature compartment 13 in the present embodiment. Fig. 5 is a functional block diagram related to temperature control of the low-temperature compartment by the controller of the refrigerator according to the embodiment of the present invention. As illustrated in Fig. 5, the controller 7 includes a time measurement unit 71 configured to measure time, a counter 72 configured to count a count value, a process transition unit 73, a temperature setting unit 74, a comparison unit 75, a control unit 76, and a storage unit 77. Each of the above-described components is achieved as a software functional component by the CPU that constitutes the controller 7 executing a computer program, or is achieved by an electronic circuit such as a DSP, an application specific IC (ASIC), or a programmable logic device (PLD).

[0026]

The process transition unit 73 performs process transition based on the time measured by the time measurement unit 71 and the count value counted by the counter 72. The temperature setting unit 74 sets a setting temperature θ_s of the low-temperature compartment 13 in accordance with a process transitioned by the process transition unit 73. The comparison unit 75 compares the setting

temperature θ_s set by the temperature setting unit 74 with a compartment temperature θ detected by the temperature sensor 15 of the low-temperature compartment 13, and outputs a result of the comparison to the control unit 76. The control unit 76 controls the compressor 2, the air-sending fan 4, and the damper 17 based on the result of the comparison by the comparison unit 75 so that the compartment temperature θ detected by the temperature sensor 15 becomes equal to the setting temperature θ_s . The storage unit 77 includes, for example, a non-volatile semiconductor memory, and stores various kinds of data and an operation program used for the temperature control.

[0027]

The following describes the temperature control of the low-temperature compartment 13 by the controller 7 in detail with reference to Fig. 6. Fig. 6 is a graph illustrating temporal change of the setting temperature and compartment temperature of the low-temperature compartment when temperature control is performed in the refrigerator according to the embodiment of the present invention. As illustrated in Fig. 6, a cycle including a low temperature process and a temperature increasing process is repeated in the temperature control of the low-temperature compartment 13. Specifically, the process transition unit 73 transitions to the temperature increasing process when a low temperature process duration ΔTL has elapsed since the start of the low temperature process. Then, the process transition unit 73 transitions to the low temperature process again when a temperature increasing process duration ΔTH has elapsed since the start of the temperature increasing process. The low temperature process duration ΔTL and the temperature increasing process duration ΔTH are determined for each refrigerator by a method to be described later, and stored in the storage unit 77. The low temperature process corresponds to a "first process" of the present invention, and the temperature increasing process corresponds to a "second process" of the present invention. The low temperature process duration ΔTL corresponds to a "first duration" of the present invention, and the temperature increasing process duration ΔTH corresponds to a "second duration" of the present invention.

[0028]

In the low temperature process, the temperature setting unit 74 sets the setting temperature θ_s to be a low-temperature setting temperature θ_L , and the control unit 76 decreases the temperature in the low-temperature compartment 13 to the low-temperature setting temperature θ_L . The low-temperature setting temperature θ_L is lower than a freezing point θ_f (for example, 0 degrees C) of a cooling target object housed in the low-temperature compartment 13, and is, for example, -4 degrees C to -2 degrees C. In the temperature increasing process, the temperature setting unit 74 sets the setting temperature θ_s to be a temperature increasing setting temperature θ_H , and the control unit 76 increases the temperature in the low-temperature compartment 13 to the temperature increasing setting temperature θ_H . The temperature increasing setting temperature θ_H is higher than the freezing point θ_f of the cooling target object housed in the low-temperature compartment 13, and is, for example, 1 degree C to 2 degrees C. The low-temperature setting temperature θ_L and the temperature increasing setting temperature θ_H have the relation of $\theta_H > \theta_L$, and are stored in the storage unit 77 in advance. The low-temperature setting temperature θ_L and the temperature increasing setting temperature θ_H may be changed or set by a user through the input unit 61. The low-temperature setting temperature θ_L corresponds to a "first temperature" of the present invention, and the temperature increasing setting temperature θ_H corresponds to a "second temperature" of the present invention.

[0029]

The low temperature process includes an introduction process and a low temperature maintaining process. As illustrated in Fig. 6, in the introduction process, the temperature setting unit 74 gradually decreases the setting temperature θ_s in each time set in advance. The stages are counted by the counter 72. The process transition unit 73 transitions to the low temperature maintaining process when the count value counted by the counter 72 becomes equal to a target value. This target value is predetermined so that the setting temperature θ_s reaches the low-temperature setting temperature θ_L at a time $TL1$. In the low temperature

maintaining process, the temperature setting unit 74 sets the setting temperature θ_s to be the low-temperature setting temperature θ_L , and the control unit 76 decreases the temperature in the low-temperature compartment 13 to the low-temperature setting temperature θ_L . Through the low temperature process as described above, the cooling target object in the low-temperature compartment 13 becomes a supercooled state in which the cooling target object is not frozen at a temperature equal to or lower than the freezing point θ_f . Then, when a time T_L is reached, in other words, when the low temperature process duration ΔT_L has elapsed since the start of the low temperature process, the process transition unit 73 ends the low temperature process, and transitions to the temperature increasing process.

[0030]

In the temperature increasing process, the temperature setting unit 74 sets the setting temperature θ_s of the low-temperature compartment 13 to be the temperature increasing setting temperature θ_H , and the control unit 76 increases the temperature of the low-temperature compartment 13 to the temperature increasing setting temperature θ_H . Specifically, the control unit 76 closes the damper 17 to stop cool air flowing into the low-temperature compartment 13, thereby increasing the compartment temperature of the low-temperature compartment 13. Alternatively, the compartment temperature of the low-temperature compartment 13 may be increased by operating the air-sending fan 4 while the compressor 2 is stopped and opening the damper 17 to circulate air in the refrigerator 1. Alternatively, the temperature may be instantaneously increased by using the heater 18. Then, when a time T_H is reached, in other words, when the temperature increasing process duration ΔT_H has elapsed since the start of the temperature increasing process, the process transition unit 73 ends the temperature increasing process, and transitions to the low temperature process.

[0031]

Fig. 7 is a flowchart illustrating temperature control processing on the low-temperature compartment in the refrigerator according to the embodiment of the present invention. The following describes the temperature control processing on

the low-temperature compartment in the refrigerator of the embodiment with reference to Figs. 1 to 7. The present processing is started when the refrigerator 1 is turned on or when processing start is selected through the input panel 6. First, the controller 7 detects the compartment temperature θ of the low-temperature compartment 13 by the temperature sensor 15, and determines whether the detected compartment temperature θ is equal to or higher than the temperature increasing setting temperature θ_H (S101). Then, when the compartment temperature θ is lower than the temperature increasing setting temperature θ_H (NO at S101), the process proceeds to step S112 and the temperature increasing process is started. When the compartment temperature θ is equal to or higher than the temperature increasing setting temperature θ_H (YES at S101), the low temperature process is started. Then, the time measurement unit 71 resets an elapsed time T and starts measuring the elapsed time T (S102).

[0032]

In the low temperature process, the introduction process is performed first. In the introduction process, the temperature setting unit 74 sets the setting temperature θ_s to be $\theta_H - \Delta\theta$ (S103). Then, a count value i counted by the counter 72 is set to be zero (S104). The time measurement unit 71 resets an elapsed time t and starts measuring the elapsed time t (S105). In this example, the setting temperature θ_s of the low-temperature compartment 13 is set to be lower than the temperature increasing setting temperature θ_H by $\Delta\theta$ (for example, 0.3 degrees C), and stage counting and measurement of the elapsed time t at each stage in the introduction process are started.

[0033]

Subsequently, the temperature setting unit 74 determines whether the elapsed time t is equal to or larger than Δt (S106). The value Δt is the duration of each stage in the introduction process, and for example, 20 minutes. Then, when the elapsed time t is smaller than Δt (S106: NO), the setting temperature θ_s set at step S103 is maintained until the elapsed time t becomes equal to or larger than Δt . When the

elapsed time t is equal to or larger than Δt (YES at S106), the setting temperature θ_s is set to be $\theta_s - \Delta\theta$ (S107), and the count value i is incremented by one (S108).

[0034]

Subsequently, the process transition unit 73 determines whether the count value i is equal to or larger than n (S109). The value n indicates the number of stages in the introduction process, and is, for example, 12. When the count value i is smaller than n (NO at S109), the process returns to step S105 to repeat the processing of the loop. Accordingly, the setting temperature θ_s of the low-temperature compartment 13 is decreased stepwise by $\Delta\theta$ in each time Δt set in advance, and the compartment temperature θ is decreased to the setting temperature θ_s .

[0035]

When the count value i is equal to or larger than n (YES at S109), the process transition unit 73 transitions the process to the low temperature maintaining process. Then, the temperature setting unit 74 sets the setting temperature θ_s to be the low-temperature setting temperature θ_L (S110). Subsequently, it is determined whether the elapsed time T since the start of the low temperature process is equal to or longer than ΔTL (S111). Then, when the elapsed time T is shorter than the low temperature process duration ΔTL (NO at S111), the setting temperature θ_s (i.e., the low-temperature setting temperature θ_L) set at step S110 is maintained until the elapsed time T becomes equal to or longer than the low temperature process duration ΔTL . When the elapsed time T is equal to or longer than the low temperature process duration ΔTL (YES at S111), the process proceeds to step S112, and the temperature increasing process is started.

[0036]

In the temperature increasing process, the time measurement unit 71 resets the elapsed time T and starts measuring the elapsed time T again (S112). Then, the temperature setting unit 74 sets the setting temperature θ_s of the low-temperature compartment 13 to be the temperature increasing setting temperature θ_H (S113).

Subsequently, the process transition unit 73 determines whether the elapsed time T is

equal to or longer than the temperature increasing process duration ΔT_H (S114).

Then, when the elapsed time T is shorter than the temperature increasing process duration ΔT_H (NO at S114), the setting temperature θ_s (in other words, the temperature increasing setting temperature θ_H) set at step S113 is maintained until the elapsed time T becomes equal to or longer than the temperature increasing process duration ΔT_H . When the elapsed time T is equal to or longer than the temperature increasing process duration ΔT_H (YES at S114), the temperature increasing process is ended, and the process returns to step S102 to start the low temperature process again.

[0037]

In the low temperature process, the cooling target object housed in the low-temperature compartment 13 is in the supercooled state in which the cooling target object is not frozen at a temperature equal to or lower than the freezing point θ_f , but the supercooled state is unstable in terms of energy. Thus, the supercooled state is potentially canceled, for example, when abrupt temperature change has occurred in the low-temperature compartment 13 due to impact of, for example, opening and closing of the door 8 or some causes. When the supercooled state of the cooling target object is canceled, minute ice crystals start to be substantially uniformly generated inside the cooling target object, and freezing of the cooling target object starts. However, the above-described transition to the temperature increasing process when the low temperature process duration ΔT_L has elapsed since the start of the low temperature process can prevent the progress and completion of the freezing, and avoid damage on tissues, cells, and the like of the cooling target object due to the ice crystals. The transition to the low temperature process when the temperature increasing process duration ΔT_H has elapsed since the start of the temperature increasing process can reduce degradation of the quality of the cooling target object.

[0038]

However, the quality of the cooling target object is potentially degraded depending on the lengths of the low temperature process duration ΔT_L and the

temperature increasing process duration ΔT_H . For example, when the temperature increasing process duration ΔT_H is too short as compared to the low temperature process duration ΔT_L , ice crystals in the cooling target object cannot be sufficiently melted, and the freezing of the cooling target object proceeds. When the temperature increasing process duration ΔT_H is too long as compared to the low temperature process duration ΔT_L , the average temperature of the cooling target object over a duration in which the cooling target object is stored potentially becomes higher than the freezing point θ_f , which leads to degradation of the quality of the cooling target object. To avoid these phenomena, in the present embodiment, the low temperature process duration ΔT_L and the temperature increasing process duration ΔT_H are set in consideration of balance between a duration in which freezing of the cooling target object is recognized and a heat amount.

[0039]

The following describes the setting of the low temperature process duration ΔT_L and the temperature increasing process duration ΔT_H in the present embodiment with reference to Figs. 8 and 9. Fig. 8 is a graph illustrating temporal change of the setting temperature and compartment temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, a heat amount q_1 radiated from the cooling target object, and a heat amount q_2 supplied to the cooling target object. Fig. 9 is a graph illustrating, when the low-temperature setting temperature θ_L is set to be -3 degrees C, the relation between a duration (freezing duration) in which freezing proceeds after supercooling of the cooling target object is canceled, and a break peak number when the cooling target object is cut.

[0040]

(Setting of low temperature process duration ΔT_L)

The low temperature process duration ΔT_L is set to satisfy the following conditions obtained by a simple experiment. First, the speed of cooling in the introduction process is set to be such a value that the cooling target object such as food can become the supercooled state. For example, it has been found by

experiment that the cooling target object becomes the supercooled state at a significantly high probability when a cooling duration for each 1 degree C is set to be 35 minutes or longer while the low-temperature setting temperature θ_L is set to be -3 degrees C. Thus, the speed of cooling in the introduction process is arbitrarily set so that such a condition is satisfied. Accordingly, a duration ΔT_{f1} until the freezing point θ_f of the cooling target object is reached since the start of the low temperature process, in other words, since the start of the introduction process, and a time $TL1$ until the introduction process ends are determined as illustrated in Fig. 8. The low temperature process duration ΔTL is set so that the time $TL1 < \text{the time } TL$ is satisfied.

[0041]

The low temperature process duration ΔTL needs to be set to be equal to or shorter than a duration until freezing of the cooling target object is recognized. The reason why the low temperature process duration ΔTL is set to be equal to or shorter than the duration until the freezing is recognized will be described below with reference to Fig. 9.

[0042]

As freezing proceeds after supercooling is canceled, generation and growth of ice crystals proceed in the cooling target object, and the touch feeling of food as the cooling target object changes. Examples of change with which a person recognizes that the cooling target object is frozen include the hardness of the cooling target object when touched, and crunchy feeling of ice particles when broken at cutting of the cooling target object. However, it has been found by experiment that the touch feeling of the cooling target object hardly changes during several hours after supercooling is canceled because generated ice crystals are minute in a small amount. The break peak number illustrated in Fig. 9 is the number of local maxima in a temporal change waveform of a cutting load from the start to the end of cutting, and represents the crunchy feeling of ice particles when broken. In Fig. 9, the deviation of the break peak number is illustrated on a graph for each freezing duration. As illustrated in Fig. 9, the break peak number has almost no change

between an unfrozen state (the freezing duration is zero) and a state after six hours have elapsed since the start of freezing. In other words, when six hours have elapsed since the start of freezing, the touch feeling of the cooling target object has hardly changed from that in the unfrozen state, and thus it is not recognized that the cooling target object is frozen. Fig. 9 indicates that eight hours is the boundary between the unfrozen state (the freezing duration is zero) and a state in which it is recognized that the cooling target object is frozen. Thus, when the low temperature process duration ΔTL is set to be equal to or shorter than eight hours (for example, 300 minutes), transition to the temperature increasing process can be performed before freezing of the cooling target object is recognized. Hereinafter, a duration until freezing of the cooling target object is recognized is referred to as an "allowable freezing duration". The value of "eight hours" is merely an example, and the allowable freezing duration varies in accordance with the refrigerator and the low-temperature setting temperature θ_L .

[0043]

(Setting of temperature increasing process duration ΔTH)

Fig. 9 also indicates that a state substantially equivalent to the unfrozen state can be maintained by returning to a state right after or within several hours after the supercooling is canceled without melting all generated ice crystals. Thus, generated ice crystals do not need to be reliably melted in the temperature increasing process when the low temperature process duration ΔTL is set to be equal to or shorter than the allowable freezing duration (for example, eight hours) until freezing of the cooling target object is recognized. However, to prevent the freezing from further proceeding, the heat amount needs to be balanced between the low temperature process and the temperature increasing process. Thus, the temperature increasing process duration ΔTH is set so that the heat amounts can be balanced between the low temperature process and the temperature increasing process.

[0044]

In the low temperature process illustrated in Fig. 8, T_{f1} represents a time at which the compartment temperature $\theta(T)$ detected by the temperature sensor 15

reaches the freezing point θ_f of the cooling target object. In the temperature increasing process, T_{f2} represents a time at which the compartment temperature $\theta(T)$ reaches the freezing point θ_f of the cooling target object. In the low temperature process in the next cycle, T_{f3} represents a time at which the compartment temperature $\theta(T)$ reaches the freezing point θ_f of the cooling target object. In addition, ΔT_{f2} represents a duration until the compartment temperature $\theta(T)$ reaches the freezing point θ_f of the cooling target object after the start of the temperature increasing process. In addition, ΔT_{f1} represents a duration until the compartment temperature $\theta(T)$ reaches the freezing point θ_f of the cooling target object after the start of the low temperature process in the next period.

[0045]

In addition, q_1 represents a heat amount radiated from the cooling target object having a temperature constant at the freezing point θ_f for a duration ΔT_1 in which the compartment temperature $\theta(T)$ is lower than the freezing point θ_f , in other words, in the duration of $T_{f2} - T_{f1}$. In addition, q_2 represents a heat amount supplied to the cooling target object having a temperature constant at the freezing point θ_f in a duration ΔT_2 in which the compartment temperature $\theta(T)$ is higher than the freezing point θ_f , in other words, in the duration of $T_{f3} - T_{f2}$. The heat amount q_1 corresponds to area of a hatched part in Fig. 8, which is enclosed by θ_f between T_{f1} and T_{f2} and the compartment temperature $\theta(T)$, and is given by Expression (1) below. In other words, the heat amount q_1 is the time integral value of the difference between the freezing point θ_f and the compartment temperature $\theta(T)$ over a duration in which the compartment temperature $\theta(T)$ is lower than the freezing point θ_f . The heat amount q_2 corresponds to area of the hatched part in Fig. 8, which is enclosed by θ_f between T_{f2} and T_{f3} and the compartment temperature $\theta(T)$, and is given by Expression (2) below. In other words, the heat amount q_2 is the time integral value of the difference between the compartment temperature $\theta(T)$ and the freezing point θ_f over a duration in which the compartment temperature $\theta(T)$ is higher than the freezing point θ_f . The heat amount q_1 corresponds to a "first heat amount" of the present

invention, and the heat amount q_2 corresponds to a "second heat amount" of the present invention.

[0046]

[Expression 1]

$$q_1 = \int_{Tf1}^{Tf2} (\theta_f - \theta(T)) dT \quad \cdot \cdot \cdot \cdot (1)$$

[0047]

[Expression 2]

$$q_2 = \int_{Tf2}^{Tf3} (\theta(T) - \theta_f) dT \quad \cdot \cdot \cdot \cdot (2)$$

[0048]

In the present embodiment, the temperature increasing process duration ΔT_H is set so that the heat amount q_1 and the heat amount q_2 balance with each other. Specifically, the temperature increasing process duration ΔT_H is set so that the heat amount q_1 and the heat amount q_2 are equal to each other, in other words, the heat amount $q_1 =$ the heat amount q_2 is satisfied. The state in which the heat amount q_1 and the heat amount q_2 are equal to each other not only includes a state in which the heat amount q_1 and the heat amount q_2 are precisely identical to each other, but also includes a state in which the heat amount q_1 and the heat amount q_2 are not identical to each other but balance with each other. Specifically, the relation of the heat amount $q_1 \leq$ the heat amount $q_2 \leq$ the heat amount $q_1 \times 1.05$ is desirable when the quality of food storage is taken into consideration. Since the low temperature process duration ΔT_L is set to be equal to or smaller than the allowable freezing duration as described above, ice crystals in the cooling target object do not need to be reliably melted as in conventional techniques, and thus the temperature increasing process duration ΔT_H is shorter than that in a conventional case in which ice crystals in the cooling target object are reliably melted.

[0049]

The temperature increasing process duration ΔT_H can be determined from the low temperature process duration ΔT_L as described below. First, a duration ΔT_{f2}

until the compartment temperature $\theta(T)$ reaches the freezing point θ_f after the start of the temperature increasing process, and a time $Tf2$ can be determined from a temperature increasing speed. The temperature increasing speed is determined by experiment. Subsequently, the heat amount $q1$ expressed by Expression (1) is expressed by an approximate expression such as Expression (3) below based on the area of the hatched part in Fig. 8. The heat amount $q2$ expressed by Expression (2) is expressed by an approximate expression such as Expression (4) below based on the area of the hatched part in Fig. 8. The temperature increasing process duration ΔTH is calculated from Expressions (3) and (4) so that the heat amount $q1 =$ the heat amount $q2$ is satisfied. The temperature increasing process duration ΔTH is, for example, 240 minutes.

[0050]

[Expression 3]

$$\begin{aligned} q1 &\approx \{\Delta T1 + (Tf2 - TL1)\} \times (\theta_f - \theta_L) \times \frac{1}{2} \\ &= \{(\Delta TL - \Delta Tf1 + Tf2) + (Tf2 - TL1)\} \times (\theta_f - \theta_L) \times \frac{1}{2} \quad \dots \dots (3) \end{aligned}$$

[0051]

[Expression 4]

$$\begin{aligned} q2 &\approx \{\Delta T2 + (TH - Tf2)\} \times (\theta_H - \theta_f) \times \frac{1}{2} \\ &= \{(\Delta TH - \Delta Tf2 + Tf1) + (\Delta TH - \Delta Tf2)\} \times (\theta_H - \theta_f) \times \frac{1}{2} \quad \dots \dots (4) \end{aligned}$$

[0052]

As described above, in the present embodiment, the low temperature process duration ΔTL is set to be equal to or shorter than the allowable freezing duration while the time $TL1 <$ the time TL is satisfied. The temperature increasing process duration ΔTH is set based on the low temperature process duration ΔTL , the heat amount $q1$, and the heat amount $q2$ so that the heat amount $q1$ and the heat amount $q2$ balance with each other.

[0053]

(Temperature transition of cooling target object)

The following describes temperature transition of the cooling target object (for example, food) when the temperature control of the present embodiment is performed. Fig. 10 illustrates temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, and is a graph illustrating an example in which supercooling of the cooling target object is not canceled. Fig. 11 illustrates temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment when the temperature control is performed in the refrigerator according to the embodiment of the present invention, and is a graph illustrating an example in which supercooling of the cooling target object is canceled.

[0054]

First, as illustrated in Fig. 10, when supercooling of food is not canceled, the food temperature continuously changes from the low-temperature setting temperature θ_L to the temperature increasing setting temperature θ_H , similarly to change of the compartment temperature of the low-temperature compartment 13, slightly after the change of the compartment temperature. Accordingly, the food in the low-temperature compartment 13 can repeatedly return to the supercooled state in the low temperature process.

[0055]

As illustrated in Fig. 11, when supercooling is canceled at a time T_f at which the food temperature becomes equal to or lower than the freezing point θ_f , minute ice crystals are generated in the food, and freezing starts. Then, minute ice crystals inside the food start melting when the setting temperature θ_s of the low-temperature compartment 13 is switched to the temperature increasing setting temperature θ_H at the time T_L . Then, at the time T_H when the temperature increasing process ends, the food returns to a state equivalent to the unfrozen state. In a period following a

period in which the supercooled state has developed, the food does not become the supercooled state but starts freezing and becomes a phase transition state at a time T_{f1} when the temperature of the food becomes equal to or lower than the freezing point θ_f .

5 [0056]

In this state, since the temperature increasing process duration ΔTH is set so that the heat amount $q_1 =$ the heat amount q_2 is satisfied in the present embodiment, the heat amount q_1 for proceeding freezing is equal to the heat amount q_2 for melting ice crystals. In addition, the low temperature process duration ΔTL is set to be equal to or shorter than the allowable freezing duration. Thus, the refrigerator 1 can return the food to a state equivalent to that right after supercooling is canceled, in other words, at the time T_{f1} and right after the start of freezing, at the time TH_2 when the temperature increasing process ends.

[0057]

15 Figs. 12 and 13 are graphs illustrating temporal change of the setting temperature, compartment temperature, and food temperature of the low-temperature compartment 13 when the temperature control is performed in a comparative example. Fig. 12 illustrates an example in which the temperature increasing process duration ΔTH is set so that the heat amount $q_1 >$ the heat amount q_2 is satisfied.

20 Fig. 13 illustrates an example in which the temperature increasing process duration ΔTH is set so that the heat amount $q_1 <$ the heat amount q_2 is satisfied.

[0058]

As illustrated in Fig. 12, when the temperature increasing process duration ΔTH is set so that the heat amount $q_1 >$ the heat amount q_2 , ice crystals generated in the supercooled state grow and freezing proceeds through each cycle, and the freezing is eventually completed. Specifically, at the time T_f when the temperature of the food becomes equal to or lower than the freezing point θ_f , supercooling of the food is canceled, and freezing starts with generation of minute ice crystals. Then, at the time TL , the setting temperature θ_s of the low-temperature compartment 13 is switched to the temperature increasing setting temperature θ_H to start melting of the

minute ice crystals in the food. When the duration from the time T_f to the time T_L is short, the food is returned to a state equivalent to the unfrozen state at the time T_H when the temperature increasing process ends.

[0059]

In a cycle following a cycle in which supercooling cancellation is developed, the food does not become the supercooled state but starts freezing and becomes a phase transition state at the time T_{f1} when the temperature of the food becomes equal to or lower than the freezing point θ_f . At this time, since the temperature increasing process duration ΔT_H is set so that the heat amount $q_1 >$ the heat amount q_2 is satisfied, the heat amount q_1 for proceeding freezing becomes larger than the heat amount q_2 for melting ice crystals. Thus, the freezing of the food proceeds and is eventually completed. Thus, when the temperature increasing process duration ΔT_H is set so that the heat amount $q_1 >$ the heat amount q_2 is satisfied, it is difficult to prevent proceeding of the freezing of the food subjected to supercooling cancellation.

[0060]

Fig. 13 illustrates a case in which the temperature increasing process duration ΔT_H is set so that the heat amount $q_1 <$ the heat amount q_2 is satisfied. More specifically, a case in which the temperature increasing process duration ΔT_H is set so that, for example, $q_0 + q_1 \leq q_2$ is satisfied in consideration of a heat amount q_0 radiated from the cooling target object such as food when supercooling is canceled. The heat amount q_0 corresponds to a third heat amount of the present embodiment, and is given by, for example, Expression (5) below. In the expression, θ_T represents a temperature at which supercooling is canceled, W represents the water content ratio of the food, and C_p represents the heat capacity of water.

[0061]

[Expression 5]

$$q_0 = \Delta(\theta_T - \theta_L) \times W \times C_p \quad \cdot \cdot \cdot (5)$$

[0062]

When the temperature increasing process duration ΔT_H is set so that $q_0 + q_1 \leq q_2$ is satisfied, all ice crystals generated in the food at supercooling cancellation can be melted to completely return the food to the unfrozen state. Accordingly, the food can always become the supercooled state in the following cycle, and thus the heat amount q_1 is a heat amount radiated from the food having a constant temperature at the freezing point θ_f through the low temperature maintaining process. However, in this case, the temperature increasing process duration ΔT_H is long to melt all ice crystals generated in the food, and the average temperature of the food inevitably becomes high.

[0063]

As described above, according to the refrigerator 1 of the present embodiment, the low temperature process duration ΔT_L and the temperature increasing process duration ΔT_H are set in consideration of the allowable freezing duration and heat amount balance of the cooling target object, and periodic temperature control is performed. Specifically, the low temperature process duration ΔT_L is set to be equal to or shorter than the allowable freezing duration, and the temperature increasing process duration ΔT_H is set so that the heat amount q_1 for proceeding freezing balances with the heat amount q_2 for melting ice crystals. Accordingly, in the refrigerator 1 of the present embodiment, the duration in which freezing of the cooling target object is recognized and the heat amount can balance with each other between the low temperature process and the temperature increasing process, and thus can return the cooling target object such as food to a state equivalent to the supercooled state without completely melting ice crystals, and decrease the average temperature of the cooling target object over a duration in which the cooling target object is stored. Thus, the refrigerator 1 in the present embodiment can prevent completion of freezing of the cooling target object without adversely affecting the cooling target object.

[0064]

Since the low temperature process includes the introduction process and the low temperature maintaining process, the cooling target object in the low-temperature compartment 13 can become the supercooled state. Since the temperature of the

low-temperature compartment 13 is increased by controlling the damper 17 in the temperature increasing process, no heat source for temperature increasing is needed, thereby preventing increase of the number of components and electric power consumption.

5 [0065]

In the above description, the controller 7 controls the damper 17 and the heater 18 in the temperature increasing process, but the present invention is not limited thereto. For example, in the temperature increasing process, the controller 7 may only control the heater 18, but not the damper 17, to increase the temperature of the low-temperature compartment 13. The heating unit is not limited to the heater 18, but may be, for example, a heat exchanger or a Peltier element.

[0066]

In a conventional refrigerator, when the function of supercooling a cooling target object is additionally provided in the lower part of the refrigerator compartment 100, the vegetable compartment 200 is adjacent to the low-temperature compartment 13 as the supercooling controlled region, which potentially leads to too much cooling of the vegetable compartment 200. Thus, a heat insulation structure needs to be formed between the low-temperature compartment 13 and the vegetable compartment 200 by using an appropriate heat insulation material, which adds a structural restriction.

[0067]

However, since the refrigerator 1 of the present embodiment includes the partition plate 40 provided in parallel with the partition members 50 between the low-temperature compartment 13 and the vegetable compartment 200 positioned below the low-temperature compartment 13, and the heater 18 as the heating unit provided in the region surrounded by the partition plate 40 and the partition members 50, the compartment temperature of the vegetable compartment 200 can be increased by controlling the heater 18 by the controller 7. Thus, in the refrigerator 1 of the embodiment, when the vegetable compartment 200 is adjacent to the low-temperature compartment 13, too much cooling of the vegetable compartment 200

can be prevented by supplying heat to the vegetable compartment 200 from the heater 18, which eliminates the need for the conventionally needed heat insulation material. Thus, the refrigerator 1 according to the present embodiment is a refrigerator having the function of supercooling the cooling target object and capable of supercooling the cooling target object without too much cooling of the vegetable compartment 200 without using a heat insulation material.

[0068]

In addition, in the refrigerator 1 of the embodiment, since the region surrounded by the partition plate 40 and the partition members 50 is partitioned into a plurality of spaces by the ribs (rib region 20) protruding from the partition plate 40 or the partition members 50, and the heater 18 is provided in one of the partitioned spaces, the heater 18 has an increased heat generation density, and thus can effectively increase the compartment temperature of the storage compartment.

[0069]

Although the embodiment of the present invention is described above with reference to the accompanying drawings, a specific configuration of the present invention is not limited thereto but may be modified within a range in which supercooling control is possible. For example, in the above-described embodiment, ice crystals generated due to supercooling cancellation of a cooling target object do not need to be completely melted in the temperature increasing process, and thus the temperature increasing process duration ΔT_H is set so that the heat amount q_1 = the heat amount q_2 is satisfied. In this case, a heat amount relation including the heat amount q_0 radiated from the cooling target object at supercooling cancellation is $q_1 = q_2 < (q_0 + q_1)$. When the heat amount q_1 = the heat amount q_2 it not precisely satisfied but $q_2 < q_0 + q_1$ is satisfied, the heat amount q_1 and the heat amount q_2 balance with each other despite of the heat amount $q_1 < \text{the heat amount } q_2$, and accordingly, effects similar to those of the above-described embodiment can be obtained. Thus, the temperature increasing process duration ΔT_H may be determined so that the heat amount $q_1 < \text{the heat amount } q_2$ and the heat amount $q_2 < (\text{the heat amount } q_0 + \text{the heat amount } q_1)$ are satisfied.

[0070]

Cooling target objects stored in the refrigerator 1 include not only food but also any objects that can be stored in the supercooled state and include natural objects such as raw meat of inedible animals, and raw meat of experimental animals such as cloned animals.

Reference Signs List

[0071]

1 refrigerator 2 compressor 3 cooler 4 air-sending fan 5, 5a, 5b
air path 6 input panel 7 controller 8 door 10 door pocket 11
shelf 12 chilled compartment 13 low-temperature compartment (supercooling
controlled region) 14, 15 temperature sensor 16, 17 damper 18 heater 19
cooling device 20 rib region 30 still air region 40 partition plate 50
partition member 61 input unit 62 display unit 71 time measurement unit
72 counter 73 process transition unit 74 temperature setting unit 75
comparison unit 76 control unit 77 storage unit 80, 81 door 90
heat insulation box 100 refrigerator compartment 200 vegetable compartment
300 freezer compartment 201, 301 housing case

CLAIMS

[Claim 1]

A refrigerator comprising:

a heat insulation box having a storage space therein, the storage space being
5 partitioned into a plurality of storage compartments by a partition member;

a low-temperature compartment provided as one of the storage compartments
and configured to store a cooling target object at a temperature equal to or lower than
a freezing point of the cooling target object without freezing the cooling target object;

a cooling device configured to cool the storage space;

10 a partition plate provided in parallel with the partition member between the low-
temperature compartment and one of the storage compartments positioned below the
low-temperature compartment;

a heating unit provided in a region surrounded by the partition plate and the
partition member; and

15 a controller configured to control the cooling device to repeatedly perform a first
process of decreasing a compartment temperature of the low-temperature
compartment, to a first temperature lower than the freezing point of the cooling target
object, from a second temperature higher than the freezing point in a duration set in
advance, and a second process of increasing the compartment temperature from the
20 first temperature to the second temperature and maintaining the second temperature
for a duration set in advance,

the region surrounded by the partition plate and the partition member being
partitioned into a plurality of spaces by a rib protruding from the partition plate or the
partition member,

25 the heating unit being provided in one of the partitioned spaces,
wherein the controller is configured to,

in the second process, control the cooling device and the heating unit to
increase the compartment temperature of the low-temperature compartment from the
first temperature to the second temperature, and

perform control so that a time integral value of a difference between the freezing point and the compartment temperature of the low-temperature compartment while the compartment temperature of the low-temperature compartment is lower than the freezing point balances with a time integral value of the difference between the freezing point and the compartment temperature of the low-temperature compartment while the compartment temperature of the low-temperature compartment is higher than the freezing point.

[Claim 2]

A refrigerator comprising:

a heat insulation box having a storage space therein, the storage space being partitioned into a plurality of storage compartments by a partition member;

a low-temperature compartment provided as one of the storage compartments and configured to store a cooling target object at a temperature equal to or lower than a freezing point of the cooling target object without freezing the cooling target object;

a cooling device configured to cool the storage space; and

a partition plate provided in parallel with the partition member between the low-temperature compartment and one of the storage compartments positioned below the low-temperature compartment;

a heating unit provided in a region surrounded by the partition plate and the partition member; and

a controller configured to control the cooling device to repeatedly perform a first process of decreasing a compartment temperature of the low-temperature compartment, to a first temperature lower than the freezing point of the cooling target object, from a second temperature higher than the freezing point in a duration set in advance, and a second process of increasing the compartment temperature from the first temperature to the second temperature and maintaining the second temperature for a duration set in advance,

the region surrounded by the partition plate and the partition member being partitioned into a plurality of spaces by a rib protruding from the partition plate or the partition member,

the heating unit being provided in one of the partitioned spaces,
wherein the controller is configured to,

control the heating unit to increase compartment temperature of the storage
compartments and perform control so that a time integral value of a difference
5 between the freezing point and the compartment temperature of the low-temperature
compartment while the compartment temperature of the low-temperature
compartment is lower than the freezing point balances with a time integral value of
the difference between the freezing point and the compartment temperature of the
low-temperature compartment while the compartment temperature of the low-
10 temperature compartment is higher than the freezing point.

[Claim 3]

The refrigerator of claim 1 or 2, wherein the controller is configured to, in the
first process, control the cooling device to gradually decrease a setting temperature
from the second temperature to the first temperature in each time set in advance.

15 [Claim 4]

The refrigerator of claim 3, wherein the first process includes an introduction
process of gradually decreasing the setting temperature in each time set in advance
until the setting temperature reaches the first temperature from the second
temperature, and a low temperature maintaining process of maintaining the setting
20 temperature that reaches the first temperature for a duration set in advance.

[Claim 5]

The refrigerator of any one of claims 1 to 4, wherein

the cooling device includes an air path through which cool air is sent to the low-
temperature compartment, and a damper configured to adjust an air volume of cool
25 air supplied to the low-temperature compartment, and

the controller is configured to, in the second process, control the damper to
increase the compartment temperature of the low-temperature compartment from the
first temperature to the second temperature.

[Claim 6]

30 A refrigerator comprising:

a heat insulation box having a storage space therein, the storage space being partitioned into a plurality of storage compartments by a partition member;

a low-temperature compartment provided as one of the storage compartments and configured to store a cooling target object at a temperature equal to or lower than a freezing point of the cooling target object without freezing the cooling target object;

a cooling device configured to cool the storage space;

a partition plate provided in parallel with the partition member between the low-temperature compartment and one of the storage compartments positioned below the low-temperature compartment; and

a heating unit provided in a region surrounded by the partition plate and the partition member,

wherein the region surrounded by the partition plate and the partition member is partitioned into a plurality of spaces by a rib protruding from the partition plate or the partition member, and the heating unit is provided in one of the partitioned spaces.

[Claim 7]

The refrigerator of claim 6, further comprising

a controller configured to control the cooling device to repeatedly perform a first process of decreasing a compartment temperature of the low-temperature compartment, to a first temperature lower than the freezing point of the cooling target object, from a second temperature higher than the freezing point in a duration set in advance, and a second process of increasing the compartment temperature from the first temperature to the second temperature and maintaining the second temperature for a duration set in advance,

wherein the controller is configured to perform control so that a time integral value of a difference between the freezing point and the compartment temperature of the low-temperature compartment while the compartment temperature of the low-temperature compartment is lower than the freezing point balances with a time integral value of the difference between the freezing point and the compartment temperature of the low-temperature compartment while the compartment temperature

of the low-temperature compartment is higher than the freezing point.

[Claim 8]

5 The refrigerator of claim 7, wherein the controller is configured to, in the second process, control the cooling device and the heating unit to increase the compartment temperature of the low-temperature compartment from the first temperature to the second temperature.