

[Name of Document] SPECIFICATION

[Title of the Invention] REFRIGERATOR

[Technical Field]

[0001]

The present invention relates to a refrigerator having a plurality of partitioned compartments and a plurality of ducts for leading cold air produced by an evaporator to the plurality of partitioned compartments.

[Background Art]

[0002]

Fig. 11 is a schematic front view of the conventional refrigerator shown in Patent Document 1 in a state of the refrigerator without a door.

In Fig. 11, reference numeral 1 denotes a refrigerator body having a plurality of compartments divided into a refrigeration compartment 2, an interchangeable compartment 4 variable relative to temperature zone, a vegetable compartment 6, and a freezing compartment 5; numeral 14 a cold air circulating fan for circulating the cold air produced by an evaporator 13 by the operation of a compressor through each compartment; numeral 43 a discharge duct of the refrigeration compartment 2, with one end opened to the evaporator 13 via a refrigeration compartment damper unit 39 and the other end opened the refrigeration compartment 2; numeral 44 a refrigeration compartment

suction duct with one end opened to the refrigeration compartment 2 and the other end communicating with the vicinity of the lower portion of the evaporator 13; numeral 50 a first interchangeable compartment damper unit provided in the intermediate of the refrigeration compartment suction duct 44 for feeding a necessary amount of the cold air to the interchangeable compartment 4 in modes other than the freezing mode set at the interchangeable compartment 4; numeral 51 a discharge duct, with one end communicating with the refrigeration compartment suction duct 44 via the first interchangeable compartment damper unit 50 and the other end opened to the interchangeable compartment 4, for the interchangeable compartment 4 set in modes other than the freezing mode; numeral 52 a suction duct communicating with the refrigeration compartment suction duct 44 for the interchangeable compartment 4; numeral 53 a vegetable compartment discharge duct (not shown) with one end communicating with the refrigeration compartment damper unit 39 and the other end opened to the vegetable compartment 6; numeral 60 a second interchangeable compartment damper unit for feeding a necessary amount of the cold air to the interchangeable compartment 4 when the interchangeable compartment 4 is set at the freezing mode; and numeral 61 an interchangeable compartment discharge duct, with one end opened to the vicinity of the evaporator 13 via the second

interchangeable compartment damper unit 60 and the other end opened to the interchangeable compartment 4, for the interchangeable compartment 4 when the interchangeable compartment 4 is set in the freezing mode.

[0003]

The operation/working of the conventional refrigerator described in Patent Document 1 will be described below. Part of the cold air passing through the refrigeration compartment damper unit 39 is discharged to the vegetable compartment 6 via the vegetable compartment discharge duct 53 and returns to the evaporator 13 via a vegetable compartment suction duct 54 (not shown) to maintain the vegetable compartment 6 at 6°C. On the other hand, when the interchangeable compartment 4 is set in the freezing mode, if the temperature within the interchangeable compartment 4 is higher than the ON setting temperature, the second interchangeable compartment damper unit 60 is opened; and if the temperature within the interchangeable compartment 4 is lower than the OFF setting temperature, the second interchangeable compartment damper unit 60 is not opened. That is, the cold air cooled in the evaporator 13 is discharged by the cold air circulating fan 14 to the interchangeable compartment 4 via the interchangeable compartment discharge duct 61 and returns to the evaporator 13 so as to maintain the temperature within the

interchangeable compartment 4 at about -18°C . On the other hand, when the interchangeable compartment 4 is set in modes other than the freezing mode, the second interchangeable compartment damper unit 60 is fully closed; if the temperature within the interchangeable compartment 4 is higher than the ON setting temperature relative to the setting temperature, the first interchangeable compartment damper unit 50 is opened; if the temperature within the interchangeable compartment 4 is lower than the OFF setting temperature relative to the setting temperature, the first interchangeable compartment damper unit 50 is not opened. Namely, part of the returning cold air from the refrigeration compartment 2 is discharged to the interchangeable compartment discharge duct 51 and returns to the evaporator 13 via the interchangeable compartment suction duct 52 so as to be maintained at individual setting temperatures (at 4°C in the refrigerating mode, and at 0°C in the chilled mode).

[0004]

Fig. 12 is a side sectional view of the vicinity of a supercooling compartment of the refrigerator described in Patent Document 2. In Fig. 12, reference numeral 4A denotes a rear discharge port; numeral 21 a damper for directly cooling an interchangeable compartment; and numeral 20 an interchangeable compartment case lid having interchangeable

compartment temperature detection means 19 disposed at its center. An interchangeable compartment case (supercooled container) 17 is arranged within the interchangeable compartment (supercooled compartment) 4. Although not shown, in the interchangeable compartment 4, a heater is provided for controlling the supercooling. Due to the interchangeable compartment case lid 20 arranged in the interchangeable compartment case 17, the cold air does not directly flow inside, so that the interchangeable compartment case 17 has a function as an indirectly cooled compartment. By the damper for directly cooling the interchangeable compartment 21 open/close controlled by controlling means (not shown) using the temperature detected by the interchangeable compartment temperature detection means 19, the supercooling freeze is achieved within the interchangeable compartment 4.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. H11-211319 (Figs. 1 to 3, Pages 5 and 6)

[Patent Document 2] Japanese Unexamined Patent Application Publication No. 2007-271152 (Fig. 6, Pages 5 to 8)

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0005]

However, in the conventional refrigerator employing the technique of Patent Document 1, for indirectly cooling the interchangeable compartment 4 to eliminate the temperature unevenness, even using the second interchangeable compartment damper unit 60, since the returning cold air from the refrigeration compartment 2 is used, if the refrigeration compartment 2 is continued to have a temperature higher than the setting temperature (when the door is frequently opened/closed in summer, for example), the refrigeration compartment damper unit 39 is continued to open, the temperature of the interchangeable compartment 4 is lowered than the setting temperature even by the indirect cooling. Also, even by reducing the opening of the second interchangeable compartment damper unit 60 for indirect cooling, when the refrigeration compartment 2 is continued to have a temperature lower than the setting temperature, the refrigeration compartment damper unit 39 is continued to close, the cooling and also indirect cooling are impossible, leading to quality defects such as cooling defects. Since the return cold air from the refrigeration compartment 2 is used for cooling the vegetable compartment 6, the temperature of the vegetable compartment 6 cannot be controlled. In particular, at low ambient air, such as at an atmospheric temperature of 10°C or less, the vegetable compartment 6 requires a hot insulation heater for

preventing the temperature from lowering below 0°C, wasting the electric power consumption. If a vegetable-compartment damper unit (not shown) is provided for controlling the temperature of the vegetable compartment 6, the temperature of the vegetable compartment 6 can be controlled; however, the number of the damper units is increased to be two for the interchangeable compartment 4, one for the refrigeration compartment 2, and one for the vegetable compartment, increasing the cost.

[0006]

Also, in the conventional refrigerator employing the technique of Patent Document 2, although the supercooling freeze can be achieved within the interchangeable compartment 4, during ordinary cooling within the interchangeable compartment 4, the cooling speed is low, leading to the waste of the electric power consumption.

[0007]

Even when Patent Document 1 is combined with Patent Document 2, the supercooling can be achieved within the interchangeable compartment 4; however, the waste of the electric power consumption cannot be avoided, thereby increasing the cost and disabling the controllability of the vegetable compartment to be improved.

[0008]

The present invention has been made for solving the

problems described above, and it is an object of the invention to provide a refrigerator having a plurality of compartments, and ducts for leading cold air produced by an evaporator to the zoned compartments, in which temperatures can be finely distributed and the supercooling is enabled as well as the refrigerator is excellent in controllability of a vegetable compartment and is suppressed in cost and further electric power consumption.

[Means for Solving the Problems]

[0009]

A refrigerator according to the present invention includes;

an evaporator for producing cold air by cooling air around its periphery;

first and second divided compartments;

a first duct for leading the cold air produced by the evaporator to the first compartment, the first duct having a directly cooling duct for directly cooling the first compartment and an indirectly cooling duct for indirectly cooling the first compartment, the directly cooling duct being provided with first air-flow regulating means,

a second duct for leading the cold air to the second compartment, and

a second air-flow regulating means dividing the cold air into the indirectly cooling duct and the second duct,

and regulating the respective air-flow of the divided cold air.

[0010]

The refrigerator of the present invention may further include;

a first sensor for detecting the temperature of a food within the first compartment;

a second sensor for detecting the room temperature of the second compartment; and

controlling means for controlling the first air-flow regulating means and the second air-flow regulating means based on the temperature detected by the first sensor,

wherein when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_{11}^{\circ}\text{C}$ as well as the temperature detected by the second sensor is higher than a predetermined temperature of $T_{10}^{\circ}\text{C}$, the controlling means closes the first air-flow regulating means, and opens the second air-flow regulating means at a predetermined angle of θ_1 , so that the cold air is divided into both the indirectly cooling duct of the first compartment and the second duct of the second compartment; when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_{11}^{\circ}\text{C}$ as well as the temperature detected by the second sensor is lower than a predetermined temperature

of $T_{10}^{\circ}\text{C}$, the controlling means closes the first air-flow regulating means, opens the second air-flow regulating means at a predetermined angle of θ_2 , and closes the second duct of the second compartment, so that the cold air is supplied only to the indirectly cooling duct of the first compartment so as to indirectly cool the first compartment.

[0011]

The refrigerator of the present invention may further include;

a first sensor for detecting the temperature of a food within the first compartment;

a second sensor for detecting the room temperature of the second compartment; and

controlling means for controlling the first air-flow regulating means and the second air-flow regulating means based on the temperature detected by the first sensor,

wherein when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_0^{\circ}\text{C}$ as well as the temperature detected by the second sensor is higher than a predetermined temperature of $T_2^{\circ}\text{C}$, the controlling means opens the first air-flow regulating means, and opens the second air-flow regulating means at a predetermined angle of θ_1 , so that the cold air is divided into both the indirectly cooling duct of the first compartment and the second duct of the second

compartment; when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_0^{\circ}\text{C}$ as well as the temperature detected by the second sensor is lower than a predetermined temperature of $T_3^{\circ}\text{C}$, the controlling means opens the first air-flow regulating means, and closes the second air-flow regulating means, so that the cold air is not supplied to the second duct of the second compartment so as to directly cool the first compartment.

[Advantages]

[0012]

According to the present invention, a refrigerator capable of storing foods with high quality can be provided in that electric power consumption during ordinary refrigeration as well as cost are suppressed; the temperature in a vegetable compartment is finely controlled; and the unevenness of temperature in one zoned compartment (an interchangeable compartment) is reduced.

[0013]

According to the present invention, supercooling is enabled in one zoned compartment (an interchangeable compartment) in that electric power consumption during ordinary refrigeration and cost are suppressed; and the temperature in a vegetable compartment is finely controlled.

[Best Mode for Carrying Out the Invention]

[0014]

First Embodiment

Fig. 1 is a front view of a refrigerator according to a first embodiment of the present invention; Fig. 2 is a side sectional view of the refrigerator according to the first embodiment. In Fig. 1, reference numeral 1 denotes a refrigerator body. The refrigerator body 1 is provided with the refrigeration compartment 2 arranged at the top. Below the refrigeration compartment 2, an ice compartment 3 and the interchangeable compartment 4 are provided. At the bottom of the refrigerator body 1, the vegetable compartment 6 is provided and a freezing compartment 5 is arranged on the vegetable compartment 6. The embodiment does not limit this arrangement of individual compartments. Reference numeral 7 denotes a refrigerator door capable of freely opening/closing the opening of the refrigeration compartment 2, in which numeral 7A represents a left refrigerator door and numeral 7B a right refrigerator door, so that the refrigerator door 7 is a so-called double door. It may also be of course a single door instead of the double door. Reference numeral 8 denotes an ice compartment door capable of freely opening/closing the opening of the ice compartment 3; numeral 9 an interchangeable compartment door capable of freely opening/closing the opening of the interchangeable compartment 4; numeral 10 a freezing compartment door

capable of freely opening/closing the opening of the freezing compartment 5; and numeral 11 a vegetable compartment door capable of freely opening/closing the opening of the vegetable compartment 6. At the rear bottom of the refrigerator body 1, a compressor 12 is arranged. The compressor 12 is one component constituting a refrigerating cycle included in the refrigerator body 1, and has a function to compress refrigerant within the refrigerating cycle. The refrigerant compressed by the compressor 12 is condensed in a condenser (not shown). The condensed refrigerant is reduced in pressure in a capillary tube (not shown). Reference numeral 13 denotes an evaporator that is one component constituting the refrigerating cycle included in the refrigerator body 1. The refrigerant reduced pressure is evaporated in the evaporator 13, so that the gas in the vicinity of the evaporator 13 is cooled due to a heat absorbing function during evaporation. Reference numeral 14 denotes a cold-air circulating fan for feeding the cold air cooled in the vicinity of the evaporator 13 to the individual compartments of the refrigerator body 1; numeral 21 an interchangeable compartment directly cooling damper for regulating the amount of the cold air fed to the interchangeable compartment 4 by the cold-air circulating fan 14; and numeral 16A an interchangeable compartment directly cooling

air duct arranged in the downstream of the damper 21 for directly cooling the interchangeable compartment. The cold air passing through the damper 21 for directly cooling the interchangeable compartment is discharged into the interchangeable compartment 4 from the rear discharge port 4A (not shown) of the interchangeable compartment 4, so that the cold air is to be directly fed into the interchangeable-compartment case 17 arranged in the interchangeable compartment 4.

[0015]

Fig. 3 is a side sectional view of the refrigerator, including a damper for indirectly cooling an interchangeable compartment and for a vegetable compartment, according to the first embodiment of the present invention. The direction of the section of Fig. 3 is the same as that of Fig. 2; however, the section position is different so that the sectional shapes are different from each other. Fig. 5 is a side sectional view of the vicinity of the interchangeable compartment of the refrigerator according to the first embodiment of the present invention. In Figs. 3 and 5, reference numeral 31 denotes a damper for indirectly cooling the interchangeable compartment and for the vegetable compartment; numeral 31A a first baffle of the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment; and numeral

31B an opening of the vegetable compartment for the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment, which is an inlet of an air duct (not shown) for leading the cold air to the vegetable compartment 6. The compartments provided in the refrigerator body 1 are provided with refrigeration compartment temperature-detecting means, ice compartment temperature-detecting means, interchangeable compartment temperature-detecting means, freezing compartment temperature-detecting means, and vegetable compartment temperature-detecting means (all not shown), respectively. In the downstream of the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment, an air duct 16B for indirectly cooling the interchangeable compartment is arranged within a ceiling insulation 18 for an interchangeable compartment, and the cold air passing the duct passes through the ceiling insulation 18 for the interchangeable compartment 4 to flow in the interchangeable compartment 4 from a ceiling blowhole 18A. In the interchangeable compartment 4, an interchangeable compartment case lid 20 is arranged. The interchangeable compartment case lid 20 is arranged directly below the ceiling blowhole 18A, so that the cold air from the ceiling blowhole 18A indirectly flows in the interchangeable compartment 4. Namely, the cold air from

the ceiling blowhole 18A abuts the interchangeable compartment case lid 20 to be dispersed in all directions on the upper surface of the interchangeable compartment case lid 20, and after sliding over the interchangeable compartment case lid 20, the cold air is substantially uniformly routed into the interchangeable compartment 4 via the gap between the interchangeable compartment case 17 and the interchangeable compartment case lid 20 from the periphery of the interchangeable compartment case lid 20. Reference numeral 19 denotes the interchangeable compartment temperature-detecting means such as a thermistor.

[0016]

Fig. 4 is a perspective view of a twin-damper that can be driven with one motor and includes a damper 21 for directly cooling the interchangeable compartment and the damper for indirectly cooling the interchangeable compartment and for the vegetable compartment. When the first baffle 31A is half-opened, the opening 31B of the vegetable compartment is opened, so that the cold air is led to the vegetable compartment 6. When the first baffle 31A is fully-opened, the opening 31B of the vegetable compartment is closed, so that the cold air is not led to the vegetable compartment 6. Hence, even when the interchangeable compartment 4 is indirectly cooled, the temperature of the vegetable compartment 6 is controlled

according to the setting temperature. If the first baffle 31A is closed, the cold air cannot enter the vegetable compartment 6 as well as the air duct 16B for indirectly cooling the interchangeable compartment. The dampers shown in Fig. 4 have an advantage of low cost due to the reduced number of motors smaller than that of individual motors.

[0017]

Fig. 6 is a block diagram of the control of the refrigerator according to the first embodiment of the present invention.

In Fig. 6, reference numeral 71 denotes a control unit including a microcomputer and a DSP; numeral 72 a memory storing various data and tables; numeral 73 an ROM storing programs and fixed data to be executed by the control unit 71; numeral 74 an input/output bus, through which the information about entire components is exchanged with the control unit 71; numeral 75 damper-motor driving means for driving a damper motor 81 for opening/closing a baffle that is air-flow regulating means of the damper 21 for directly cooling the interchangeable compartment and the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment; numeral 76 fan motor driving means for driving a fan motor 82 for rotating the circulating fan 14; numeral 77 compressor-motor driving means for driving a compressor motor 83 for rotating the

compressor 12; numeral 78 input controlling means for converting results detected by a thermistor 19 that is the interchangeable compartment temperature-detecting means into digital signals to feed the signals to the control unit 71; and numeral 79 input controlling means for converting results detected by a thermistor 23 that is the vegetable compartment temperature-detecting means into digital signals to feed the signals to the control unit 71.

[0018]

Fig. 7 is a flowchart of the controlling of the control unit 71 about the control of the damper for directly cooling the interchangeable compartment and the damper for indirectly cooling the interchangeable compartment and for the vegetable compartment, during the ordinary freeze of the refrigerator interchangeable compartment according to the first embodiment of the present invention. At Step S1, the control unit 71 determines whether the compressor 12 satisfies operation conditions. The operation conditions are that the temperature detected by the temperature detection means 23 of the freezing compartment 5 is a predetermined temperature or more, for example. When the determination is NO at Step S1, the process returns to Step S1. When the determination is YES at Step S1, the process proceeds to Step S2. The control unit 71 determines whether the interchangeable compartment thermistor 19 is a

predetermined temperature $T0^{\circ}\text{C}$ or more at Step S2. When the control unit 71 determines the interchangeable compartment thermistor 19 to be the predetermined temperature $T0^{\circ}\text{C}$ or less at Step S2, the process returns to Step S2. When the control unit 71 determines the interchangeable compartment thermistor 19 to be the predetermined temperature $T0^{\circ}\text{C}$ or more at Step S2, the process proceeds to Step S3. At Step S3, the control unit 71 opens the damper 21 for directly cooling the interchangeable compartment, and then the process proceeds to Step S4. At Step S4, the control unit 71 determines whether the interchangeable compartment thermistor 19 is a predetermined temperature $T1^{\circ}\text{C}$ or less. At Step S4, if the interchangeable compartment thermistor 19 is determined not to be the predetermined temperature $T1^{\circ}\text{C}$ or less, the process returns to Step S4. At Step S4, when the interchangeable compartment thermistor 19 is determined to be the predetermined temperature $T1^{\circ}\text{C}$ or less, the process proceeds to Step S5.

[0019]

At Step S5, the control unit 71 closes the damper 21 for directly cooling the interchangeable compartment. When the determination is YES at Step S1 independently from Step S2 to Step S5, the process proceeds to Step S6. The control unit 71 determines whether the vegetable compartment thermistor (not shown) is a predetermined temperature $T2^{\circ}\text{C}$

or more at Step S6. When the control unit 71 determines the vegetable compartment thermistor (not shown) to be the predetermined temperature $T2^{\circ}\text{C}$ or less at Step S6, the process returns to Step S6. At Step S6, when the control unit 71 determines the vegetable compartment thermistor (not shown) to be the predetermined temperature $T2^{\circ}\text{C}$ or more, the process proceeds to Step S7. At Step S7, the control unit 71 opens the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment at a predetermined angle of 00 . Then, the process proceeds to Step S8. At Step S8, the vegetable compartment thermistor (not shown) is determined whether to be a predetermined temperature $T3^{\circ}\text{C}$ or less. At Step S8, if the vegetable compartment thermistor (not shown) is determined not to be the predetermined temperature $T3^{\circ}\text{C}$ or less, the process returns to Step S8. At Step S8, when the vegetable compartment thermistor (not shown) is determined to be the predetermined temperature $T3^{\circ}\text{C}$ or less, the process proceeds to Step S9. At Step S9, the control unit 71 closes the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment.

[0020]

Since the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable

compartment is opened at Step S7, the indirect cooling air duct is communicated with the interchangeable compartment 4; however, if the angle of the first baffle 31A is set rather small, the velocity of the cold air led to the ceiling blowhole 18A after passing through the ceiling insulation 18 for an interchangeable compartment is reduced, so that the large part of the cold air that has passed through the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment flows in the opening 31B. Hence, a temperature influence on the interchangeable compartment 4 is very small, so that the interchangeable compartment 4 can be controlled by only the damper 21 for directly cooling the interchangeable compartment. According to the flowchart shown in Fig. 7, the temperature can be controlled without being influenced by operating conditions of the interchangeable compartment 4. Since the cold air that has passed through the damper 21 for directly cooling the interchangeable compartment is directly injected into the interchangeable compartment case 17, the interchangeable compartment 4 can be efficiently cooled, thereby suppressing the waste of the electric power consumption of the refrigerator body 1.

[0021]

On the other hand, Fig. 8 is a flowchart of the controlling by the control unit 71 about the control of the

damper 21 for directly cooling the interchangeable compartment and the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment, during the supercooling freeze of the interchangeable compartment 4 according to the first embodiment of the present invention. The supercooling freeze means a freezing mode achieving a supercooling state that means an entirely not frozen state even a substance is at a temperature below its freezing point. The freezing point means a temperature at which the substance starts freezing. Namely, the supercooling state is the state of not entirely frozen even at a temperature to start freezing. For instance, the freezing point of water is 0°C. Various substances have various freezing points, and the freezing point in foods with a large salt or sugar content has a tendency to lower than 0°C. Upon describing the freezing in the supercooling state or the freezing after going through the supercooling state with reference to water, the supercooling state means that when water is cooled, even the temperature is lowered below 0°C, which is the freezing point, 100% water stays in liquid water. The water reaching the supercooling state may also be frozen later on to be ice; however, any stimulus is required at this time. The stimulus may be stimulation in temperature or physical one. In such a manner, the freezing can be started by the

stimulation. The transient period of time from the supercooling state to the start of freezing is several seconds and momentary; however, the rate of the ice momentary freezing during the starting freeze is several percentages out of the whole and for having the 100% ice, the cooling time is further required.

[0022]

The difference between the ordinary freeze and the supercooling freeze will be described herein with reference the comparison. The most distinct difference between the ordinary freeze and the supercooling freeze is the point whether becoming the supercooling state or not. During the ordinary freeze, below the freezing point, the freezing starts without becoming the supercooling state.

Another distinct difference between the ordinary freeze and the supercooling freeze is the state during the starting freeze. Phenomena during the starting freeze will be described herein with reference to an example of water contained in a PET bottle. During the ordinary freeze, upon start of freezing, the freeze is started from water in the vicinity of the surface water contained in the PET bottle to have thin ice on the surface; then, the ice spreads toward the inside so as to finally freeze entirely. The ice grows around an ice nucleus that is a cluster with a predetermined size or more developed with water molecules, and the ice

nucleus is developed during the starting freeze.

Accordingly, during the ordinary freeze, almost all the ice nuclei are formed on the surface, from which the ice may grow toward part in a water state.

[0023]

On the other hand, during the supercooling freeze, upon starting freeze, the ice nuclei are uniformly formed over the entire water in the PET bottle. The ice grows in every part, the inside as well as the surface, of the water in the PET bottle, so that the ice does not grow in a predetermined direction.

As for the difference after completion of the freezing between the ordinary freeze and the supercooling freeze, due to the difference of the cooling process, in the ordinary freeze, large needle ice crystals are developed from the surface toward the inside, whereas, in the supercooling freeze, small particulate ice crystals are uniformly developed both in the surface and the inside.

Also, in rapid freezing, the states in the starting freeze and after completion of the freezing are identical to the ordinary freeze at the point that water is rapidly frozen by abutting cold air on the surface. First, the surface temperature is rapidly reduced, so that the freeze starts from the surface. However, as the point different from the ordinary freeze, the cooling speed to cool the

inside is large, so that the ice nuclei tend to grow even in the inside and the large ice crystal may not grow in comparison with during the ordinary freeze. When considering food freezing, the size and shape of the ice crystal after completion of the freezing have a great influence on the food quality during defrosting. Most foods are composed of cells, protein, and glucide, so that if the structure is once destroyed by the ice crystal, the structure may not be recovered perfectly. Hence, when the size and shape of the ice crystal produced during freezing do not destroy the original structure of foods, the freezing excellent in quality may be achieved.

[0024]

Then, the advantages and innovative properties in freezing foods with the supercooling freeze will be described. The most significant merit of the freezing foods with the supercooling freeze is the high-quality freezing. As described above, in the freezing after going through the supercooling state, foods have been sufficiently cooled up to the inside in a process proceeding to the supercooling state, so that ice nuclei are uniformly formed all over the entire foods to grow as small particulate ice crystals. With increasing difference between the freezing point and the minimum temperature when reaching the supercooling state, the number of ice nuclei formed at the starting to freeze is

increased to form more fine ice crystals. When the supercooling is sufficiently achieved (with decreasing temperature reaching the supercooling state), the state of foods nearer to that before freezing can, therefore, be maintained even after defrosting from freeze.

[0025]

When considering the food cooling and the size/shape of the ice crystal, the transit time through the temperature zone of -1°C to -5°C , which is the maximum ice crystal forming band, has been conventionally taken into account. This is a concept that the ice crystal is reduced in size when rapidly passing through the maximum ice crystal forming band.

In the case of the supercooling freeze, the period of time is long to remain in the neighborhood temperature zone including the maximum ice crystal forming band (-1°C to -10°C) in a supercooled state. However, the supercooled state is a non-frozen state, so that as long as being in the supercooled state, even the transient period of time through this temperature zone is long, the ice crystal is not increased in size after freezing and fine ice crystals can be formed. To freeze foods with high quality in the neighborhood temperature zone including the maximum ice crystal forming band by forming fine ice crystals is a quite innovative freezing method. Upon canceling the supercooled

state, the freezing starts and is completed after going through a phase conversion state, in which the temperature is not changed; and it has been confirmed that as long as going through the supercooled state, even if the transient period of time through the maximum ice crystal forming band is long after that, the ice crystal is not increased in size. Hence, in view of this point, this may also be an innovative freezing method.

As long as going through the supercooled state, even if the transient period of time through the maximum ice crystal forming band is long after that, the ice crystal forming state is scarcely affected; however, if rapidly freezing when proceeding to the freezing process, the possibility of the ice crystal increasing in size is further reduced as well as the reducing factor of food quality other than the ice crystal can also be avoided, so that foods can be frozen with further improved quality.

[0026]

The merit of freezing foods reaching the supercooled state by canceling the supercooling has been only described above; however, foods reaching the supercooled state are not necessarily frozen. The merit of maintaining the supercooled state is that the structure of foods cooled at a low temperature cannot be affected by the ice crystals because although the foods are stored at the temperature of

the freezing point or below, at which the foods otherwise become frozen, the foods are perfectly not frozen in this state to form no ice crystal. It has been generally known that storing foods at lower temperature is effective for preserving the freshness because of suppressing various chemical changes of the foods; this method may be referred to a method achieving both merits of the low-temperature storage and the non-frozen. Also, the foods need not being defrosted. However, the non-frozen state also has a disadvantage; that is, non-frozen water contained in the foods can be used for bacteria breeding and various chemical changes. Hence, it is necessary to pay attention to this point much more than the frozen food. Namely, for achieving the supercooling freeze, foods need to be uniformly cooled and this is possible by indirectly cooling the foods as one method.

[0027]

Then, the flowchart of Fig. 8 will be described. At Step S101, a supercooling mode is started. Main starting means for starting the supercooling mode is to allow a user to operate provided display panel/switches (not shown). After Step S101, the control unit 71 firstly closes the damper 21 for directly cooling the interchangeable compartment at Step S102. This cools foods within the interchangeable compartment 4 uniformly for achieving the

supercooling freeze by avoiding to directly inject cold air into the interchangeable compartment 4. After Step S102, the process proceeds to Step S103 for determining whether the compressor 12 is operating. When the compressor 12 is determined to be stopped (NO) at Step S103, the process returns to Step S102. When the compressor 12 is determined to be operating (YES) at Step S103, the process proceeds to Step S104. At Step S104, the control unit 71 determines whether the result detected by the vegetable compartment thermistor 23 is a predetermined temperature of $T_{10}^{\circ}\text{C}$ or more. When the detected result is determined not to be the predetermined temperature of $T_{10}^{\circ}\text{C}$ or more (NO) at Step S104, the process proceeds to Step S106. At Step S106, the control unit 71 opens the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment at a predetermined angle of θ_{11} by controlling the damper-motor driving means 75. When θ_{11} is 90° , for example, the opening 31B of the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment is closed with the first baffle 31A, so that the cold air cannot flow in the vegetable compartment 6, preventing unnecessary cooling. When the result detected by the vegetable compartment thermistor 23 is determined to be the predetermined temperature of $T_{10}^{\circ}\text{C}$ or more (YES) at Step S104, the process proceeds to Step

S105. At Step S105, the control unit 71 opens the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment at a predetermined angle of θ_{10} by controlling the damper-motor driving means 75. When θ_{10} is 45° , for example, the opening 31B of the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment is not closed with the first baffle 31A, so that the cold air is injected into the vegetable compartment 6. Accordingly, regardless of the determination at Step S104, the cooling of the vegetable compartment 6 can be controlled independently from the cooling of the interchangeable compartment 4. After Step S105 and Step S106, any process proceeds to Step S107. At Step S107, the control unit 71 determines whether the result detected by the interchangeable compartment thermistor 19 is the predetermined temperature of $T_{11}^\circ\text{C}$ or less. When the result detected by the interchangeable compartment thermistor 19 is determined to be the predetermined temperature of $T_{11}^\circ\text{C}$ or more (NO) at Step S107, the process returns to Step S107. When the result detected by the interchangeable compartment thermistor 19 is determined to be the predetermined temperature of $T_{11}^\circ\text{C}$ or less (YES) at Step S107, the process proceeds to Step S108. At Step S108, the control unit 71 opens the damper 21 for directly cooling the interchangeable compartment by controlling the damper-

motor driving means 75. By Step S108, foods within the interchangeable compartment 4 are stimulated by directly injecting cold air into the interchangeable compartment 4, so that the supercooling is achieved. By the way, the predetermined temperature of $T_{11}^{\circ}\text{C}$ is mainly the freezing point of meat, which is about -5°C . Depending on the size/shape of the meat, poke rib with a weight of about 100g can be perfectly frozen, for example, achieving the frozen state with high quality.

[0028]

Second Embodiment

Fig. 9 is a side sectional view of the vicinity of an interchangeable compartment of a refrigerator according to a second embodiment of the present invention. Fig. 10 is a block diagram of the control of the refrigerator according to the second embodiment of the present invention. In Fig. 9 or 10, reference numeral 22 denotes an infrared radiation sensor for measuring the surface temperature of a food within the interchangeable compartment 4, and the ceiling of the interchangeable compartment 4 may be suitable for its installation location because the inside of the interchangeable compartment case 17 can be overlooked from the ceiling; and numeral 88 represents input controlling means for converting the temperature information detected by the infrared radiation sensor 22 into digital signals to

feed the signals to the control unit 71.

According to the embodiment, since the infrared radiation sensor 22 is used, the temperature nearer to the food can be detected in comparison with the interchangeable compartment thermistor 19, which detects air temperature, so that the supercooling achieving probability can be increased. The reason why the temperature nearer to the food can be detected is that while the interchangeable compartment thermistor 19 only detects the temperature nearest to the interchangeable compartment thermistor 19, the infrared radiation sensor 22 detects the infrared radiation emitted from the surface of a substance separated from the sensor. Since the amount of the infrared radiation is increased with increasing temperature, the temperature is measured by the amount of the infrared radiation. According to the second embodiment, only the role of the interchangeable compartment thermistor 19 in the first embodiment is replaced by the infrared radiation sensor 22; due to the working of the infrared radiation sensor 22 mentioned above, the temperature nearer to a food can be detected, leading to the success in the supercooling.

Also, according to the embodiment, the controlling flowchart of the control unit 71 is identical to Figs. 7 and 8.

[Brief Description of the Drawings]

[0029]

[Fig. 1] Fig. 1 is a front view of a refrigerator according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a side sectional view of the refrigerator, including a directly cooling damper of an interchangeable compartment, according to the first embodiment.

[Fig. 3] Fig. 3 is a side sectional view of the refrigerator, including a damper for indirectly cooling an interchangeable compartment and for a vegetable compartment, according to the first embodiment of the present invention.

[Fig. 4] Fig. 4 is a perspective view of a twin-damper mounted on the refrigerator according to the first embodiment of the present invention and combining a damper of directly cooling the interchangeable compartment with a damper for indirectly cooling the interchangeable compartment and for the vegetable compartment.

[Fig. 5] Fig. 5 is a side sectional view of the vicinity of the interchangeable compartment of the refrigerator according to the first embodiment of the present invention.

[Fig. 6] Fig. 6 is a block diagram of the control of the refrigerator according to the first embodiment of the present invention.

[Fig. 7] Fig. 7 is a flowchart of the controlling of the control unit 71 about the control of the damper for directly

cooling the interchangeable compartment and the damper for indirectly cooling the interchangeable compartment and for the vegetable compartment, during the ordinary freeze of the refrigerator interchangeable compartment according to the first embodiment of the present invention.

[Fig. 8] Fig. 8 is a flowchart of the controlling by the control unit 71 about the control of the damper 21 for directly cooling the interchangeable compartment and the damper 31 for indirectly cooling the interchangeable compartment and for the vegetable compartment, during the supercooling freeze of the refrigerator interchangeable compartment 4 according to the first embodiment of the present invention.

[Fig. 9] Fig. 9 is a side sectional view of the vicinity of an interchangeable compartment of a refrigerator according to a second embodiment of the present invention.

[Fig. 10] Fig. 10 is a block diagram of the control of the refrigerator according to the second embodiment of the present invention.

[Fig. 11] Fig. 11 is a schematic front view of the conventional refrigerator shown in Patent Document 1 in a state of the refrigerator without a door.

[Fig. 12] Fig. 12 is a side sectional view of the vicinity of a supercooling compartment of the refrigerator described in Patent Document 2.

[Reference Numerals]

[0030]

1: refrigerator body, 2: refrigeration compartment, 3: ice compartment, 4: interchangeable compartment, 4A: rear discharge port, 5: freezing compartment, 6: vegetable compartment, 7: refrigerator door, 7A: left refrigerator door, 7B: right refrigerator door, 8: ice compartment door, 9: interchangeable compartment door, 10: freezing compartment door, 11: vegetable compartment door, 12: compressor, 13: evaporator, 14: cold air circulating fan, 16: interchangeable compartment cooling duct, 16A: interchangeable compartment directly cooling duct, 16B: interchangeable compartment indirectly cooling duct, 17: interchangeable compartment case, 18: ceiling insulation for interchangeable compartment, 18A: ceiling blowhole, 19: interchangeable compartment temperature detection means, 20: interchangeable compartment case lid, 21: damper for directly cooling interchangeable compartment, 22: infrared radiation sensor, 23: vegetable compartment temperature detection means, 31: damper for indirectly cooling interchangeable-compartment and for vegetable compartment, 31A: first baffle, 31B: opening of vegetable compartment, 39: refrigeration compartment damper unit, 43: discharge duct of refrigeration compartment, 44: refrigeration compartment suction duct, 50: first interchangeable

compartment damper unit, 51: first interchangeable
compartment discharge duct, 52: interchangeable compartment
suction duct, 53: vegetable compartment discharge duct, 54:
vegetable compartment suction duct, 60: second
interchangeable compartment damper unit, 61: second
interchangeable compartment discharge duct, 71: control unit,
72: memory, 73: ROM, 74: input/output bus, 75: damper-motor
driving means, 76: fan motor driving means, 77: compressor
motor driving means, 78 to 80: input controlling means, 81:
damper motor, 82: fan motor, 83: compressor motor.

[Name of Document] CLAIMS

[Claim 1]

A refrigerator comprising:

an evaporator for producing cold air by cooling air around its periphery;

first and second divided compartments;

a first duct for leading the cold air produced by the evaporator to the first compartment, the first duct having a directly cooling duct for directly cooling the first compartment and an indirectly cooling duct for indirectly cooling the first compartment, the directly cooling duct being provided with first air-flow regulating means,

a second duct for leading the cold air to the second compartment, and

a second air-flow regulating means dividing the cold air into the indirectly cooling duct and the second duct, and regulating the respective air-flow of the divided cold air.

[Claim 2]

The refrigerator of claim 1, wherein the first air-flow regulating means and the second air-flow regulating means are a twin-damper driven by one motor.

[Claim 3]

The refrigerator of claim 1 or 2, wherein the first compartment is an interchangeable compartment variable

relative to temperature zone.

[Claim 4]

The refrigerator of any one of Claims 1 to 3, wherein the second compartment is a vegetable compartment with a setting temperature set at higher temperature than that of the first compartment.

[Claim 5]

The refrigerator of any one of Claims 1 to 4, wherein the first compartment includes a case and a lid member for covering the case, and

wherein the cold air from the indirectly cooling duct abuts the lid member before flowing in the first compartment, so that the cold air cools the first compartment indirectly.

[Claim 6]

The refrigerator of any one of Claims 1 to 5, wherein the second air-flow regulating means includes two openings, one opening being connected to the indirectly cooling duct of the first compartment, the other being connected to the second duct of the second compartment.

[Claim 7]

The refrigerator of any one of Claims 1 to 6, further comprising:

a first sensor for detecting the temperature of a food within the first compartment;

a second sensor for detecting the room temperature of the second compartment; and

controlling means for controlling the first air-flow regulating means and the second air-flow regulating means based on the temperature detected by the first sensor,

wherein when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_{11}^{\circ}\text{C}$ as well as the temperature detected by the second sensor is higher than a predetermined temperature of $T_{10}^{\circ}\text{C}$, the controlling means closes the first air-flow regulating means, and opens the second air-flow regulating means at a predetermined angle of θ_1 , so that the cold air is divided into both the indirectly cooling duct of the first compartment and the second duct of the second compartment; when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_{11}^{\circ}\text{C}$ as well as the temperature detected by the second sensor is lower than a predetermined temperature of $T_{10}^{\circ}\text{C}$, the controlling means closes the first air-flow regulating means, opens the second air-flow regulating means at a predetermined angle of θ_2 , and closes the second duct of the second compartment, so that the cold air is supplied only to the indirectly cooling duct of the first compartment so as to indirectly cool the first compartment.

[Claim 8]

The refrigerator of any one of Claims 1 to 6, further comprising:

a first sensor for detecting the temperature of a food within the first compartment;

a second sensor for detecting the room temperature of the second compartment; and

controlling means for controlling the first air-flow regulating means and the second air-flow regulating means based on the temperature detected by the first sensor,

wherein when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_0^{\circ}\text{C}$ as well as the temperature detected by the second sensor is higher than a predetermined temperature of $T_2^{\circ}\text{C}$, the controlling means opens the first air-flow regulating means, and opens the second air-flow regulating means at a predetermined angle of θ_1 , so that the cold air is divided into both the indirectly cooling duct of the first compartment and the second duct of the second compartment; when determining that the food temperature detected by the first sensor is higher than a predetermined temperature of $T_0^{\circ}\text{C}$ as well as the temperature detected by the second sensor is lower than a predetermined temperature of $T_3^{\circ}\text{C}$, the controlling means opens the first air-flow regulating means, and closes the second air-flow regulating means, so that the cold air is not supplied to the second

duct of the second compartment so as to directly cool the first compartment.

[Claim 9]

The refrigerator of Claim 7 or 8, further comprising a third sensor provided instead of the first sensor for detecting the room temperature of the first compartment.