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給食経営管理実習における環境に配慮した食事計画の取り組み

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Ⅰ Introduction

In facilities for providing meals, plans are drawn up for each work area in order to implement hygiene management based on HACCP, and controls for room and refrigerator temperatures are applied at Critical Control Points as a means of preventing hazards[1)]. A refrigerator has functions of inhibiting enzyme activity that alters food quality and the growth of microorganisms, and enabling storage with the original hygiene and quality of food for a certain period of time[2)]. The previous report[3)] examined the use of refrigerators and freezers in the households of university students and clarified concerning temperature control. Energy consumption until 2010 is indicated by the Kyoto Protocol, and according to the Japan Electro-Manufacturing-Association, with their annual energy consumption displayed on refrigerators, operability, cleavability and energy conservation, as well as safety, are required of refrigerators. In September 2009, the Industrial Science and Technology Policy and Environment Bureau of the Ministry of Economy, Trade and Industry established JIS (Japanese Industrial Standards) to measure the power consumption of industrial refrigerators etc. and is considering citing the Top Runner Standard of an industrial refrigerator based on the Energy Conservation Law. As has been discussed, characteristics of equipment, as well as human use, connect deeply to energy consumption, and therefore, it is necessary to understand the characteristics of equipment such as refrigerators. To this end, this study compares refrigerator temperature and room temperature/humidity with the objective of energy conservation and temperature control in the food service management practicum.

Ⅱ Survey method

1. Survey period and Subjects

In the survey, which was conducted during the October-to-January period seven times each in FY2005 and FY2006, refrigerator temperature and room temperature/humidity were measured during the food service management practicum at a university in the suburbs of Sapporo, Hokkaido.

2. Measurement method

1) Measurement method of refrigerator temperature and room temperature/humidity

Temperature in the refrigerator and room temperature/humidity were measured using a data logger (made by Sato Keiryoki) at 1-minute intervals from the beginning (0 minutes) to the end (160 minutes) of the practicum, and respective temperature and humidity data were recorded in the logger. Data loggers were set up on the upper shelf of the pass-through refrigerator, which was for

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the exclusive use in the preparation room and cooking room, and in front of the refrigerator to measure room temperature and humidity. The pass-through refrigerator used (made by FUJIMAC) had a capacity of 694L, a rated voltage of 100V, a rated frequency of 50/60 Hz, a power consumption of 509/563W, an outside dimension of 760mm (inside dimension of 660mm), a weight of 170kg and a settable temperature of −5℃ to +10℃.

As per food service management standards, refrigerator temperature was set at or below 10℃, room temperature at or below 25℃, and humidity at or below 80%, and recording paper was used for monitoring. The person in charge of the examination monitored and checked the data at the beginning of the practicum, an hour later, and at the end of the practicum.

2) Temperature and humidity in Sapporo, Hokkaido

The day's highest and lowest temperature and humidity readings as of 15:00 in Sapporo, Hokkaido, were recorded from the general news/weather page of the Hokkaido Shimbun (newspaper) of the following day.

3) Sensible temperature of subjects

Sensible temperature was obtained by the method of Koda et al.[5] using the formula for calculation from the Missenard method.

Sensible temperature$=t-1/2.3(t-10)(0.8-h/100)$

t: temperature (℃), h: relative humidity (%)

3. Statistical processing

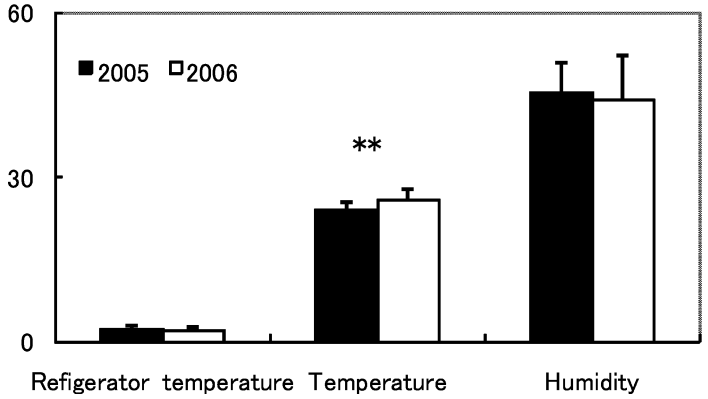
Endpoints are shown as mean±standard deviation. Statistical significance tests were conducted with Student's t-tests and analysis of variance, and the significance level was set at less than 5%.

III Results and discussion

1. Discussion of refrigerator temperature and humidity considered from menus

Yearly changes in refrigerator temperature, room temperature/humidity are shown in Fig.1, and menus and levels of satisfaction with food services are shown in Table 1-2. According to Fig. 1, the room temperatures of FY2005 are 24.0±1.6℃, and those of FY2006 are 25.8±2.2℃, showing a significant difference in yearly comparison (**$p<0.01$). Average humidity is 44.0% to 45.3%, both within the standard 80%. Room temperature and humidity control is necessary from a safety/hygiene standpoint, and furthermore, is considered to affect working efficiency and it is inferred that errors in work management are likely to occur if room temperature and humidity exceed the standards. From these reasons, it is thought that consideration needs to be given to prior confirmation of an operation process chart toward the practicum group, since menus, workflow lines of practicum groups and other factors also affect temperature control.

In both FY2005 and FY2006, the menu that raised refrigerator temperature was "rice, *mabo-dofu* (bean curd with ground beef and chili peppers), *aona-ae* (leafy greens dressed with sauce), fruit and milk" (5.1℃ in 2005, 9.8℃ in 2006), which shows that refrigerator temperature is associated with storage conditions of food materials[5]. A rise in refrigerator temperature was seen 60 minutes after the start of practicum. It is inferred that since the job is to cut food materials in the unhygienic area until around 50 minutes after the start of practicum, the temperature reached the highest point in 60 minutes, when the operating rate of the pass-through refrigerator in the



**p<0.01

Fig.1 Changes in refigerator temperature and temperature/humidity.
Refigerator temperature (℃), Temperature (℃), Humidity (%)

preparation room and cooking room was high, and dropped after that.

Meanwhile, the highest point in room temperature was 30.7℃ (in 2005, *buta-jiru* (pork miso soup)), 33.9℃ (in 2006, bibimbap (Korean mixed rice)), and the highest point in humidity was 80.6% (in 2005, bibimbap), 67.8% (in 2006, *bita-jiru*). Cooking methods such as boiling food, simmering food, heating soup, and cooking (steaming) rice are considered to affect room temperature and humidity, and therefore, it is thought necessary to study menus.

The level of satisfaction with food services was calculated from "very bad" (−2 points), "bad" (−1 point), "acceptable" (0 points), "good" (+1 point) and "very good" (+2 points). The level of satisfaction with food services went up each time the food service management practicum was

Table 1 Menus and levels of satisfaction with food services (2005).

		1	2	3	4	5	6	7
Refrigerator temperature (℃)	Max	4.9	5.1	4.4	3.7	4.6	3.8	4.3
	Min	1.6	1.7	1.6	1.7	1.3	1.7	1.6
	Average	2.5	2.6	2.4	2.3	2.5	2.8	2.0
Temperature (℃)	Max	30.7	30.6	28.3	27.6	25.9	20.1	20.4
	Min	24.7	24.2	25.1	22.0	21.5	14.1	11.9
	Average	27.9	29.0	26.6	25.6	24.1	19.0	16.8
Humidity (%)	Max	49.8	44.3	58.5	57.8	49.5	71.4	80.6
	Min	33.8	28.6	35.8	33.9	30.8	37.3	32.1
	Average	42.4	36.6	45.6	44.8	39.9	52.6	54.1
Weather of Sapporo	Max (℃)	18.7(△4.1)	16.5(△3.5)	16.3(△4.7)	10.0(△0.9)	5.3(▼2.0)	-6.5(▼1.7)	-0.2(▼1.8)
	Min (℃)	6.1(△0.3)	6.3(△1.8)	8.0(△4.7)	3.3(△1.7)	0.8(▼1.3)	-1.0(▼0.3)	-4.3(△3.1)
	weather	cloudy	cloudy	cloudy	rain	sleet	fine	cloudy
	Humidity(%)	49	52	57	72	77	65	78
Menu		rice *buta-jiru* *hijiki-ni* fruit milk	rice *mabo-dofu* *aona-ae* fruit milk	rice miso soup foil grilling fruit milk	fried rice niratama-soup *peanut-ae* fruit milk	fried rice *tofu-soup* salada milk	fried rice niratama-soup *peanut-ae* fruit milk	bibimbap *wakame-soup* *hakusai-ae* fruit milk
Levels of satisfaction		0.9	0.8	1.1	0.9	1.4	1.5	1.4
Sensible temperature (℃)		25.0	25.4	24.1	23.2	21.6	17.9	16.0

Table 2 Menus and levels of satisfaction with food services (2006).

		1	2	3	4	5	6	7
Refrigerator temperature (℃)	Max	4.5	3.3	9.8	3.4	3.4	2.9	3.6
	Min	1.4	1.1	−0.3	1.3	1.6	0.8	0.1
	Average	2.5	2.3	2.2	2.2	2.5	1.7	2.3
Temperature (℃)	Max	30.8	25.6	29.3	33.9	28.9	28.2	27.1
	Min	25.4	21.7	21.4	22.4	19.8	19.2	19.7
	Average	27.5	24.4	26.7	28.8	24.8	23.7	24.5
Humidity (%)	Max	58.2	67.8	59.3	54.4	62.3	60.1	57.8
	Min	45.8	36.5	22.9	29.5	21.4	32.6	12.4
	Average	51.0	55.4	41.9	39.1	39.1	42.8	38.3
Weather of Sapporo	Max (℃)	23.2(△4.6)	14.5(▼0.8)	9.0(▼3.1)	14.8(△4.7)	10.2(△3.6)	4.5(▼0.6)	-2.5(▼2.1)
	Min (℃)	11.5(△2.1)	7.6(△1.3)	6.8(△3.0)	6.4(△4.2)	0.1(△0.3)	0.2(△1.7)	-6.7(△0.5)
	weather	fine	fine	fine	rain	fine	cloudy	snow
	Humidity(%)	54	51	46	57	53	90	61
Menu		fried rice *tofu-soup* salada milk	rice *buta-jiru* *hijiki-ni* fruit milk	rice *mabo-dofu* *aona-ae* fruit milk	bibimbap *wakame-soup* *hakusai-ae* fruit milk	rice pork and beands salada milk	fried rice *tofu-soup* salada milk	fried rice niratama-soup *peanut-ae* fruit milk
Levels of satisfaction		0.8	0.4	0.8	0.9	1.1	1.1	1.3
Sensible temperature (℃)		25.3	22.9	23.9	25.5	22.2	21.5	21.9

conducted (a total of 7 times), but the menu of "rice, *mabo-dofu*, *aona-ae*, fruit and milk" showed low satisfaction both in 2005 and in 2006 (0.8 points).

2. Sensible temperature and level of satisfaction with food services

We showed at under colum in table 1 and 2 results on sensible temperature and level of satisfaction with food services.

The sensible temperature is lower than the room temperature actually measured, and it is also reported that the sensible temperature is 1-2℃ lower than the actual measured value according to calculation by Koda et al[5]. When sensible temperatures exceeded the standard 25℃, levels of satisfaction with food services were low (0.8-0.9 points) both in 2005 and in 2006. Since sensible temperature can be calculated from air temperature, therefore, prior estimate and studies on levels of satisfaction with food services are considered to be necessary.

3. Correlation between room temperature and humidity/air temperature

The relationship between the temperature of the food service management practicum room and air temperature is shown in Fig.2-3, and a correlation between them was sought with the response variable as the air temperature and the explanatory variable as the room temperature. There is a correlation between the lowest measurement of room temperature and that of air temperature: $y=1.1x+17.4$ (**$p<0.01$, FY2005), $y=0.3x+20.3$ (*$p<0.05$, FY2006), showing a significant difference. In other words, when the air temperature was low, so was the room temperature. The relationship between the room temperature and humidity is shown in Fig.4-5. Room temperature and humidity are expressed in linear function formulas: $y=-3.0X+44.0$ (**$p<0.01$, FY2005) and $y=-0.5x+59.3$ (*$p<0.05$, FY2006), each showing a significant difference. From these results, it can be understood that in Hokkaido, the temperature drops sharply from October to January (Table 1-2), which also affects room temperature. However, no correlation is seen between refrigerator

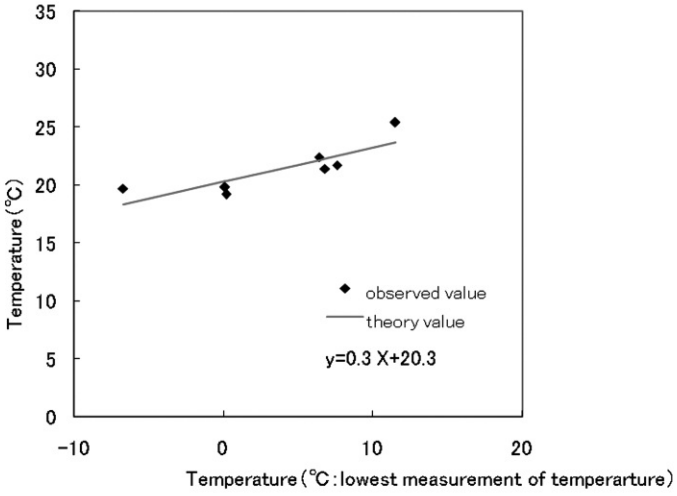


Fig.2 The relationship between temperature and air temperature (2006).

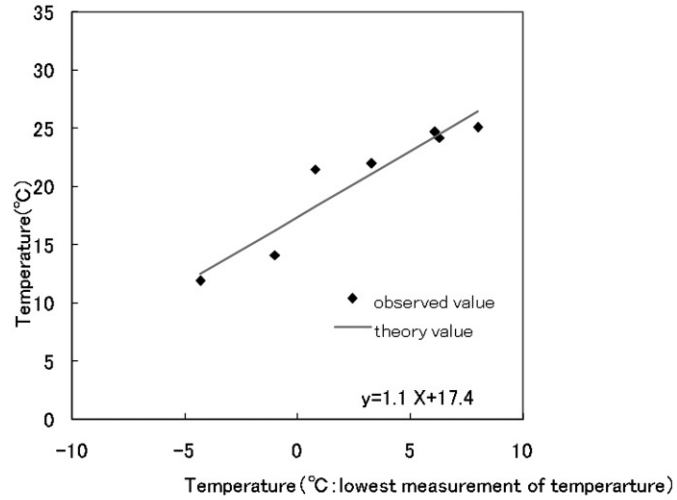


Fig.3 The relationship between temperature and air temperature (2005).

temperature and air temperature/room temperature/humidity.

According to Yoshida et al.[6], a refrigerator adjusts the temperature that has once risen taking time to lower it to its initial temperature, and adjusts its motor operation to lower its temperature in accordance with temperature changes inside the refrigerator, which is thought to have affected the above result. Measurement this time was conducted during the winter period in Hokkaido, which has the most significant change in temperature. We would like to conduct future studies on refrigerator temperature control and freezer temperature control such as for a freezer for preserved food during the summer period, when air temperature reaches the highest point in the year.

4. Power consumption is in proportion to ambient temperature and refrigerator contents[7].

Therefore, it is thought that when temperature conditions in the refrigerator rise, the motor operates, increasing the power consumption and raising the cost. Older refrigerators used to temporarily stop cooling and cycle on and off when the temperature went down to a certain point,

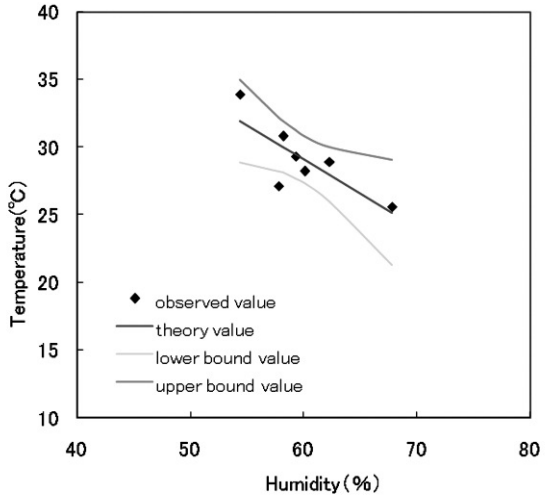


Fig.4 The relationship between the room temperature and humidity (2006).

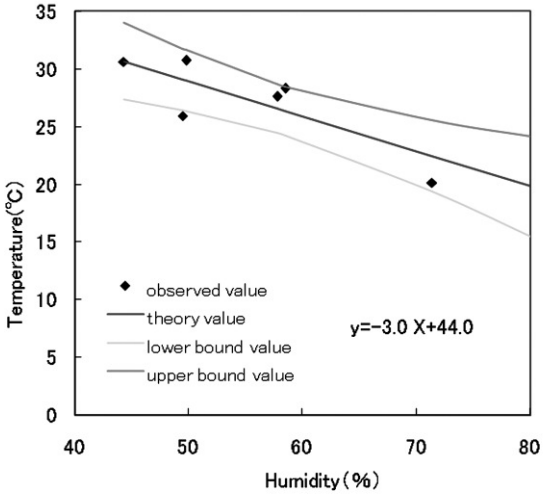


Fig.5 The relationship between the room temperature and humidity (2005).

but the introduction of inverter control and PAM control[8] in recent years has allowed meticulous control of the number of revolutions of the motor without stopping it. The minute-by-minute record of the refrigerator temperature during the food service management practicum showed the temperature was controlled inside the refrigerator. In order to reduce energy consumption and cost, it is necessary to shorten operating time of the refrigerator, which is affected by air temperature, room temperature, door opening/closing frequency and other factors.

The rated frequency of the refrigerator used this time is 50Hz, and its power consumption is 509W, and accordingly, the amount of energy consumed and CO_2 emissions can be obtained from refrigerator operating time (h).

Consequently, though it depends on the refrigerator model, the longer the refrigerator operating time (h) becomes, the more power consumption increases, accompanied by increased cost and CO_2 emission. Currently, energy conservation measures are taken for refrigerators[7]. In future food service management practicum, we would like to incorporate temperature control, putting mea-

sures viewed from energy consumption, as well as safety standpoints of HACCP, in perspective.

Summary

In this study, refrigerator temperature and room temperature/humidity are compared during the October-to-January period seven times each in FY2005 and FY2006, with the objective of studying energy conservation and temperature control in the food service management practicum.

1. Room temperatures were 24.0±1.6℃ in FY2005 and 25.8±2.2℃ in FY2006, showing a significant difference in yearly comparison (**$p < 0.01$). The average humidity was 44.0–45.3%, both within the standard 80%.
2. The menu with the highest refrigerator temperature was "rice, *mabo-dofu*, *aona-ae*, fruit and milk," and it can be inferred that menus, workflow lines of practicum groups and other factors affect refrigerator temperatures.
3. There is a correlation between the temperature in the food service management practicum room and air temperature: when the air temperature was low, the room temperature also became low. Room temperature and humidity are expressed in a linear function formula, each showing a significant difference.
4. As for sensible temperatures and levels of satisfaction with food services, satisfaction levels were low (0.8–0.9 points) when the sensible temperature exceeded the standard 25℃ both in FY2005 and FY2006.
5. As the refrigerator operating time (h) becomes longer, power consumption and CO_2 emission increase, and therefore, measures need to be taken viewed from energy consumption in the food service management practicum.

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