15. RECENT PROGRESS IN ENVIRONMENTAL PHYSIOLOGY OF DOMESTIC ANIMALS IN JAPAN

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The livestock lives in environment. In studies on livestock raising, therefore, problems involved in environment appear to be fundamentally important. Nevertheless, attention has been paid to such problems for only 20 years. Until recently, particular breeds of livestock were raised only in suitable areas, and the livestock is generally endowed with a certain adaptability. Thus, problems involved in environment used to cause little difficulty in livestock raising. However, during the last two decades in Japan, the demand for livestock products has rapidly expanded, which has resulted in common practice of raising domestic animals and poultry of only a limited breeds all over the country. Japan is small in area, but stretching rather long from south to north. Therefore, her climate is a complexed one. For these reasons, introduction of domestic animals as they are from developed European countries has caused some technical difficulties. Furthermore, the past small-scale enterprises have been replaced by much larger-scale ones, which has brought about revolution in livestock raising. Another difficulty has been caused by introducing European technics of livestock feeding and management as they are into this country. Under such circumstances, investigations on environment have been carried out.

Environment may imply "natural environment" and "artificial environment." Attention has been paid to such common problems as temperature, humidity, air movements (wind), rainfall, altitude, noise, lighting, etc. Much has been studied on such projects as environmental factors and productivity, environmental factors and physiological functions, adaptation, indicators of environment, improvement in environment, etc. The present report deals with, among the important investigations carried out in the past decade, mainly heat and some fundamental studies on improvement of hot environment.

Characteristics of the Climate in Japan and Enviroment in the Stall

Japan is situated in middle latitude, stretching from latitude 25° to 45° north. However, as seen in Figure 1, her climate is very complexed. From the climate, Japan can be divided into two areas, the Pacific side and the Japan Sea side.[1] The difference in climate between these areas is large in winter and small in summer. Each area is characterized by 1) in the Pacific side area, there is much rainfall from typhoons and during the rainy season. The total rainfall is over 2,000 mm. Damages from typhoons are often. 2) The Japan Sea side area has much snowfall; the totall snowfall is over 4 m. There is also much rainfall during the rainy season and typhoons. The yearly rainfall reaches about 2,500 mm. 3) In the west and north parts of Hokkaido, the temperature goes down to −10°C or below. Snowfall reaches about 50 cm. The summer is very short.

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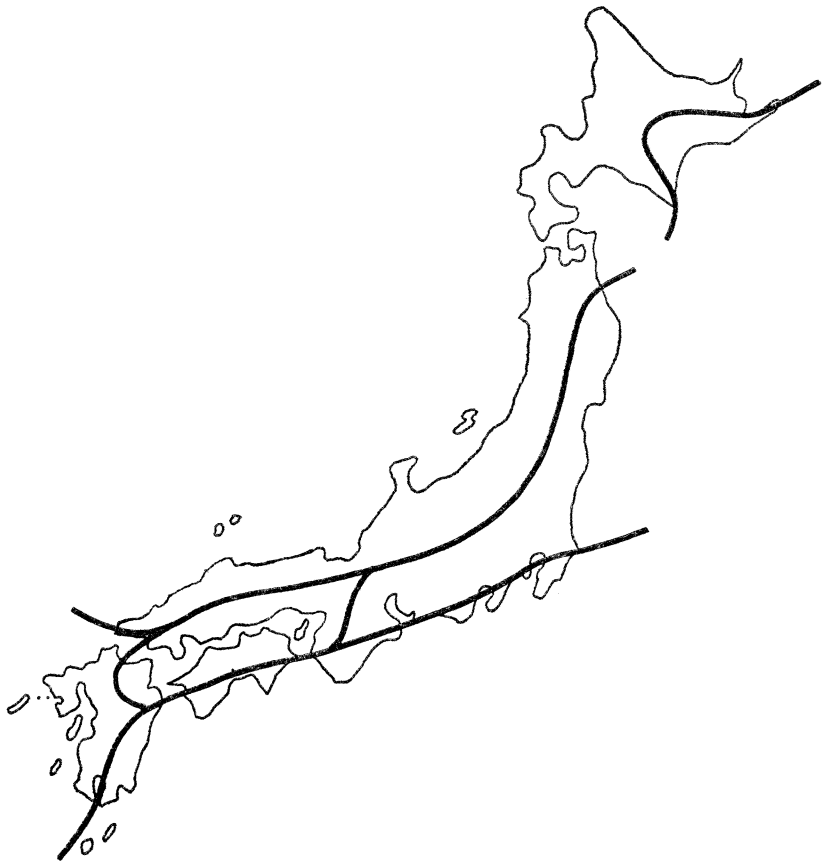

Fig. 1. Divisions of the climate in Japan (from Sekiguchi)

Since it is situated to the east of Asian Continent, a large part of Honshyu belongs to the zone of temperate, humid climate. Hokkaido, Tohoku and Chyubu mountainous areas belong to the zone of sub-frigid, humid climate; so far as temperature is concerned, however, they belong to the frigid zone. Japan can be divided into many characteristic climatic zones, because she is situated to the east end of Asian Continent with the Japan Sea between them, surrounded by both warm and cold currents and has complicated geographical features, being rich in mountainous areas. For these reasons, her climate is characterized by: a) marked geographycal differences, b) the east coastal climate, c) seasonal wind climate, d) much rain and high humidity, e) complicated seasonal and climatic changes, and f) frequent occurrence of meteorological calamities.

With regard to temperature in summer, it becomes higher than 20°C in all areas. Such high temperatures as 26°C or above continue in Setouchi area and the southern part of Kyushu, with an average daily maximum temperature of 32.5°C. It sometimes reaches as high as 38°C. In winter, it becomes below 0°C in the inland areas north to Chyubu and mountainous areas. It becomes down to −10°C or below in some parts of Hokkaido, with an average daily minimum temperature of −16°C. The minimum temperature sometimes goes down to as low as −40°C or below. It is not uncommon that yearly temperatures vary in a range over 40°C.

The problems encountered in feeding and management in the stall under such

environment were investigated on dairy cattle, beef cattle, pigs and chickens in 1969 and 1970. Some excellent examples were selected on the basis of previous knowledge and experiences.[2]

We investigated environmental conditions of the stall for dairy cattle at the National Institute of Animal Industry in Chiba. We found that in summer the temperature and humidity of the stall for dairy cattle changed in a similar mode as the ambient ones, because the stall was left open, and that the accommodated cows, excreting heat and moisture, worsened the conditions by elevating the indoor temperature.[3] The indoor temperature of the stall differed considerably from the outdoor temperature during winter, because it was usually kept closed. The accommodated cows created environmental conditions entirely different from the outdoor conditions. Stalls on common farms are influenced more by the outdoor conditions, particularly by heat during the summer and coldness during the winter. The increase in the carbon dioxide content was highly correlated to the elevation in temperature and humidity, rapidly reaching a constant value. The findings indicate the necessity for ventilation for preventing stagnation of heat during the summer and for stagnation of carbon dioxide gas during the winter.

Effect of Heat

Under the climatic conditions of our country, the problem arising from the influence of environmental temperature, especially of heat, is so important that must be studied first. Although the actual temperature is not so high as that in South-Asian countries, it was found that the cow tended to decrease in milk production and the weaning animal to stunt by the high temperatures during the summer.

Studies were made by S. Okamoto et al.[5] at Kyushyu Agricultural Experiment Station during the period of 1953–1962 to find the causes for decreased milk production, the change in quality of milk, particularly the decreased fat contents, and in compositions of blood and urine, occurring in the summer and also by experimentally induced high environmental temperatures. They reported that the higher the milk production of the cow, the greater the decrease rate in milk and milk fat production. Seasonal variations in blood compositions such as erythrocyte and eosinophile populations, serum protein, cholesterol and ascorbic acid contents, and chemocorticoid excretion, were studied. It was suggested that the adrenocortical glands of such cows that are otherwise good milk producers but showing markedly decreased rate in milk production from heat were more hyperfunctional.

Interrelationships among environmental temperature, physiological conditions of the animal, milk production, and milk composition were discussed statistically by K. Kano[7] of the Livestock Farm, University of Tokyo. He observed that milk production was affected at an ambient temperature higher than 20°C, and the heart rate, the rectal temperature, and the packed cell volume were clearly correlated to milk production.

Recently, S. Watanabe et al.[8] analyzed the Na:K ratios in mixed and parotidian saliva in heat stress and suggested an increased aldosterone secretion.

Before S. Okamoto et al.[6] reported, the change in body temperature, pulse and respiration rates of Holstein cows in a hot environment had been reported by S. Ishii[9] of the same experiment Station. He observed that the body temperature and the respiration rate increased markedly as the environmental temperature rose, and that the critical temperatures affecting the body temperature and the respiration rate were 26°C and 23°C, respectively. He also carried out two different experiments; one was in the sun in the summer and the other in test rooms with artificially controlled temperatures. The results indicated that the body temperature was more suitable as an indicator of heat tolerance than the respiration rate. Some other experiments were also carried

out to find the causes of the diurnal variations in body temperature, pulse and respiration rates, and to examine the possible prevention of the elevation in body temperature by experimentally reversing day and night.

Feed digestion in a hot environment, which has been paid much interest by many scientists,[10] affected productivities of the animal. The influence of high environmental temperature and supplementation with enzyme on digestion of nutrients by beef cattle were studied by I. Kurohiji et al.,[11] Kyushyu Agricultural Experiment Station. They observed a reduced rate of digestion of organic matters in a ration in a high temperature environment compared with that in a low temperature environment, and a particularly reduced digestion of crude fibers in a high temperature environment in the summer.

Studies were made on energy metabolism in cattle by T. Hashizume et al.,[12] National

Table 1. Effects of temperatures on the average cardiorespiratory functions of three Holstein cows

	6°C	17°C	28°C
Body temperature (°C)	38. 1	38. 1	38. 4
Pulse per min.	42	41	41
Respirations per min.	9	16	23
Ventilation rate (S. T. P.) liters per min.	41. 1	50. 9	68. 0
Ratio of O_2 Consumption to ventilation rate (% O_2 consumed/air inhaledd)	3. 31	2. 53	1. 97

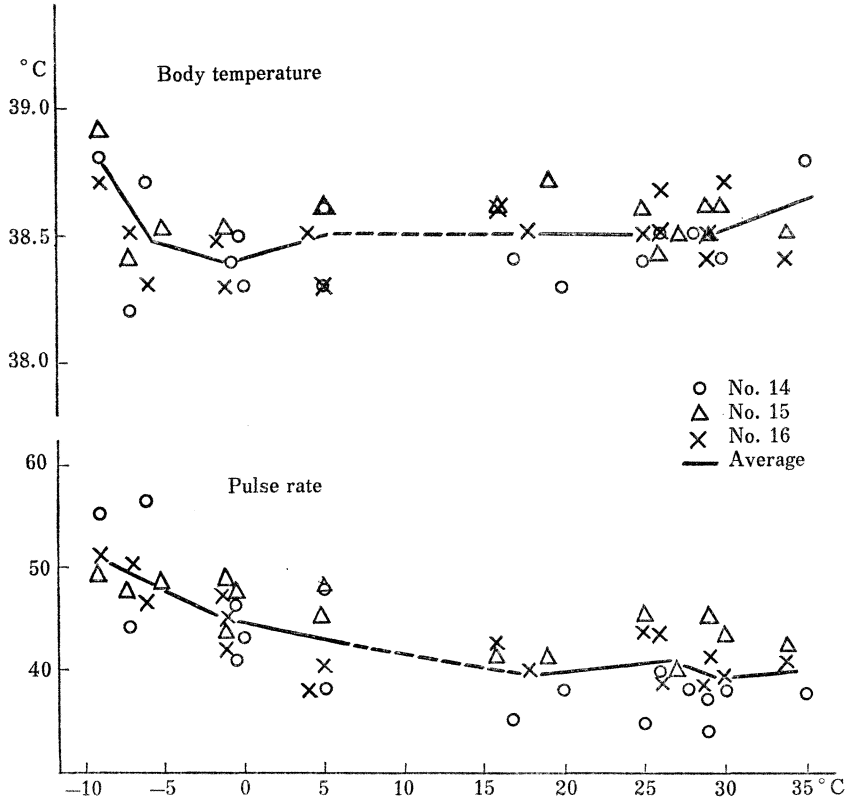

Fig. 2. The influences of temperatures on resting metabolism

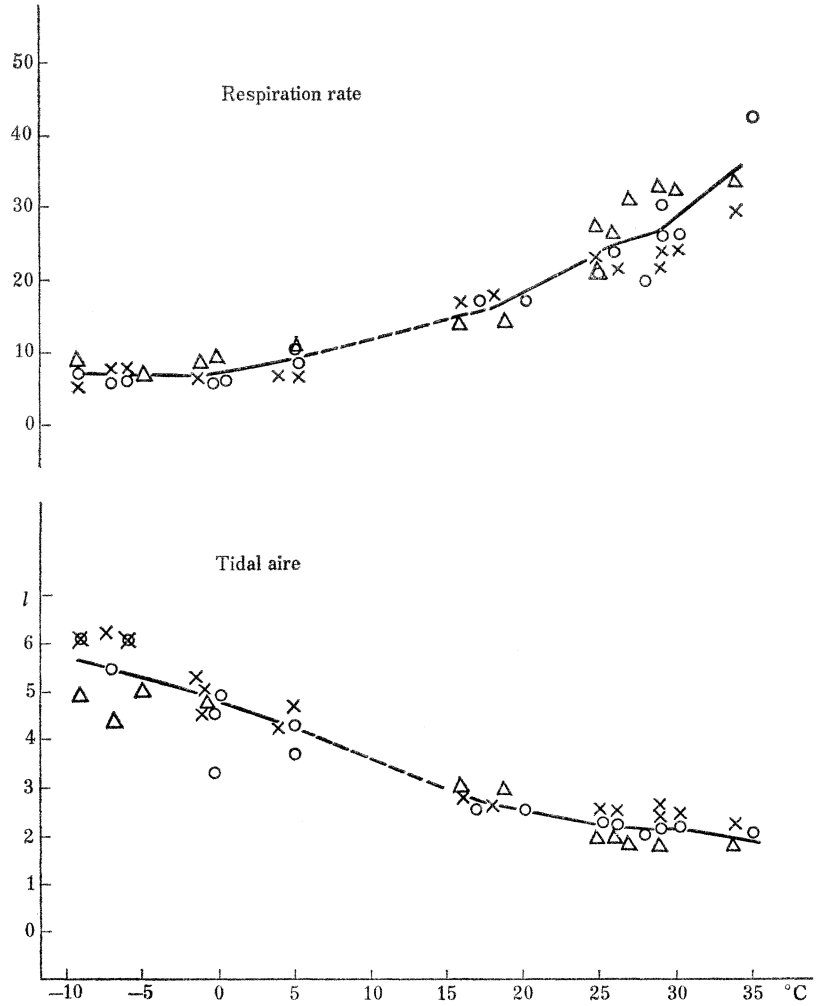

Fig. 3. The influences of temperatures on resting metabolism

Institute of Animal Industry in Chiba. The resting metabolism and the cardiac function were measured in Holstein cows maintained in air conditioned test room regulated at three levels of temperatures (Table 1). Later, influences of temperatures on resting metabolism were studied by T. Hashizume et al.[13] in the cattle maintained for six months in the climatic rooms regulated at various temperatures, which gradually elevated from 18°C up to 35°C or lowered from 18°C down to −10°C. The results are shown in Figs. 2–4.

From these results, it was found[14] that the physiological specific-ventilation, expressed in terms of $1:0_2\%$ consumed, was a suitable index of the balance of the production and consumption of heat in the animal body.

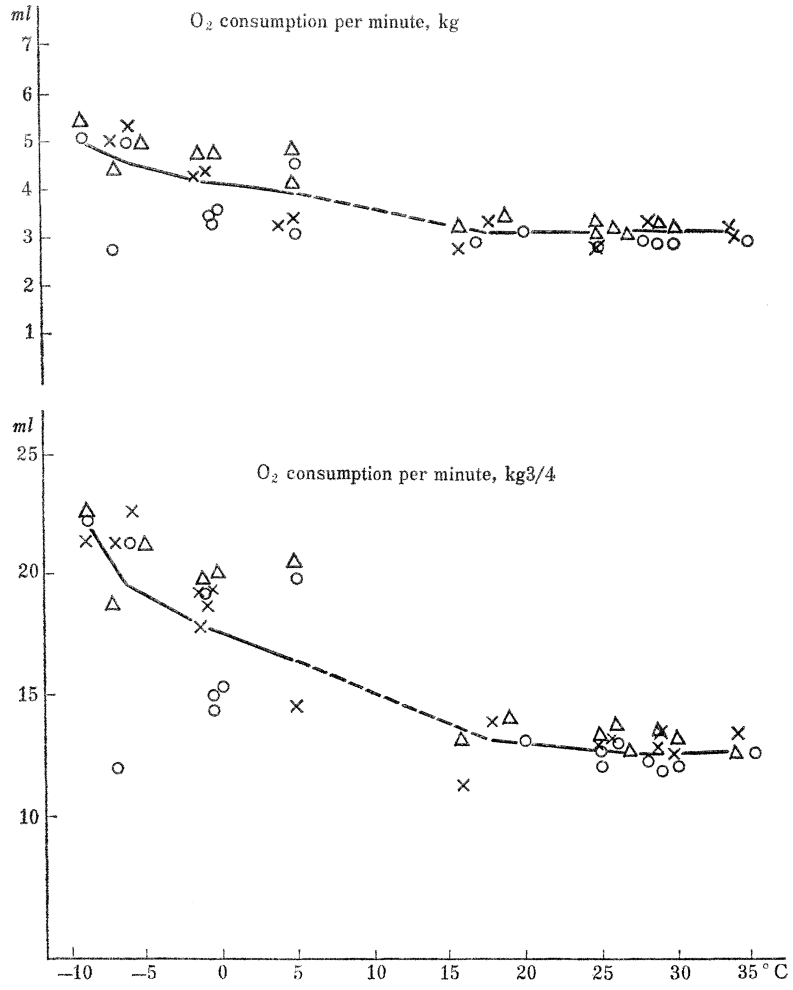

Fig. 4. The influences of temperatures on resting metabolism

Environmental Temperature and Feed Intake

It was reported previously that the environmental temperature influenced the feed intake[9] and digestion of nutrients.[11] S. Yamamoto of Tohoku University was much interested in this problem in relation to rumination and studied the effects of the environmental temperature and feed intake upon the physiological functions of the ruminant. 1) The correlationship between the environmental temperature and the physiological reaction in the sheep fed on corn silage was studied.[15] Any physiological reaction observed could be regarded to have resulted from the interaction between the feed consumption and the environmental temperature; the respiration rate was considered to be a suitable indicator of the physiological reaction of the heat balance. 2) Correlationship between the environmental temperature and the physiological reaction in the sheep fed on orchard hay was studied in comparison with those fed on corn silage.[16] The results suggested that the physiological reactions in the sheep fed on silage are affected more markedly than those fed on hay. 3) Differences in the physiological reactions were measured in the

sheep before and after feeding at various environmental temperatures.[17] Although the the effects of the environmental temperatures were not necessarily very clear, the heart rate remarkably increased by feeding and the rectal temperature rose in response to the increase in the environmental temperature, especially after feeding. 4) Thhe role of the rumen contents on the temperature regulation in the ruminant was studied by removing the whole rumen contents through the permanent rumen fistula.[18] The fact that removal of the rumen contents suppressed the increase in the respiration rate under a hot condition indicates that the rumen content accelerates the initiation of thermal polypnea inducing a high level of the respiration rate. 5) Furthermore, investigations were made on the effect of the rumen temperature on the physiological reactions in the sheep and goats with the rumen temperature controlled by pouring or perfusing with water held in a temperature-controlled room.[19] It was found that thermal polypnea developing in the animal in the hot room diminished immediately by administering with cold water into the rumen. Polypnea developed in the animals kept in a room regulated at 20°C only when the rumen temperature raised above 42°C.

It has been considered that the sun as a heat source markedly influences physiological conditions of the animal. Some studies were made in the sheep on pasture by S. Yamamoto et al.,[20] and T. Ito and K. Miura.[21] They summarized that the effects of heat from the sun on the increase in the respiration rate resulting from feed intake appeared at temperatures higher by 10–17°C than that resulting from feed intake in the temperature controlled room.

Effect of Humidity

High temperature restrains the animal from heat dissipation by radiation, convection, or conduction; high humidity also restrains the animal from heat dissipation by evaporation from the outer surface or the respiratory tract. The characteristic heat of this country consists of high temperature and high humidity. Attempts were made, therefore, to examine the effects of high temperature on the cow with special attention to high humidity. Under the different heat conditions, one at 40°C (higher temperature) in combination with 50% humidity and the other at 37°C with 85% humidity (higher humidity), effects of heat on the respiration rate and the body temperature of the cow were measured (Fig. 5). In these experiments, the effect of humidity appeared to

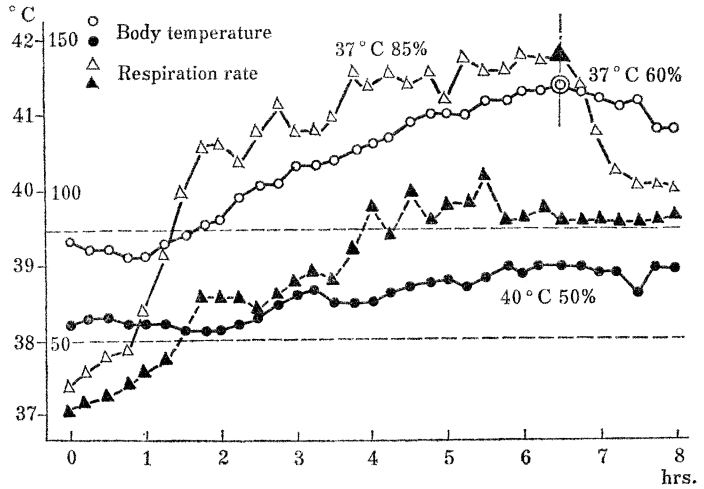

Fig. 5. The effect of heat

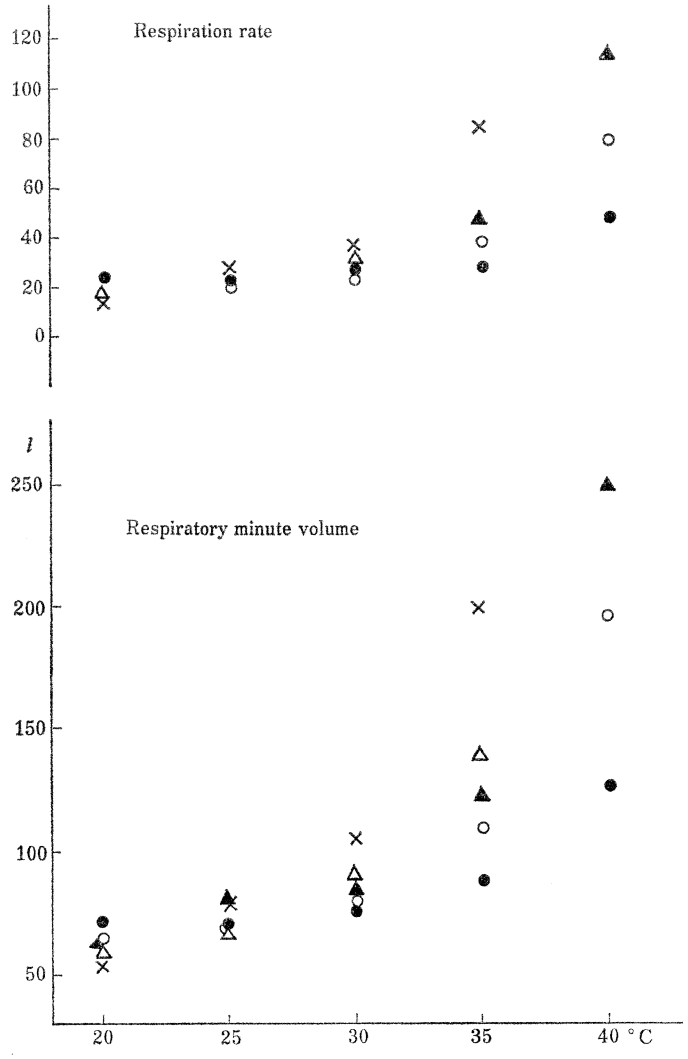

Fig. 6. Ambient temperature and relative humidity (1)

be larger than that of temperature. We, intending to define the effects of temperature and humidity on the cow, set up 25 different conditions in the climatic room by combining each of five temperatures ranging from 20°C to 40°C and of five humidities ranging from 50 to 90%.[22] The results are shown in Fig. 6; the influence of humidity became apparent at a temperature above 30°C.

It would be convenient to express a combination of a certain temperature and humidity in a single index value. From the data obtained by the above experiments, an index in a formula, D.T.×0.1+W.T.×0.9, reported by M. Kato[23] (Fig. 7) appeared to be most suitable. In the formula, D.T. is dry-bulb temperature and W.T. wet-bulb temperature. For a similar purpose, an attempt was made by K. Mimura[24] to obtain an index of effective temperature in Holstein cows on the farm of Hiroshima University. The formula, DBT × 0.35 + WBT × 0.65, was obtained. The values from this formula did not alawys accord with ours. It seemed that the values differed depending upon the

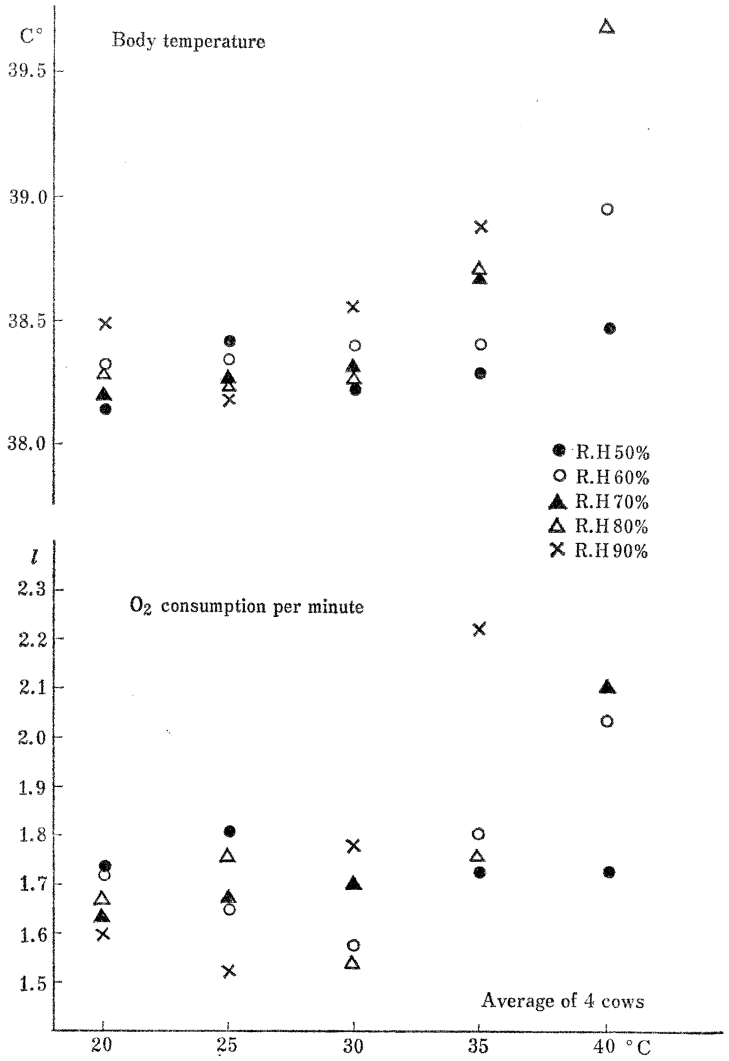

Fig. 6. Ambient temperature and relative humidity (2)

field and the controlled room environments.

In the studies on the effects of dry-bulb and wet-bulb temperatures on the respiration rate of the sheep, S. Yamamoto et al.[25] found that the formula, DBT × 0.1 + WBT × 0.9, was applicable to all the data. The effective temperature for the pig was also studied by S. Yamamoto et al.[26] From the average respiration rate as an index, the formula, DBT×0.6+WBT×0.4, was obtained for rearing pigs. The correlation between the factor for DBT and that for WBT may indicate characteristic regulation mechanism for the body temperature of rearing pigs. The effects of heat near the upper critical temperature in the climate room at the National Institute of Animal Industry on the physiological function and milk production of lactating cows were measured by I. Notsuki et al.[27] It was clarified that the milk production decreased remarkably above 32.5°C and 50% humidity, and the responses to heat appeared in the order of; increased physiological specific-ventilation, increased respiration rate, increased repiratory volume,

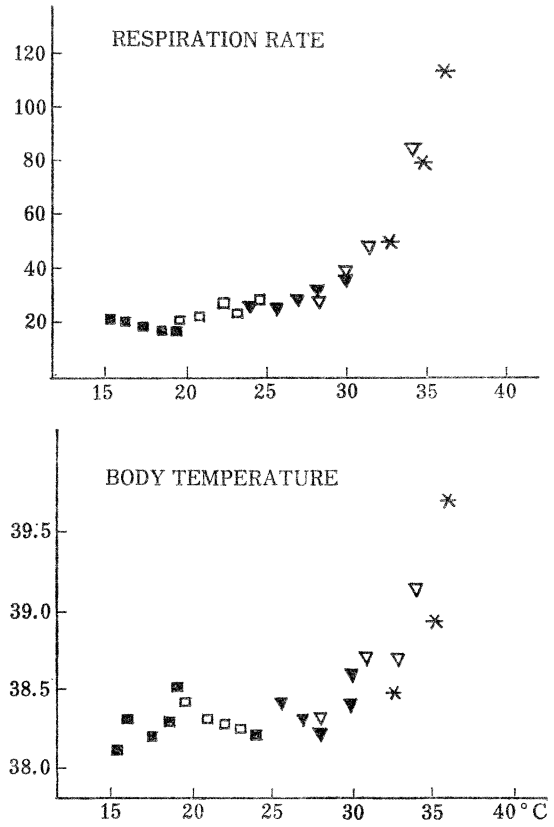

Fig. 7. Relationships between a single index, combined the temperature and humidity, and physiological reactions of cow

increased drinking water consumption, raised skin temeprature, decreased body weight, decreased hemoglobin content, increased 0_2 consumption, raised body temperature, and decreased appetite and milk production. From the schematic diagram of Kleiber, a new equation to estimate the lower critical temperatures for dry and lactating cows were presented by T. Hamada[28] of the National Institute of Animal Industry.

Effect of Rainfall and Air Movement

Rainfall is one of the important climatic elements in this country. The animal may get wet in the rain; its influence upon the regulation of the body temperature was studied with sprinklers during the four seasons by H. Tatsumi et al.[29] of the National Institute of Animal Industry. In general, the wet skin increased heat dissipation from the body surface, resulting in decreased respiration rate and the body temperature by about 0.5°C in 2 hrs. This finding may be useful for preventing the increase in the body temperature due to the heat accumulaton in the summer.

Wind can be harmful to unsheltered animals at low temperatures. To find the extent of influence of wind in winter, H. Tatsumi et al.[30] made measurements on the cows kept in climatic rooms regulated at different temperatures between 15°C and −15°C at an air movement speed below 3 m/sec. The oxygen consumption increased largely at temperatures below 0°C (Fig. 8).

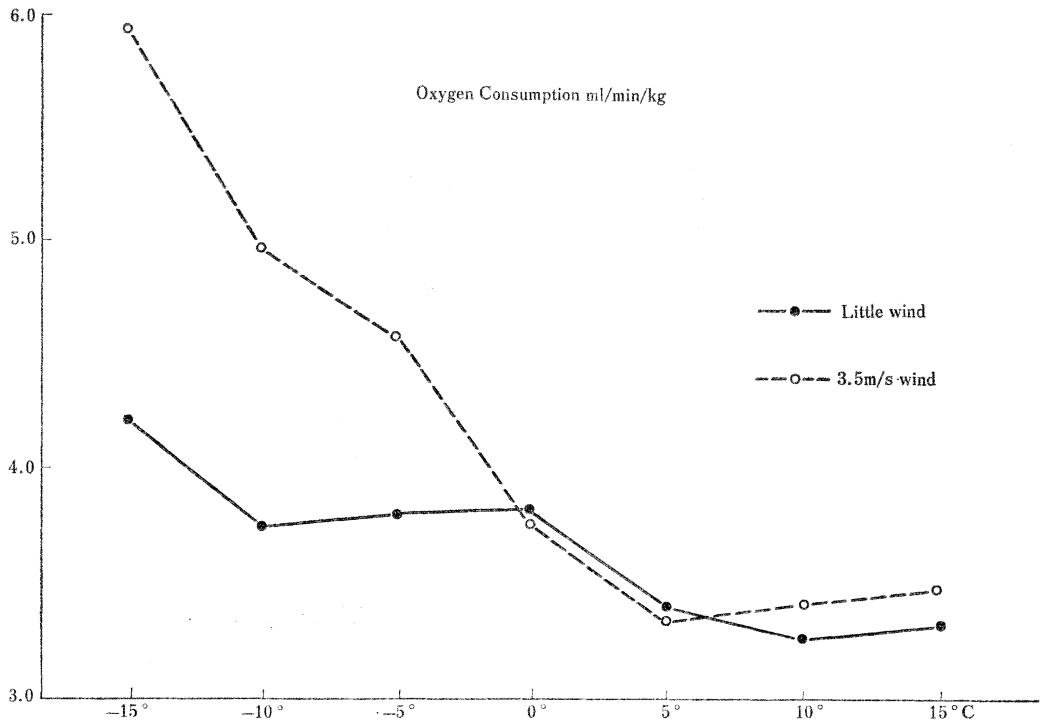

Fig. 8. Cold and wind

To relieve the cow from the hot environmental conditions in the summer, the effects of the room cooler upon the milk production by dairy cows were studied by S. Okamoto et al.[31] of Kyushyu University. The room cooler was found to be effective in the experiments, but seems to be too expensive to use practically at the present time. To make use of wind for this purpose, effects of air movements at a high environmental temperature was investigated by I. Notsuki et al.[32] at an air movement slower than 0.7 m/sec, at a temperature between 25–40°C and a humidity between 59–90% in the climatic room at the National Institute of Animal Industry. It was ascertained that the experimental air movement at a high temperature increased exhalation of heat from the body surface of the cow and diminished the heat stress.

The Effect of High Altitude

It is cooler in areas of higher altitudes than those of lower altitudes. It would be promising to make use of such regions for relieving the animals from heat in summer. M. Kanematsu et al.[33] of Shinshyu University carried out ecological and physiological studies on grazing a herd of the breed of dairy cattle newly developed in this country in mountainous grassland located at high altitude. In relation to these data, H. Sawazaki et al.[34] of Tokyo University surveyed electrocardiograms and physical properties of blood samples of cows of three groups; two groups were raised at high altitudes and the other at a low altitude. Cardiac hypertrophy was recognized in about 60% of the cows raised at altitude of about 1,500 m above the sea level, but in none of these animals circulatory disturbance was observed. It was presumed that an environment of a high altitude causes cardiac hypertrophy, which might serve as an useful indicator of the influence of high altitude. He[35] studied this point more in detail with

five groups of mice. It was confirmed that exposure of the animal to a high altitude increased the weights of the heart, the adrenal gland and the kidney.

On Poultry Feeding

Two remarkable results reported recently will be introduced. M. Yoshida et al.[36] of the National Institute of Animal Industry studied the effects of environmental temperature and dietary energy and protein levels on the performance of broiler-type chicks. The following conclusions were drawn, which will be presented briefly. Levels of dietary energy and protein and environmental temperature gave sharp influence upon the performance of the chicks. The following equations, 2) and 4), were found suitable to describe the relationship:

$$2)\quad Y_1 = -43.14 + 4.264E + 6.685P + 0.01877(T-22.5)^3$$

$$4)\quad Y_2 = 19.13 + 7.541E + 5.184P - 0.7109\ (T-17.9)^2$$

where, Y_1: feed efficiency (g/kg), Y_2: body weight gain in four weeks (g), E: dietary level of total digestible nutrients (%), P: dietary protein level (%), and T: environmental temperature (°C). It seems that at an environmental temperature between 19 and 23°C, growth rate of the chicks may be close to the maximum and feed efficiency almost constant.

On the other hand, from the studies on the effects of environmental temperature on egg production, feed intake and water consumption by laying white Leghorns, T. Ito et al.[37] reported that the higher the temperature, the lesser the feed intake. At 35°C, egg production rate was lowest, being 73%, but feed efficiency for egg production was highest, being 61%; the net efficiency for egg production was highest at 32.5°C.

The two reports would be of interest in feeding and management of poultry.

Recent progresses in the studies of environmental physiology of the domestic animal in this country were reported. The report, however, dealt mainly with the cow and little with the swine, poultry, and other species. Much more has to be studied on the influences of environmental factors, such as cold, snow, photoperiod, noise, gas contents, behavior, adaptation, etc.

In near future, practice of large-scale, intensive feeding of animals and poultry shall be realized everywhere in this country. The problems of environmental control will be more important in improving environmental conditions of the stall. More studies will also be needed on adaptation of the domestic animal in the field and the climatic room.

Discussion

Tim Bhannasiri, Thailand: Concerning the decreasing in milk production during the summer time, what do you think about the main problem, the temperature or humidity?

Answer: I think that, of course, the high temperature is main problem in summer. However, as the formula, D.T.×0.1+W.T.×0.9 (Fig. 6) shows, the effect of humidity becomes clear above 30°C, and the milk production decreases remarkably above 32.5°C and 50% in Holstein cow in climatic room experiments.

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