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A Cross-regional Comparison of Growth in Japanese Black Calves

Hisashi NABENISHI [1]* and Atusi YAMAZAKI

[1] Laboratory of Animal Feeding and Management, Division of Animal Science, School of Veterinary Medicine, Kitasato University (Towada, Aomori, 034-8628, Japan)

Abstract

This study, conducted over a four-year period (January 2013 to December 2016) in Northern and Southern Japan, aimed to compare environmental factors affecting the growth of calves born at the same time of the year in these two geographical regions. Data were collected from calf markets to calculate the daily gain (DG) of each calf based on body weight and age (in days). There were no significant differences in DG between the two regions. In both regions, DG of calves born in winter and spring tended to be lower than that of calves born in summer and fall. In Northern Japan, the mean DG showed a significantly negative correlation with the temperature–humidity index (THI) during the three months after birth. However, there was no significant correlation with THI during the month of birth. By contrast, in Southern Japan, the mean DG showed a significantly positive correlation with THI during the month of birth. However, there was no significant correlation with THI during the three months after birth. These observations suggest potential drawbacks of the current barn structures adapted to the environment of each region and indicate the importance of appropriate rearing management, considering the seasonal changes of each region.

Discipline: Animal industry
Additional key words: temperature-humidity index (THI), calf, heat stress, cold stress

Introduction

Ambient temperature, relative humidity, and wind speed are important environmental factors affecting thermic stress. Thermic stress in calves negatively affects welfare (Silanikove 2000) and indirectly causes economic losses because of the costs incurred by reduced growth (Virtala et al. 1996, Snowder et al. 2006). Therefore, understanding environmental factors associated with calf growth is essential to improve calf growth.

Housing calves aims to reduce climatological effects and provide a specific microclimate. Selecting a housing system depends on predominant climate factors in a region (Webster 1974a). Each housing system has its own climatic traits, associated benefits, and drawbacks. The most favorable housing for dairy calves depends on how cold and hot weather affects calf growth and health (Collier et al. 1982, Young 1983, Broucek et al. 2009). Therefore, the incidence of thermic stress in calves may be related to the type of housing selected (Moore et al. 2012).

Climate conditions in Japan are characterized by four distinct seasons, with a large variation in temperature and humidity; this variation is expected to significantly impact calf health and growth. The Japanese Black cattle are widely raised for their meat. Their calves are characterized by a lower-than-normal birth weight (Ogata et al. 1999). In addition, these calves are more susceptible to illness or death compared with Holstein calves in Japan (Ohtsuka et al. 2011). Nabenishi & Yamazaki (2017) demonstrated the effects of the temperature-humidity index (THI) on the health and growth of Japanese Black calves in Southwestern Japan. Many studies have focused on either regional or seasonal impacts on cattle production but not on both on a comprehensive, national scale. In addition, the Japanese archipelago is extremely elongated longitudinally, and its topography varies considerably. Therefore, regional differences in the climate are vast, and calf growth may vary because of seasonal fluctuations and the diverse geographic and climatic landscape of Japan. This study aimed to quantify and compare regional and

*Corresponding author: e-mail nabe9@vmas.kitasato-u.ac.jp
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calf markets held in each area during the study period was 48 times. Daily gain (DG) was calculated using measured body weight and age (in days) of the two sexes at the calf markets:

DG (kg/day) = body weight (kg) at the calf market/ age (in days) at the calf market.

The mean monthly value of the daily mean temperature and relative humidity data of the two regions during the study period were obtained from local meteorological observatories (Northern Japan: Aomori City; Southern Japan: Miyakonojo City) made available by the Japan Meteorological Agency (2017). Monthly mean THI was calculated using the following formula, previously reported in Nabenishi et al. (2011):

$$\text{Mean THI} = [0.8 \times \text{mean T} + (\text{mean RH }(\%)/100] \times (\text{mean T} - 14.4) + 46.4$$

T: temperature (°C); RH: relative humidity (%).

2. Statistical analysis

Paired student's t-tests were performed to compare THI and DG (pairs with month and sex) between the regions. DG was compared across the months using analysis of variance using the general linear model, followed by Tukey's honest significant difference test. The model included the effects of sex, region, month of birth, and region × month of birth interaction. Pearson's correlation coefficients were calculated to evaluate potential correlations between DG and THI during the month of birth to three months after birth for the two regions. All statistical analyses were performed with JMP, version 8.01 (SAS Institute Inc., Cary, NC), and a *p*-value of <0.05 was considered statistically significant.

Results

The monthly mean temperature, relative humidity, and THI of the two regions throughout the study period are shown in Table 1. The monthly mean THI of Northern Japan was significantly lower than that of Southern Japan throughout the year ($p < 0.01$). THI of July in Northern Japan was the same as that of June in Southern Japan.

The calf markets in Northern and Southern Japan during the study period revealed respective mean (±SD) body weights of 302.3 ± 6.5 and 288.5 ± 5.2 kg and ages of 300 ± 4.1 and 287.0 ± 1.5 days. The mean DG values of Northern and Southern Japan were 1.01 ± 0.02 and 1.01 ± 0.02 kg/day, respectively. There were significant effects of sex ($F_{1, 167} = 3592.9$, $p < 0.01$), month of birth ($F_{11, 167} = 8.6$, $p < 0.01$), and region × month of birth interaction ($F_{11, 167} = 4.1$, $p < 0.01$). However, there was no significant effect of region ($F_{1, 167} = 1.7$, $p = 0.19$). Figure 2 shows the comparison between the regions for mean DG, sorted by month of birth. There were no significant differences between the regions throughout the year. In both regions, the DG values of calves born in winter (December to February) and spring (March to May) tended to be lower than those of calves born in summer (June to August) and fall (September to November). In Northern Japan, the DG values of calves born in April and May were significantly lower than those of calves born in September. In Southern Japan, the DG values of calves born in March and April were significantly lower than those of calves born in August.

Table 2 shows, for the two regions, the relationship between the mean DG at the calf market and monthly mean THI during the birth month till three months after birth. In Northern Japan, the mean DG showed a significantly negative correlation with THI during the two ($p = 0.005$) and three months after birth ($p < 0.001$). However, there was no significant correlation with THI during the month of birth and one month after birth. By contrast, in Southern Japan, the mean DG showed a significantly positive correlation with THI during the month of birth ($p < 0.001$) and one month after birth ($p = 0.014$). However, there was no significant correlation with THI during the two and three months after birth.

Table 1. Monthly mean temperatures, relative humidity, and THI for the study period (four years; January 2013 to December 2016)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern Japan												
T (°C)	-1.3 ± 0.5	-0.5 ± 0.7	3.3 ± 0.6	8.9 ± 0.5	14.4 ± 0.7	18.0 ± 0.2	22.3 ± 0.4	24.1 ± 0.3	19.9 ± 0.4	13.1 ± 0.5	7.1 ± 0.8	1.8 ± 0.6
RH (%)	80.5 ± 1.2	76.3 ± 1.9	71.0 ± 0.7	63.8 ± 3.0	70.5 ± 2.5	79.8 ± 2.1	80.3 ± 1.7	78.0 ± 1.2	75.8 ± 1.5	72.0 ± 1.6	75.0 ± 1.0	78.8 ± 1.9
THI	32.8 ± 0.8	34.6 ± 1.3	40.1 ± 1.0	49.1 ± 1.0	57.1 ± 0.9	63.4 ± 0.4	70.8 ± 0.4	73.6 ± 0.7	67.6 ± 1.6	56.6 ± 0.9	47.2 ± 0.7	36.8 ± 1.6
Southern Japan												
T (°C)	6.3 ± 0.3	4.6 ± 0.3	11.7 ± 0.4	16.1 ± 0.7	20.1 ± 0.3	22.4 ± 0.4	26.7 ± 0.6	27.3 ± 0.4	24.2 ± 0.6	19.9 ± 0.7	14.1 ± 0.9	8.2 ± 1.0
RH (%)	72.5 ± 2.4	71.8 ± 1.8	71.3 ± 1.3	73.8 ± 3.7	73.0 ± 2.7	86.0 ± 2.1	81.0 ± 2.1	79.8 ± 2.5	80.3 ± 2.5	76.3 ± 2.2	80.0 ± 1.5	76.0 ± 0.7
THI	45.5 ± 0.4	47.6 ± 0.4	54.1 ± 0.6	60.3 ± 1.0	66.4 ± 0.4	71.0 ± 0.5	77.8 ± 0.6	78.7 ± 0.4	73.0 ± 0.5	65.6 ± 0.7	57.0 ± 1.4	47.8 ± 1.3

T: temperature; RH: relative humidity; THI: temperature-humidity index

Discussion

We compared the growth of calves born during the same period in Northern Japan, which is characterized by cold temperature in winter, and Southern Japan, which is characterized by hot conditions in summer. We found no significant differences in DG between the two regions during the study period. When calves were sorted by birth month, we did not observe any significant differences in DG between the regions. We were surprised that no significant difference was found in calf growth between the two regions despite significant regional differences in monthly mean THI throughout the year. In Northern Japan, closed-type barns are used to mitigate the impact of cold temperature and snow coverage in winter, with rearing management focused on anti-cold measures. By contrast, open-type barns and rearing management focused on anti-heat measures are used in Southern Japan. The barn type tends to shift from the closed-type to the open-type along the border of the southern part of Tohoku region (Okada et al. 1984). The capacity of cows to compensate for climatic effects may vary with the housing system (Tripon et al. 2014). Thus, we assumed that the barn and management styles adapted to the environment of each region modify the impact of the external environments.

In this study, we found no significant effect of region on DG over the study period. However, there was a significant interaction between region and month of birth. In addition, we also observed different DG responses to THI during the month of birth and three months after

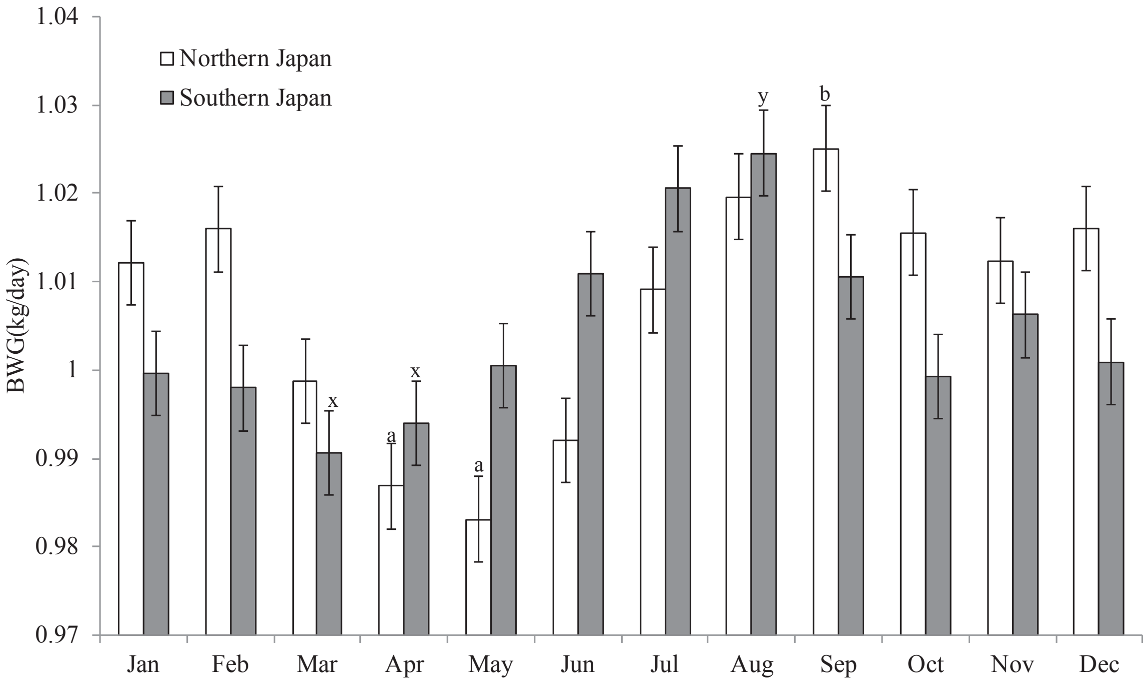

Fig. 2. Comparison between the two regions for mean DG (mean ± SEM) at the calf market sorted by birth month

Open bar, Northern Japan; solid bar, Southern Japan. a–b, x–y, A significant difference was observed between months for each region ($p < 0.05$).

Table 2. Relationship between the mean DG at the calf market and monthly mean THI during the month of birth to three months after birth, in two different regions (n = 96)

	THI							
	Month of birth		1 month after birth		2 months after birth		3 months after birth	
	r	*p*	r	*p*	r	*p*	r	*p*
DG at the calf market								
Northern Japan	0.058	0.697	-0.198	0.198	-0.401	0.005	-0.569	<0.001
Southern Japan	0.469	<0.001	0.353	0.014	0.117	0.428	-0.153	0.300

DG: daily gain; THI: temperature-humidity index birth between the two regions. In Northern Japan, the mean DG showed a significantly negative correlation with THI during the three months after birth. By contrast, in Southern Japan, the mean DG showed a significantly positive correlation with THI during the month of birth. These results demonstrated that, in Southern Japan, DG was lower in calves with lower THI during the month of birth, whereas in Northern Japan, it was lower in calves with higher THI during three months after birth. Nabenishi & Yamazaki (2017) observed different DG responses to THI between the month of birth, during which lower THI was associated with lower DG, and three months after birth, wherein higher THI was associated with lower DG, concluding that calves are susceptible to cold conditions immediately after birth and to hot conditions three months after birth. Possible explanations for this include a low body surface area/body weight and thinner skin and subcutaneous fat immediately after birth (Gonzalez-Jimenez & Blaxter 1962, Olson et al. 1980, Berman 2003, Iaer et al. 2014) as well as decreased dry matter intake because of increased heat generation from rumen development three months after birth (Nabenishi & Yamazaki, 2017). During cold temperatures, protection from wind, provision of a dry lying area, and adequate feed are important (Webster 1974b). In the hot environments of northern Mexico, high THI had a minimal influence on calf mortality, whereas low THI markedly increased calf mortality (Mellado et al. 2014). Hence, Mellado et al. (2014) suggested that efforts should be made to minimize environmental stress of calves born in cold months as well as calves under chronic heat that generally prevails for most of the year. Conversely, all calves were reared in roofed pens with open sides, and shade diminished the severity of heat stress experienced by calves housed in these structures (Spain & Spiers 1996). These observations suggested that in Southern Japan, the open-type barn structure focused on measures against hot conditions during summer may make it difficult to take measures against cold temperatures during the winter, resulting in low DG when the birth month's THI is low.

In Northern Japan, closed-type barn structures are common. With hot conditions, however, windbreaks can impair airflow and increase heat stress, resulting in decreased DG (Mader et al. 1997). In particular, in closed-type barns without proper ventilation, air quality is poor, pathogen concentration is high, and associated diseases are often problematic (Barrington et al. 2002, Lago et al. 2006). In addition, lower DG is associated with respiratory disease (Virtala et al. 1996). Thus, frequent ventilation of barns is essential to supply fresh air and minimize the amount of humidity and airborne contaminants (Roland et al. 2016). In Northern Japan, where the closed-type barn structure focuses on measures against cold temperature during winter, the use of these barns may make it difficult to take measures against hot conditions during the summer, resulting in low DG when THI is high three months after birth. These results suggest drawbacks of each barn structure adapted to regional environments.

In Northern Japan, the DG of calves born in April and May was significantly lower than that of calves born in September. In Southern Japan, the DG of calves born in March and April was significantly lower than that of calves born in August. Interestingly, there was a one-month time lag in DG between Northern and Southern Japan. In addition, a one-month time lag in THI was observed between Northern and Southern Japan, suggesting a potential effect on DG on the change in THI after birth. By combining the data of the two regions, the DG of calves born in March-May was significantly lower than that of calves born in August. Weaning imparts multiple stressors, such as loss of access to the mother and milk and changes in the social and physical environment. Thus, the weaning period is the most stressful time for calves (Weary et al. 2008). In the two regions where the study was performed, the weaning period, three months after birth, overlapped with the period of heat stress; therefore, the combination of weaning and heat stress could have contributed to the low DG of calves born during the spring (Nabenishi & Yamazaki 2017).

In conclusion, despite very different climate conditions, we noted no significant difference in the growth of calves born during the same period between Northern and Southern Japan. Nevertheless, we observed different DG responses to THI between the two regions regarding month of birth and three months after birth. DG was lower in calves with lower THI during the birth month in Southern Japan, whereas it was lower in calves with higher THI values during the three months after birth in Northern Japan. These observations may suggest potential drawbacks of the current barn structures that are adapted to environments in each region and indicate the importance of appropriate rearing management that considers seasonal changes. Good management includes measures against hot conditions during the summer in Northern Japan and measures against cold temperature during winter in Southern Japan.

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