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Short communication

Welfare of lactating Holstein cows under outdoor grazing and indoor housing in relation to temperature and humidity in summer in Japan

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ABSTRACT

Aim: The aim of this study was to investigate the differences in the physiological responses of lactating Holstein cows between outdoor grazing and indoor housing in summer in Japan.
Method: The cows ($n=16$) were grazed outside from indoor housing and returned indoors 3 weeks later, with a 1-week transition phase to mitigate each environmental change. Grazing cows remained in pasture except for milking twice per day and concentrate feeding before milking. Indoors, the cows were tethered except for milking twice per day and about 5.5 h of exercise in an open-air paddock.
Results: When the Temperature–Humidity Index (THI) threshold was above 72, urinary cortisol levels were higher only in the grazing phase. The indoor cows took a longer time to prepare to lie down compared with grazing cows.
Conclusions: This study suggests that forcing cows outside during hot weather can induce certain physiological stress responses in lactating Holstein cows. Cows exhibit more fluid lying-down movements on pasture, suggesting that the comfort of lying conditions of indoor housing was not ideal.

1. Introduction

In Japan, only a minority of farmers provide cattle with pasture access. However, dairy and beef cattle farmers have adopted the grazing system step by step (29.4% of dairy farmers and 12.9% of beef farmers in 2009: the Ministry of Agriculture, Forestry and Fisheries of Japan, 2011). The grazing of cattle is generally thought to have a better 'image' than intensive housing systems. Indeed, it has been found that on-pasture animals have fewer cases of illness such as mastitis (Washburn et al., 2002) and lameness (Hernandez-Mendo et al., 2007) and are able to perform more natural behaviour (Hemsworth et al., 1995). For instance, cattle on pasture spent less time performing stereotypies (Redbo, 1990), which are used as behavioural indicators of poor welfare in farm animals, compared with indoor animals. Physiological effects of grazing have also been reported, such as the finding that stress hormone increased after cattle were moved to indoor tethering from pasture (Redbo, 1993; Higashiyama et al., 2007) but did not change after their return to pasture (Higashiyama et al., 2007).

However, indoor housing provides cattle certain benefits, such as a high-quality diet and protection from adverse weather conditions in the outdoor environment. In a recent study, Legrand et al. (2009) reported that lactating Holstein cows preferred pasture only at night and preferred indoor housing during the day, especially when the temperature and humidity increased, under the housing and environmental conditions tested. Charlton et al. (2011) also reported that lactating Holstein cows exhibited a partial preference to be indoors, which was influenced by rainfall and milk yield.

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Breeds that evolved in Europe tend to be more vulnerable to tropical conditions such as increased temperature and humidity than breeds of *Bos indicus* origin such as the Brahman. Holstein is an especially heat-sensitive breed relative to Jerseys and Brown Swiss (Garcia-Peniche et al., 2005). In addition, the state of lactation is particularly sensitive to thermal stress for dairy cows (Hemsworth et al., 1995). Although Japan is located in a temperate region, high temperatures have often been recorded in recent summers (Japan Meteorological Agency, 2010). High humidity is also characteristic of summer in Japan. Hence, summer grazing may promote stress rather than good animal welfare because of the exposure to direct outdoor environment for lactating dairy cows, especially Holsteins, which comprise the majority breed for dairy cows housed in Japan.

This 2-year study sought to investigate the difference in urinary cortisol levels and lying-down and rising behaviours between outdoor grazing and indoor housing in lactating Holstein cows in summer. Urinary cortisol was used as an indicator of physiological stress because this hormone, the secretion of which exhibited pulsative and circadian variation, accumulated in urine over several hours, and it could be collected non-invasively (Higashiyama et al., 2007). Lying-down and rising movements served as valuable behavioural parameters for the study of welfare evaluation of the environment in cattle (Lidfors, 1989) and might be associated with changes in cortisol secretion (Ladewig and Smidt, 1989). Hence, we also examined the duration of lying-down and rising actions under grazing or indoor housing conditions.

2. Materials and Methods

All experiments were performed at the Tohoku Agricultural Research Center (TARC) in Morioka, located 465 km north of Tokyo, at latitude 39°45′N and longitude 141°08′E. This area forms a basin, so there is a large variation in the temperature, with a maximum temperature of 37.2 °C during the summer and a minimum temperature of −20.6 °C during the winter. The average annual precipitation is 1254 mm (Morioka Meteorological Observation and Weather Station: http://www.jma-net.go.jp/morioka/tokusei.htm (in Japanese)). All experimental procedures were in compliance with the Animal Experimental Guidelines of the TARC.

2.1 Animals and experiment design

Altogether, 16 mid–late-lactating Holstein cows, aged 4.0 ± 0.48 years (mean ± standard error of the mean (SEM)), producing an average of 25.3 ± 1.54 kg day^{-1}, with body weights of 605 ± 19.4 kg, were used in this study. Dairy cows in the TARC, including the ones used in the current study, are usually housed indoors and in an outdoor open-air paddock all year round. Twice a day, at 0600 and 1630 h the cows were milked in a 2×3 tandem milking parlour. Milk yield was recorded daily. Water and mineral blocks were continuously available.

Three experiments were conducted during two consecutive summers in this study because urine sampling on pasture needed sufficient workers. Five cows without grazing experience were used in the first period (period 1) experiment in 2008, three cows without grazing experience were used in the second period (period 2) experiment in 2008 and eight cows (six with approximately 1-month grazing experience and two without grazing experience) were used in the third period (period 3) experiment in 2009. Cows in the experiment were familiar with each other before the experiment. The cows in the experiment were transferred from indoor confinement to pasture, and they returned indoors after grazing. A 1-week transition phase was provided in order to mitigate each environmental change. Each period consisted of five phases over a total of 9 weeks: 1 week before the experiment (B), 1 week of transition phase to adapt to grazing (TG; day 0 at the start), 3 weeks of grazing (G), 1 week of transition phase to adapt to indoor living (TI) and 3 weeks of indoor living (I).

In the TG phase, the cows were forced onto pasture from milking time in the morning until 1300 h for the first 3 days and afterwards from milking time in the morning until evening. Except for these times, they were treated as same as in the I phase. By contrast, cows in the TI phase were forced to be in the I phase from milking time in the morning until 1300 h for the first 3 days and afterwards from milking time in the morning until evening. Except for these times, they were treated as same as in the G phase. The G phase in periods 1, 2 and 3 was conducted from 30 June to 17 July, from 8 to 25 September 2008 and from 3 to 23 August 2009.

In the G phase, the cows were on pasture for 24 h, except for milking twice daily and concentrate feeding (total digestible nutrients (TDNs) content 79.9%, crude protein (CP) content 14.0%, on a dry-matter (DM) basis) according to the Japanese Feeding Standard for Dairy Cattle (NARO, 2006) in the tie-stall before each milking. Pasture, which had a total area of 1 ha and was dominated by orchardgrass (*Dactylis glomerata* L.) and subdominated by perennial ryegrass (*Lolium perenne* L.), was divided into five equal paddocks with movable electric wires, and cows grazed in each paddock in rotation every 2–3 days. Averaged pre- and post-grazing sward heights were 19.7 and 13.3 cm. The fresh forage contained in pasture averaged 62.7% TDN and 15.2% CP on a DM basis. A 5×5-m shaded area was provided in pasture. In addition, the shade of Japanese red pine woods, which were planted beside the pasture, was available. Only the experimental cows grazed on pasture. Fresh drinking water was available *ad libitum* from a water cup located near the shaded area. The pasture and the cattle house were connected with an approximately 110-m passage.

In the I phase, the cows were tethered in tie-stalls by a chain approximately 1-m long attached to the cow's collar and the front partition, except for during milking twice daily. The tie-stall design is common for small-scale farmers, which make up the majority of dairy farmers in Japan. In addition, the cows stayed in an open-air paddock (900 m^2) close to the cattle house for 2 h after morning milking and 3.5 h before afternoon milking, during which times each stall was cleaned. In the open-air paddock, the cows were with non-experimental cattle. The individual stalls measured $1.3 \text{ m} \times 1.75 \text{ m}$ and were placed in two rows, facing a common feeding manger. The concrete