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The energy expenditure of 2 Holstein cow strains in an organic grazing system

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ABSTRACT

Until recently, measurements of energy expenditure (EE; herein defined as heat production) in respiration chambers did not account for the extra energy requirements of grazing dairy cows on pasture. As energy is first limiting in most pasture-based milk production systems, its efficient use is important. Therefore, the aim of the present study was to compare EE, which can be affected by differences in body weight (BW), body composition, grazing behavior, physical activity, and milk production level, in 2 Holstein cow strains. Twelve Swiss Holstein-Friesian (H_{CH}; 616 kg of BW) and 12 New Zealand Holstein-Friesian (H_{NZ}; 570 kg of BW) cows in the third stage of lactation were paired according to their stage of lactation and kept in a rotational, full-time grazing system without concentrate supplementation. After adaption, the daily milk yield, grass intake using the alkane double-indicator technique, nutrient digestibility, physical activity, and grazing behavior recorded by an automatic jaw movement recorder were investigated over 7 d. Using the ^{13}C bicarbonate dilution technique in combination with an automatic blood sampling system, EE based on measured carbon dioxide production was determined in 1 cow pair per day between 0800 to 1400 h. The H_{CH} were heavier and had a lower body condition score compared with H_{NZ}, but the difference in BW was smaller compared with former studies. Milk production, grass intake, and nutrient digestibility did not differ between the 2 cow strains, but H_{CH} grazed for a longer time during the 6-h measurement period and performed more grazing mastication compared with the H_{NZ}. No difference was found between the 2 cow strains with regard to EE (291 ± 15.6 kJ) per kilogram of metabolic BW, mainly due to a high between-animal variation in EE. As efficiency and energy use are important in sustainable, pasture-based, organic milk production systems, the determining factors for EE, such as methodology, genetics, physical activity, grazing behavior, and pasture quality, should be investigated and quantified in more detail in future studies.

Key words: energy expenditure, dairy cow, Holstein-Friesian, pasture

INTRODUCTION

Pasture-based milk production systems have recently gained international interest due to economic, environmental, animal welfare, and product quality issues. The economic benefit of such systems is based on the efficient use of pasture herbage and linked with reasonable milk production per cow (Dillon et al., 2005). If pasture herbage is used efficiently per area, so that milk production per hectare is optimized, then the herbage intake per cow, which is the main determinant for individual milk production, is limited by the reduced herbage allowance (Delagarde et al., 2001). Consequently, high-genetic merit cows for milk production in pasture-based systems suffer from a negative energy balance accompanied by lower BCS and impaired fertility. It has been previously shown that cows fed on pasture alone benefit from supplemental feeding to express their high-milk production potential in an efficiently managed grass-based system and to reduce the need to mobilize excessive amounts of body reserves in early lactation (Kennedy et al., 2002; Pedernera et al., 2008). Therefore, it is advisable to use dairy cows that are able to meet their energy requirements for production and maintenance in a pasture-based system. Bruinenberg et al. (2002) found that grass-fed dairy cows have a 10% higher metabolizable energy requirement for maintenance (**ME_m**) in indirect calorimetry experiments. However, ME_m is not only influenced by diet, but also by physical activity. For example, grazing cows had 21% higher energy expenditure (**EE**) compared with grass-fed cows kept indoors (Kaufmann et al., 2011). The energy requirements relative to maintenance may increase up to 50% depending on grazing conditions, including herbage availability (allowance and mass) and digestibility, distances walked (distance to the milking parlor and watering points), weather, topography, and

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interaction between these factors (CSIRO, 2007). More generally, according to Gruber et al. (2007), current energy systems established in Europe and the United States underestimate the ME_m for dairy cows. Those authors concluded that an increase in internal organ mass and feed intake, as well as a decrease in BCS, can be reasons for the increased ME_m in high-yielding dairy cows. In fact, it has been reported that recommended ME requirements for zero energy balance in cows fed fresh pasture were too low (Mandok et al., 2013). Currently, precise information about additional energy costs under pasture-based conditions is not available.

In New Zealand, Holstein cows are bred for the specific needs of pasture-based, low-input dairy production, including selection for milk solids, lower BW, fertility, and longevity (Miglior et al., 2005). This is in contrast to most other countries, where selection in the past was done primarily for enhanced productivity without taking body size or feed conversion efficiency into account (Pryce et al., 2007). In the future, this may change as new breeding goals could be defined and less intensive production environments may gain in importance (Boichard and Brochard, 2012). McCarthy et al. (2007) showed that New Zealand (**NZ**) Holstein cows were able to achieve high DMI and milk production in a pasture-based feeding system by grazing for a longer period of time in comparison to other high-yielding Holstein strains. Compared with Swiss Holstein cows, the NZ Holstein cows had a lower BW, showed a different body condition around calving, ruminated for a longer period of time, and tended to take more steps on the pasture (Schori and Münger, 2010; Piccand et al., 2013). As a moderate positive correlation exists between EE and walking and eating time (Kaufmann et al., 2011), the higher energy requirements of dairy cow strains on pasture may be partly caused by differences in grazing behavior, and physical activity. Brosh et al. (2006) and, more recently, Aharoni et al. (2013) allocated specific energy costs to foraging activities and locomotion of beef cows during grazing. The objective of the current study was to determine EE based on CO_2 production using the ^{13}C bicarbonate dilution technique with New Zealand Holstein-Friesian cows and heavier, high-producing Swiss Holstein-Friesian cows in a full-time grazing system without concentrate supplementation. To explain possible differences in EE between strains with differences in grazing behavior or physical activity, these variables were recorded simultaneously.

MATERIALS AND METHODS

Animals and Experimental Design

All experimental procedures were in accordance with the Swiss guidelines for animal welfare and were approved (No. 2011_10_FR) by the Animal Care Committee of the Canton of Fribourg, Switzerland. Before selecting the cows for the experiment, a medical check-up including vital parameters, as well as udder and claw health, was performed. The 12 selected Swiss Holstein-Friesian ($\mathbf{H_{CH}}$) cows were from a strain of North American origin (52% of the third generation of their ancestors originated from the United States or Canada) and selected for high milk yield. Their average economic breeding value (**ISEL**; Swiss Holstein Breeding Association, Posieux, Switzerland), which includes productivity, quality of milk, conformation, udder health, longevity, and fertility, was 981 ± 25.9. The average ISEL was similar to that of the Swiss Holstein cow population in 2011 (1,023 ISEL; September 2012, E. Barras, Holstein Association of Switzerland, Posieux, Switzerland, personal communication). The 12 chosen New Zealand Holstein-Friesian ($\mathbf{H_{NZ}}$) cows were from a strain selected within a seasonal calving, pasture-based dairy system with a high emphasis on the production of milk solids, fertility, and longevity. At least 2 generations of male ancestors were Holstein-Friesians with genetics from New Zealand. The ISEL of the H_{NZ} was 801 ± 31.0. The experiment was set up as a balanced complete block design and consisted of 2 consecutive experimental weeks. Twelve matched pairs of H_{CH} and H_{NZ} cows were formed according to the following criteria: number of lactations, DIM, and age for primiparous cows. The cow pairs were equally divided between the 2 consecutive experimental weeks so that each cow passed a period of 7 d where data was collected. At the start of the first experimental week, H_{CH} cows were on average in the 2.6 (SD 1.8) lactation, had been 173 (SD 19) DIM, had an average BW of 616 (SD 30.9 kg), a BCS of 2.6 (SD 0.26), an average height at the withers of 147 (SD 3.6) cm, a chest circumference of 197 (SD 6.0) cm, and were producing 21.1 (SD 2.26) kg of milk/d. The H_{NZ} cows were on average in the 2.6 (SD 1.7) lactation, had been 179 (SD 16) DIM, had on average a BW of 570 (SD 55.9) kg, a BCS of 2.9 (SD 0.27), an average height at the withers of 135 (SD 4.7) cm, a chest circumference of 188 (SD 8.5) cm, and produced 17.6 (SD 3.96) kg of milk/d. On March 30, the grazing period started. The cows received hay and were supplemented with 264 (SD 16.0) kg of cereal mixture and 48 (SD 17.1) kg of a protein concentrate per cow during the first 80 d of lactation. The supplementation was terminated in mid-May so that the cows received solely herbage until the start of the experiment in mid-September. During the experiment, the cows grazed from 0800 to 1400 h and from 1800 to 0430 h on the pasture. Between the daily grazing periods, the cows were kept in a freestall barn and milked at 0530 and 1630 h in a milking par-