Assessing feed efficiency in grazing dairy cows through infrared thermography and behaviour sensors

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Abstract

Genetic selection for feed efficiency is hindered by the cost and difficulty of measuring individual feed intake. The objective was to explore the use of phenotypic proxies, namely surface temperature (ST), rectal temperature (RT), feeding behaviour and physical activity, to predict feed efficiency variables, i.e. feed conversion efficiency (FCE) and residual feed intake (RFI), in grazing dairy cows. Two groups of 14 Holstein and 14 Swiss Fleckvieh dairy cows were investigated during two mid- and one late-lactation period. During 7-day measuring periods, feeding and rumination behaviour, activity and individual herbage intake using the n-alkane marker technique of each cow was recorded. The ST was recorded indoors, once for each measurement period after morning milking at multiple body locations with a thermal camera. Estimated average within-herd feed efficiency was 0.78 (*SD = 0.17)* for FCE and -1.18 (*SD = 1.96*) for RFI with no significant difference (*P > 0.05*) between the breeds. FCE and RFI were best explained by maximum right front feet ST (R^2 = *0.34*) and time interval between 2 consecutive foot strikes (R^2 = *0.17*), respectively. The relationships were weak to very modest; however, they might be further improved by including other features such as milk and blood variables.

Keywords: eating, rumination, behaviour, surface temperature, feed efficiency

Introduction

Achieving greater feed efficiency is one possible approach to improve sustainability of dairy production. Genetic selection for feed efficiency is greatly limited by the high costs associated with individual feed intake measurements. Previous studies (Cantalapiedra-Hijar *et al.*, 2015; Decruyenaere *et al.*, 2015) have identified biomarkers for nutrient utilization that are easier to implement, less stressful for animals and less expensive. Temperature regulation and animal activity have been identified as important aspects of physiological variation that could affect feed efficiency in dairy animals (Herd and Arthur, 2009). The objective of the study was to explore the use of the biomarkers ST, RT, feeding behaviour and activity, to predict feed efficiency variables, namely FCE and RFI, in grazing dairy cows.

Material and Methods

The study comprised two mid-lactation and one late-lactation experimental periods. Each entailed a 21-day adaption period and a 7-day measurement period. Per experimental period twenty-eight lactating dairy cows, approximately half of them primiparous, were grazed on established rotational pasture. The cows were evenly divided between the Swiss Fleckvieh and Swiss Holstein breeds. Individual herbage intake was estimated during grazing with the n-alkane double indicator technique (Rombach *et al.*, 2019), and if concentrate was supplemented it was registered individually through the automatic feeding station. Based on the individual intakes of cow's FCE, expressed as total dry matter intake/energy-corrected milk yield, and RFI, expressed as effective minus required total dry matter intake, were computed. The behavioural characteristics (e.g. rumination, bites and strides) were recorded throughout the measurement periods with a halter and pedometer (RumiWatch, Itin and Hoch GmbH, Liestal, Switzerland). The recorded data were processed using the evaluation software RumiWatch converter version 0.7.3.36.

Thermal images were recorded indoors, once before morning feeding, according to manufacturer's recommendations, with an infrared camera (FLIR T620, FLIR Systems Inc., Wilsonville, OR, USA). The camera measured the surface temperature of body parts of the cows via radiated heat. The evaluated anatomical regions for the ST were eyes, ears, head, cheeks, snout, ribs, flanks, limbs, udder and rear area. The RT of each animal was measured immediately after thermal imaging using a digital thermometer (SC 12, SCALA Electronic GmbH, Stahnsdorf, Germany). The recorded data (milk yield and composition, body weight, behaviour, activity, ST and RT) were averaged per cow and period, as

herbage intake was estimated per measurement period. The relationships between feed efficiency and ST, RT, feeding behaviour and physical activity were analysed with a linear model in R. Measurement period and breed were included in the model as fixed effects.

Results and discussion

The RFI (*P = 0.19*) and FCE (*P = 0.10*) values were not different between breeds. However, considerable between-animal variations for FCE (0.78, *SD = 0.17*) and RFI (-1.18, *SD = 1.96*) were observed, which is in accordance with a previous study (Arndt *et al.*, 2015). The ST tended to be higher in efficient cows. According to Case *et al.* (2012), more efficient animals have a higher metabolic rate and therefore the extra excess heat is lost as radiant heat. The maximum ST of right front feet (23.8°C, *SD = 4.7*; R^2 = *0.34*) and the minimum cheek (24.9°C, *SD = 4.1*; R^2 = *0.14*) best explained the FCE and RFI, respectively. Feed efficiency could not or only very weakly be predicted with RT (37.7°C, *SD = 0.4*) at R^2 = *0.09* and R^2 = *0.00* for FCE and RFI, respectively.

Table 1. Prediction of feed efficiency of grazing primiparous and multiparous Swiss Holstein and Swiss Fleckvieh cows with behaviour, activity and thermal biomarkers

	R^2		*P*-value	
Biomarker	FCE[1]	RFI[2]	Breed	Parity
Eating and rumination activities[3]	0.30-0.31	0.10-0.13	>0.05	>0.05
Locomotion activities[4]	0.25-0.30	0.08-0.17	>0.05	>0.05
Surface temperatures of body locations (°C)[5]	0.26-0.34	0.06-0.14	>0.05	>0.05
Rectal temperature (°C)	0.09	0.00	0.94	0.13

[1] FCE = feed conversion efficiency, [2] RFI = residual feed intake

[3] Eating and rumination activities included elements such as eating, chewing, drinking and rumination

[4] Locomotion activities included elements such as walking, lying, standing and strides

[5] Surface temperatures of body locations were eyes, ears, head, cheeks, snout, ribs, flanks, limbs, udder and rear

Feeding behaviour makes an important contribution to the underlying variation in feed efficiency of cattle (Fitzsimons *et al.*, 2017). The amount of time spent grazing (605 minutes per day, *SD = 55*; R^2 = 0.30) and amount of time spent with other activities (355 minutes per day, *SD = 88*; R^2 = *0.17*)) excluding activities attributable to any ruminating, feed intake or drinking activity, best predicted FCE and RFI, respectively. This is in accordance with Kenny *et al.* (2018), as low feed efficient cattle spent proportionately more time eating than their high feed-efficient contemporaries. Physical activity contributes to energy consumption and is interconnected with feeding-related behaviour, especially under grazing conditions. In accordance with Kenny *et al.* (2018) the physical activity (e.g. walking) was higher in low feed-efficient compared with high feed-efficient cows. The FCE and RFI were best explained by the average duration (1679 ms per stride, *SD = 42.6*) of one stride of the leg (R^2 = *0.17* and R^2 = *0.30*, respectively). Based on our study, a more efficient cow (low RFI and FCE) would spend less time grazing, have cooler body extremities and a lower core temperature compared with a less efficient cow. Biological differences between more and less efficient dairy cows may be useful to select the most efficient animals.

Conclusions

Feeding behaviour, ST, RT and physical activity were correlated with feed efficiency traits and thus indicate the potential for application of some of these measurements in the assessment of efficiency traits in dairy cows. The relationships observed so far were modest but might be improved by their combination and by including other characteristics such as milk and blood variables. Moreover, these findings open the possibility of considering alternative methods to assess feeding efficiency through biological and behavioural proxies.

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