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Phenotypically divergent classification of preweaned heifer calves for feed efficiency indexes and their correlations with heat production and thermography

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ABSTRACT

The aims of this study were (1) to assess if there is phenotypical divergence for feed efficiency (FE) during the preweaning phase; (2) if FE is correlated with heat production (HP) measured by the face mask method or (3) by surface skin temperature via thermography, and (4) whether these methods are applicable to preweaned calves. Holstein × Gyr heifer calves (n = 36, birth body weight = 32.4 ± 6.6 kg) were enrolled and on trial between 4 and 12 wk of age and were classified into 2 residual feed intake (RFI) and residual body weight gain (RG) groups: high efficiency (HE; RFI, n = 10; and RG, n = 9) and low efficiency (LE; RFI, n = 10; and RG, n = 8). Calves were fed milk (6 L/d) and solid feed (95% starter and 5% chopped Tifton 85 hay, as fed). Growth was monitored weekly and feed intake (milk and solid feed) daily, during the whole period. Gas exchanges (O_2 consumption and production of CO_2 and CH_4) were obtained using a face mask at 45 ± 5 d of age and HP was estimated. Maximum temperatures were measured at 7 sites with an infrared camera at 62 ± 7 d of age. There was divergence in RFI and RG. Respectively, HE and LE calves had RFI of −0.14 and 0.13 kg/d, and RG of 0.05 and −0.07 kg/d. Dry matter intake was 15% lower in HE-RFI compared with LE-RFI, but no differences were observed in average daily weight gain. Within the RG test, no differences were observed in dry matter intake or average daily gain. The HE-RFI calves consumed less O_2 (L/d) and produced less CO_2 (L/d). Heart rate and HP were lower for HE-RFI calves compared with LE-RFI. Residual feed intake was correlated with HP (r = 0.48), O_2 consumption (r = 0.48), CO_2 production (r = 0.48), and heart rate (r = 0.40). No differences were observed in HP and gas exchanges between RG groups. Methane production was null in both groups. Eye temperature measured by thermography was 0.5°C greater in HE-RG than LE-RG calves. Differences in skin temperature between HE and LE calves were not observed at the other sites. These results support the hypothesis that calves are divergent for RFI, RG, and FE during preweaning and divergence tests are applicable during this phase. The face mask method described here is a useful tool for estimating differences in HP among phenotypically divergent RFI calves. Eye temperature measured by infrared thermography may have potential to screen phenotypically divergent RG calves.
Key words: calorimetry, residual feed intake, residual gain, thermography

INTRODUCTION

In dairy farming, approximately 60% of the production costs are related to feed (Ho et al., 2005). An alternative to reduce feeding costs and increase production efficiency would be to improve efficiency of feed usage (Berry et al., 2014). In addition to the economic aspect, greater efficiency results in reduced waste of natural resources and methane emissions (Waghorn and Hegarty, 2011), thus reducing environmental impacts.

Presently, residual feed intake (**RFI**) is the most used index of feed efficiency (Koch et al., 1963). Residual feed intake is independent of growth rate and BW. It is defined as the difference between realized intake and predicted intake, using a linear regression of individual intake as a function of mean metabolic body weight (**BW$^{0.75}$**) and ADG, where RFI is the residual term. Highly feed efficient animals present negative RFI (i.e., realized intake is smaller than predicted intake), whereas animals with low feed efficiency present positive RFI (i.e., realized intake is greater than predicted intake). In addition to RFI, other measurements of efficiency have been described. Residual body weight gain (**RG**)

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is similar to RFI, but instead of regressing feed intake on BW and ADG as for RFI, RG is obtained from the regression of ADG on feed intake and BW (Crowley et al., 2010). Hence, RG is positively associated with growth rate, but it is not associated with feed intake (Berry and Crowley, 2013).

Holstein heifer calves selected according to varying RFI during the growth phase presented divergences in RFI during the first lactation, even though the divergences were reduced at that time (Macdonald et al., 2014; Gilbert et al., 2017). It has been observed that this variation in RFI has moderate heritability (h^2 = 0.45, Crowley et al., 2010). Thus, the selection of low-RFI animals as replacements could be an interesting tool, given that the association between efficiency in early and adult life could reduce time and costs of feed efficiency research and increase the selection pressure for this trait. Few studies, however, have evaluated this trait during the preweaning phase.

Although the biological mechanisms controlling RFI have not been fully elucidated, differences in digestion, nutrient requirements, and biochemical efficiency of feed usage have been identified as important factors (Herd and Arthur, 2009). The greatest variation in feed efficiency is likely related to variation in energy expenditure (Paddock, 2010). Energy expenditure, also known as heat production, can be estimated using indirect calorimetry, which measures oxygen consumption and carbon dioxide and methane production by the animal (Paddock, 2010). Regulation of body temperature has also been identified as an important aspect of physiological variation that could contribute to feed conversion efficiency in dairy cows (Herd and Arthur, 2009). This is due to greater use of energy sources for production of metabolic heat in detriment of milk yield in animals with greater body temperature (Britt et al., 2003). The use of infrared thermography (**IRT**) is another method for measurement of surface (e.g., skin) temperature, and allows obtainment of measurements in a noninvasive manner (Montanholi et al., 2008).

The objectives of this experiment were to evaluate if phenotypically divergent classification is observed in relation to RFI and RG of preweaned heifer calves, and to determine if measurements of heat production (estimated by indirect calorimetry with a face mask) and of surface body temperature (measured by IRT) could be applied to the selection of high-efficiency calves during the preweaning phase. Our hypothesis was that there is phenotypically divergent classification in preweaned calves and that high efficient animals produce less heat.

Table 1. Nutrient composition of hay, starter, and TMR (95% starter and 5% hay) offered to preweaned heifer calves between 4 and 12 wk of age

Nutrient composition (%, unless otherwise indicated; DM basis)	Hay	Starter	TMR
DM	90.3	89.3	89.3
CP	13.6	22.2	21.8
OM	80.8	77.9	78.0
Ether extract	3.7	4.6	4.6
NFC	16.7	59.5	57.3
NDF	70.1	24.5	26.8
ADF	33.3	9.9	11.0
Gross energy (kcal/kg)	3,928.0	3,728.0	3,738.0
Ca	0.8	2.0	1.9
P	0.3	0.5	0.5

MATERIALS AND METHODS

This study was approved by the Ethics Committee of Embrapa Dairy Cattle, Brazil (protocol no. 02/2014). The experiment was conducted at the Embrapa Dairy Cattle Experimental Farm, located in Coronel Pacheco, Minas Gerais, Brazil.

Calves, Housing, Management, and Treatments

Holstein × Gyr F_1 crossbred heifer calves (n = 36; BW at birth = 32.4 ± 6.6 kg, mean ± SD) born during the spring (October to December) were enrolled in the experiment. Immediately after birth, the calves were removed from their dams, weighed, and had their umbilical cords immersed in 10% iodine solution. Colostrum (10% of birth BW; >50 g of IgG/L) was fed within 6 h after birth. Passive transfer of immunity was assessed using total serum protein. Blood samples were collected via jugular venipuncture within 48 h after birth, centrifuged at 1,800 × *g* for 10 min at room temperature (22–25°C), and total serum protein (g/dL) was measured using a refractometer (Serum protein REF-301, Biocotek, Beilun, Ningbo, China).

Calves were housed in sand-bedded individual pens (1.25 × 1.75 m, tethered with 1.2-m-long chains), which were allocated in a barn with open sides and end-walls. Calves were fed 6 L of milk/d during the whole preweaning period, split into 2 equal meals offered at 0700 and 1400 h. Calves were fed transition milk until 3 d of age and whole milk from 4 d of age until weaning. Water and solid feed were offered in buckets for ad libitum intake (10% orts of solid feed) throughout the experimental period. Solid feed as-fed was composed of 95% starter (Soylac Rumen 20% Flocculated, Total Alimentos, Três Corações, Minas Gerais, Brazil) and 5% chopped Tifton 85 hay (Table 1). Growth was monitored weekly and feed intake (milk and solid feed) was monitored daily until d 82 of age, when all calves were abruptly weaned.