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Comparison of maintenance energy requirement and energetic efficiency between lactating Holstein-Friesian and other groups of dairy cows

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ABSTRACT

The objectives of the present study were to investigate the effects of cow group on energy expenditure and utilization efficiency. Data used were collated from 32 calorimetric chamber experiments undertaken from 1992 to 2010, with 823 observations from lactating Holstein-Friesian (HF) cows and 112 observations from other groups of lactating cows including Norwegian (n = 50), Jersey × HF (n = 46), and Norwegian × HF (n = 16) cows. The metabolizable energy (ME) requirement for maintenance (ME_m) for individual cows was calculated from heat production (HP) minus energy losses from inefficiencies of ME use for lactation, energy retention, and pregnancy. The efficiency of ME use for lactation (k_l) was obtained from milk energy output adjusted to zero energy balance ($E_{l(0)}$) divided by ME available for production. The effects of cow groups were first evaluated using Norwegian cows against HF crossbred cows (F_1 hybrid, Jersey × HF and Norwegian × HF). The results indicated no significant difference between the 2 groups in terms of energy digestibility, ratio of ME intake over gross energy intake, ME_m (MJ per kg of metabolic body weight, MJ/kg$^{0.75}$), or k_l. Consequently, their data were combined (categorized as non-HF cows) and used to compare with those of HF cows. Again, we detected no significant difference in energy digestibility, ratio of ME intake over gross energy intake, ME_m (MJ/kg$^{0.75}$), or k_l between non-HF and HF cows. The effects were further evaluated using linear regression to examine whether any significant differences existed between HF and non-HF cows in terms of relationships between ME intake and energetic parameters. With a common constant, no significant difference was observed between the 2 groups of cows in coefficients in each set of relationships between ME intake (MJ/kg$^{0.75}$) and ME_m (MJ/kg$^{0.75}$), $E_{l(0)}$ (MJ/kg$^{0.75}$), HP (MJ/kg$^{0.75}$), ME_m:ME intake, $E_{l(0)}$:ME intake, or HP:ME intake. However, ME_m values (MJ/kg$^{0.75}$) were positively related to ME intake (MJ/kg$^{0.75}$), irrespective of cow group. We concluded, therefore, that cow groups evaluated in the present study had no significant effects on energy expenditure or energetic efficiency. However, the maintenance energy requirement (MJ/kg$^{0.75}$) was not constant (as adopted in the majority of energy rationing systems across the world) but increased with increasing feed intake.

Key words: maintenance energy requirement, energy utilization efficiency, cow group, lactating dairy cow

INTRODUCTION

Milk yield-oriented breeding programs for Holstein-Friesian (**HF**) dairy cows have made significant progress in the past few decades, with the HF population being the dominant dairy cow breed on the majority of United Kingdom (**UK**) dairy farms. However, it is now widely recognized that selection programs with a single production trait, namely milk production, have inadvertently resulted in production burden, metabolic stress, health, and fertility problems (Seykora and McDaniel, 1983; König et al., 2008). Several studies have demonstrated unfavorable genetic correlations between milk yield and ketosis (0.25 to 0.65), mastitis (0.15 to 0.68), and lameness (0.24 to 0.48; Lucy, 2001; Ingvartsen et al., 2003). For example, the fertility of HF dairy cows in the United States declined steadily from 1960 until the early to mid-2000s. Corrective action would take 20 to 30 yr to return those cows to the fertility levels they had 30 yr ago (Gary and Joan, 2011). Therefore, there is increasing interest in the use of non-HF breeds (e.g., Jersey, Norwegian) or crossbred (mainly HF based) dairy cows around the world, especially in New Zealand, where crossbreeding of Jerseys with HF cows accounts for more than 40% of the whole dairy population (Dairy NZ, 2014). In the UK, 87 different breeds of cattle were registered as of June 1, 2008, including 4.0 million purebred cattle and 4.8 million crossbred cattle (Defra, 2008).

The potential benefits of HF crossbred dairy cows can be achieved through combinations of inherent advantages from different groups of dairy cows. Schwager-

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Suter et al. (2001) compared differences in net energetic efficiency for HF, Jersey, and Jersey × HF cows, which was calculated as the ratio of milk energy to total net energy intake. Results showed that Jersey × HF cows had a higher net energetic efficiency compared with those of the HF and Jersey breeds, in agreement with the study of Prendiville et al. (2009), in which Jersey and Jersey × HF cows required approximately 8 and 11% less energy, respectively, to produce 1 kg of milk solids (fat + protein) compared with HF cows. In addition, with better fertility and udder health, Jersey-HF crossbred cows had a net profit of £39/cow per year over pure Holstein cows when managed under farm conditions of Northern Ireland (AgriSearch, 2012). Nevertheless, most research has been undertaken on the comparison of performance characteristics, health, or profitability traits among different cow groups. Few studies have been conducted on the comparison of maintenance energy requirement and energy utilization efficiency between lactating HF cows and other groups of dairy cows

Therefore, the objectives of the present study were to perform a meta-analysis to investigate the possible effects of different groups of dairy cows on ME requirement for maintenance (**ME_m**) and the efficiency of utilization of ME for lactation (**k_l**) using data derived from 32 calorimeter experiments involving HF and other groups of dairy cows between 1992 and 2010.

MATERIALS AND METHODS

Animals and Feeds

In the current study, 935 observations were collated from 32 calorimetric chamber experiments undertaken between 1992 and 2010 at the Agri-Food and Biosciences Institute (Hillsborough, UK) including 823 observations from HF cows and 112 observations from the "other" group of dairy cows (**non-HF**) that included Norwegian (n = 50) and HF crossbred (F_1 hybrid, Jersey × HF, n = 46; Norwegian × HF, n = 16) cows. The majority of these studies were published in peer-reviewed scientific journals, and all references are presented in the Appendix. The HF group had a mean Profit Index value of £15 based on the calculation of PTA2010 proof and had relatively high production performance in the whole UK HF population. The HF crossbred animals, including Jersey × HF and Norwegian × HF, were the offspring of a breeding program in the herd of this institute, with the Norwegian cows representing the top 10% of the whole population in Norway when they arrived at this institute in 1999. The stage of lactation when measured in calorimeter chambers ranged from early to late lactation, with mean postcalving days of 159 for HF cows, 158 for Norwegian cows, 179 for Jersey × HF cows, and 247 for Norwegian × HF cows, respectively.

Data used were derived from forage-only diets (n = 66) or a mixture of forage and concentrates (n = 869). The forage used in individual diets included grass silage (n = 623), mixture of grass silage and maize silage (n = 160), mixture of grass silage and whole-crop wheat silage (n = 4), mixture of fresh grass and straw (n = 4), maize silage (n = 6), whole-crop wheat silage (n = 6), straw (n = 36), fresh grass (n = 42), dried grass (n = 20), and dried lucerne (n = 34). The grass silages were produced from primary growth, primary regrowth, and secondary regrowth material with grass either unwilted or wilted before ensiling and ensiled with or without application of silage additives. The concentrates used included a mineral-vitamin supplement and some of the following ingredients: cereal grains (barley, wheat, or maize), by-products (maize gluten meal, molassed or unmolassed sugar-beet pulp, citrus pulp, or molasses), and protein supplements (soybean meal or rapeseed meal). The concentrate portion of the diet was offered in a complete diet mixed with forage or as a separate feed from forage.

Digestibility and Calorimeter Measurements

Energy intake and output data used in the present study were measured in digestibility trials and by indirect open-circuit respiration calorimeter chambers. Before the commencement of nutrient utilization measurements, all dairy cows were offered their experimental diets for at least 3 wk in group-housed cubicle accommodation with free access to water. Afterward, animals were transferred to metabolism units and remained in individual stalls for between 5 and 8 d with measurement of total feed intake and total collection of feces and urine undertaken during the final 3 to 6 d. Animals were then housed in calorimeter chambers for 3 to 5 d with total measurement of gaseous exchange (CH_4, CO_2, and O_2) taking place during the final 2 to 4 d. All equipment, sampling procedures, analytical methods, and calculations used in the calorimetric studies were described by Gordon et al. (1995) and calibration of the chambers by Yan et al. (2000).

Calculation of Maintenance Energy Requirement and Energetic Efficiency

The ME_m (MJ/d) for individual cows was estimated from heat production (**HP**, MJ/d) minus energy losses from the inefficiencies of ME use for lactation, tissue change, and pregnancy (Eq. [1] and [2]), with HP, milk energy output (**E_l**, MJ/d), and tissue energy change