Livestock Science 178 (2015) 150–157

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Maintenance energy requirements of young Holstein cattle from calorimetric measurements at 6, 12, 18, and 22 months of age

H.P. Jiao [a,b], T. Yan [a,*], D.A. Wills [a], D.A. McDowell [c]

[a] Agri-Food and Biosciences Institute, Large Park, Hillsborough, Co. Down BT26 6DR, United Kingdom
[b] New Hope Ecological Dairy Husbandry Ltd., Chengdu 610063, China
[c] Faculty of Life and Health Sciences, University of Ulster, Newtownabbey, Co. Antrim BT37 0QB, United Kingdom

ARTICLE INFO

Article history:
Received 18 June 2014
Received in revised form
27 May 2015
Accepted 28 May 2015

Keywords:
Calorimeter measurement
Energy metabolism
Maintenance energy requirement
Young Holstein cattle

ABSTRACT

Twenty five-month old Holstein cattle (10 steers and 10 heifers) were used in a four-period (28 d/period) study with measurements made at the age of 6, 12, 18, and 22 months, to evaluate effects of gender on energy utilization efficiency and maintenance energy requirement. Cattle were offered perennial ryegrass silage mixed with concentrates. In each period, the cattle were housed together in a cubicle accommodation for the first 20 d, individually in metabolism units for the next 3 d, and then in indirect open-circuit respiration calorimeter chambers for the final 5 d with feed intake, feces and urine outputs, and gaseous exchange measured during the final 4 d. There was no difference ($P > 0.05$) in any period between gender groups in terms of growth performance, energy intake, energy output, or energetic efficiency, with the exception of period three when the steers had a greater ($P < 0.05$) feed and energy intake than heifers. Data from the two groups were therefore pooled to develop relationships between metabolizable energy (ME) intake and retained energy (RE) for each measurement period and for the whole experimental period. Retained energy was strongly related to ME intake ($P < 0.001$), with R^2 values ranging from 0.85 to 0.93. Net energy (NE) and ME requirements for maintenance (NE_m and ME_m) derived from these relationships were greater for cattle at the age of 6 months than those at 12, 18, and 22 months (NE_m = 0.57, 0.48, 0.47, and 0.41 MJ/kg$^{0.75}$; and ME_m = 0.78, 0.62, 0.59, and 0.63 MJ/kg$^{0.75}$, respectively). These maintenance energy requirements were greater than those recommended in energy feeding systems currently used in Europe, North America, and Australia. The results indicate that current feeding systems may underestimate maintenance requirements for young dairy cattle, resulting in a reduced estimate of the efficiency of production.

1. Introduction

The efficiency of energy utilization and maintenance energy requirement are key parameters for dairy cattle to maximize production efficiency. A considerable volume of research has been undertaken over the last three decades to quantify the effects of a range of diet and animal factors on energy metabolism of dairy cows. Some early research has been used to develop a series of energy feeding systems for dairy cows in Europe (e.g., Agricultural and Food Research Council (AFRC), 1993; National Institute for Agricultural Research (INRA), 1989; Van Es, 1978) and North America (National Research Council (NRC), 2001). However, there have been few systematic studies to

* Corresponding author.
E-mail address: tianhai.yan@afbini.gov.uk (T. Yan).

http://dx.doi.org/10.1016/j.livsci.2015.05.031
1871-1413/

quantify the maintenance energy requirement of young dairy cattle of different ages.

There is evidence indicating that current high yielding dairy cows have greater metabolic rates (Yan et al., 1997b) and require more energy for maintenance than 30 years ago (Yan et al., 1997a; Kebreab et al., 2003). This implies that young Holstein cattle with high genetic merit for milk production may also have greater maintenance energy requirements than those recommended in current energy feeding systems (e.g., AFRC, 1993; NRC, 2001) which were developed using data obtained over three decades ago. However, there is little quantitative information available on maintenance energy requirements of young Holstein cattle with high genetic merit at different ages. Lack of such information makes precise feeding of diets for young Holstein cattle difficult. Therefore, the objectives of the present study were to evaluate energetic efficiencies of young Holstein cattle at various ages and then use these data to develop relationships between energy intake and retention to quantify maintenance energy requirements for these cattle at different ages.

2. Materials and methods

The present study was conducted under the regulations of Department of Health, Social Services and Public Safety of Northern Ireland in accordance with the Animals Scientific Procedures Act (1986). Data on growth performance and energy utilization obtained in the first period of the present study when cattle were 6 months old were published by Jiao et al. (2013).

2.1. Animals, experimental design, and diet

Twenty autumn-calved Holstein cattle (10 steers and 10 heifers) at the age of 5 months were used in a four-period study (28 d/period) with measurements taken at 6, 12, 18, and 22 months of age, respectively. Five days after birth, calves were reared under the same management regime and weaned at the age of 50 ± 6.2 d. All steers were castrated at the age of 4–5 months (134 ± 14.3 d) and heifers were bred by artificial insemination between 14 and 16 months of age (450 ± 23.7 d). Before the commencement of the study, the cattle were blocked into 10 pairs for similar age, body weight (BW) and body condition score (BCS). Each pair was gradually introduced into trials with an interval of 7 d, because there were only two indirect open-circuit respiration calorimeter chambers available. In each period, the cattle were housed as a single group in a cubicle accommodation for the first 20 d, and then transferred to metabolism units where they were tied up individually in stalls for 3 d, before being housed in chambers for 5 d. Gaseous exchange rates (O_2, CO_2 and CH_4) were measured over the final 96-h period. All equipment, procedures, analytical methods and calculations used in the calorimetric measurements were as reported by Gordon et al. (1995).

The cattle were fed a single mixed diet based on concentrates and perennial ryegrass silage for ad libitum intake once daily at 0900 h during the 4 periods. The ingredient and chemical composition of the concentrates and chemical composition of the grass silage are presented in Table 1. The diet offered was a typical ration of concentrate and grass silage used on UK commercial farms and prepared daily using a Belle Premier 200XT feed mixer (Belle Engineering Ltd., Sheen, Derbyshire, UK). The same grass silage was used for all four experimental periods. In the first period, the concentrate supplement was offered at a ratio of 550 g/kg of dry matter (DM), while it was given at a fixed rate of 2 kg DM daily in each of the other three periods. During the winter interval between the 2nd and the 3rd periods, both heifers and steers were housed in a single group and fed concentrates at 2 kg DM daily and grass silage ad libitum. During the summer intervals between the 1st and the 2nd periods, and between the 3rd and the 4th periods, heifers and steers were managed as a single group and grazed on pasture. Given that heifers were due to calf between 23 and 25 months age (730 ± 23.7 d), all chamber measurements for heifers and steers in period four were undertaken at 22 months of age (674 ± 15.3 d).

The grass silage was prepared from a first harvest of perennial ryegrass from a single sward in spring 2010. The silage used in all four periods came from a single silo. After completion of each period, the silo was completely sealed and reopened just before the beginning of the next period. Silage fermentation characteristics were monitored throughout the study. To minimize the effects of variation in silage quality during the final 8 d measurement period, enough silage material was removed from the silo 2 d before the start of each measurement period. The silage was completely mixed and put in plastic bags sufficient for one pair of cattle for 3 d. All bags were then completely evacuated and stored in an open barn until use.

Table 1
Ingredient composition of concentrates and chemical composition of concentrates and grass silage used in the present study.

	Concentrate	Grass silage
Concentrate ingredient, % on DM basis		
Rolled barley	49.5	
Sugar beet pulp	15	
Full-fat soybeans	20	
Ground corn grain	10	
Molasses	2.5	
Mineral–vitamin mix[a]	3	
Chemical composition[b]		
Dry matter content,[c] %	86.5 ± 1.3	18.8 ± 3.8
Gross energy, MJ/kg of dry matter	18.3 ± 0.7	19.5 ± 0.5
CP, % of dry matter	18.1 ± 0.5	12.5 ± 6.0
NDF, % of dry matter	20.8 ± 4.8	62.5 ± 10.0
ADF, % of dry matter	8.8 ± 5.4	38.9 ± 9.4
Ash, % of dry matter	5.6 ± 1.6	8.1 ± 5.7
pH		4.18 ± 0.4

[a] Composition (g/kg): Ca, 180; P, 60; Mg, 50; Na, 50; Cu, 1.3; Zn, 6.0; Mn, 3.5; I, 0.06; Co, 0.032; Se, 0.02. Vitamin composition (IU/kg): vitamin A, 600,000, vitamin D_3, 120,000, vitamin E, 1300.
[b] Results are expressed as mean ± SD value.
[c] Alcohol-corrected toluene DM.