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Prediction of body weight and empty body composition using body size measurements in lactating dairy cows

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ABSTRACT

Body composition and live animal measurements of Holstein–Friesian lactating dairy cows ($n=146$) were obtained from a large herd to represent a range of animal factors including parity, live weight (LW), body condition score (BCS), milk yield and stage of lactation. Live animal measurements were recorded 3 or 4 days prior to slaughter, including LW, BCS, milk yield, heart girth, belly girth, withers height and length. The objective was to develop prediction equations for body weight and component mass from body size measurements and other live animal data. All body size measurements were positively ($P<0.001$) related to LW, empty body (EB) weight (EBW), carcass weight and EB masses (kg) of lipid, CP, DM, water and ash and total GE content (MJ). The correlation coefficients (r) in these relationships were highest with heart girth (0.62 to 0.88), followed by belly girth (0.52 to 0.88) and length (0.51 to 0.83) and lowest with withers height (0.35 to 0.69). Heart girth was therefore selected as the primary predictor and a number of equations were then developed for prediction of body weight and EB mass, with the effect of parity or stage of lactation removed, where appropriate. All relationships were significant ($P<0.001$) and each predictor had a significant effect on the relationship ($P<0.05$). The adjusted R^2 values in the linear/quadratic relationships of heart girth with body weight and EB masses ranged from 0.53 (lipid mass) to 0.78 (LW). Addition of a range of other live animal variables (belly girth, length and BCS) to support heart girth significantly improved all relationships, with the Cp statistic and RMSPE (root mean square prediction error) values considerably reduced and adjusted R^2 values increased. These equations were evaluated through internal validation, by developing a range of similar new equations from two thirds of the present data and then validating these new equations with the remaining one third of data. The validation revealed a high prediction accuracy for LW, EBW, carcass weight and EB masses of CP, water and DM, a relatively good accuracy for EB lipid mass and total GE content, and a relatively poor accuracy for EB ash mass. In conclusion, body size measurements can be used together with other live animal factors to accurately predict body weight and EB component mass of lactating dairy cows. These equations provide an alternative approach to estimate body weight and component mass of lactating dairy cows.

1. Introduction

The contents of fat and protein in body tissues of lactating dairy cows is a direct reflection of nutritional strategies, and also varies greatly with age (i.e., from first to later lactations) and also stage of lactation. During early lactation, cows often mobilise their body reserves to compensate for deficits in energy and protein supply for milk production and this can result in live weight (LW) loss as much as 1.1 kg/d during the first eight weeks of lactation (Gibb et al., 1992). This loss can be regained during later lactation when the nutrient requirements for milk production are lower. The accurate estimation of body composition of lactating dairy cows is important for development of appropriate management and nutritional approaches to improve production efficiency and animal welfare for the dairy industry. This reflects increasing evidence that energy

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requirement for maintenance of cattle is mainly derived from body protein metabolism (Agnew and Yan, 2000).

Live weight and other live animal measurements have been used in a number of studies to develop prediction models for body component mass of lactating dairy cows (Gibb et al., 1992; Andrew et al., 1994; Yan et al., 2009). However, measurement of LW of large animals (e.g., dairy cows) requires weigh scales which are not always available on commercial farms. In such situations, LW of dairy cows is often visually estimated and this could result in error in estimation, although heart girth has been used to estimate LW of cattle for many decades. Nevertheless, body weight is a function of body size (skeletal development), body fatness and gut fill and these variables can be easily measured (e.g., body size) or estimated (e.g., fatness from body condition score (BCS) and gut fill from DM intake which relates to milk yield). Therefore, body size measurements together with other live animal measurements may provide an alternative to LW, to estimate body weight and component mass of lactating dairy cows. However, there is little information in the literature on the relationships between body size measurements and body weight and component mass of lactating dairy cows.

In 1999, Holstein–Friesian lactating dairy cows ($n = 146$) were slaughtered at the Agri-Food and Biosciences Institute following a disease incident, and a wide range of variables were assessed including body weight and component mass, live animal variables and body size measurements (heart girth, belly girth, length and withers height). The objective of the present study was to develop prediction equations for body weight and component mass using body size measurements and other live animal data.

2. Materials and methods

2.1. Animals and feeds

Body composition data of Holstein–Friesian lactating dairy cows ($n = 146$) used in the present study were derived from a compulsory slaughter programme in 1999, which resulted from a consequence of a disease incident. Cattle were selected from the disease free herd at the Agri-Food and Biosciences Institute to represent a range of parity, BCS, genetic merit (low to high), stage of lactation (early to late) and live weight (light to heavy) within the overall herd. Forty seven cows were in the first lactation, 47 in the second lactation and the remaining animals were in the third lactation or over. These cows had been subjected to a variety of nutritional and management regimes across a range of indoor feeding experiments before slaughter. They were housed in cubicle areas with box stalls and milked twice daily commencing at 06.00 and 16.00 h, and offered *ad libitum* mixed diets of grass silages and concentrate supplements, with forage proportions in diets ranged from proportionately 0.30 to 0.60 (DM basis) according to milk yield. No extreme diets were offered and all concentrate ingredients and their proportions in concentrate supplements used in the present study were within the range of normal practice. The silages were made from perennial ryegrass dominant swards and encompassed primary growth and first and second regrowth materials. The concentrates used included a vitamin and mineral supplement and some of the following ingredients: barley, wheat, maize, maize gluten meal, molassed sugar-beet pulp, citrus pulp, molasses, soyabean meal and rapeseed meal.

Milk production was recorded daily and daily milk yield used in the present study was averaged for the week before slaughter. The LW and BCS data were recorded 3 or 4 days prior to slaughter and on the same day of slaughter, after morning milking but prior to feeding. The mean LW and BCS from the 2 records were used in the present study. Body condition of each cow was scored by two experienced technicians (one for each recording time) using the method as described by Mulvanny (1977), with body condition scores ranging from 1 (very thin) to 5 (very fat). Body size measurements included heart girth (around cow behind the shoulder), belly girth (around cow just in front of the udder), withers height (from the floor to the top of the back in a line up the middle of the shoulder) and length (from front tip of shoulder to edge of pin bone).The live animal data are presented in Table 1.

2.2. Body composition analysis

Animals were offered their experimental diets on the morning prior to the day of slaughter, and were then transported a distance of 70 km to the lairage in the late evening, put into lairage and slaughtered early on the following day. Alternatively, some animals were transported to the lairage early on the day of slaughter. Prior to slaughter, cows were milked and feeds and water were freely available for all cows.

All procedures for the determination of body composition were undertaken over a period of two weeks. After slaughter, foetus and associated fluid and membranes were removed for pregnant cows. The exsanguinated bodies of the animals were then divided into eight components, namely, hide, feet, udder (milk was drained), head (including spinal cord and thymus), alimentary tract (excluding all contents which were measured, except contents of omasum), urino-genital tract, pluck (trachea,

Table 1
Live animal measurements and body composition data of lactating dairy cows ($n = 146$).

	Mean	SD	Minimum	Maximum
Live animal data				
Live weight (kg)	574	74.4	419	781
Milk yield (kg/d)	25.0	5.57	12.2	44.1
Days in milk	147	74.0	21	498
Body condition score	2.5	0.49	1.1	4.0
Parity	2.4	1.5	1	7
Empty body contents (kg or MJ)				
Empty body weight	415.3	61.37	296.7	608.4
Carcass weight	230	37.4	155	351
Lipid	43.2	21.34	16.6	133.7
Crude protein	76.8	10.00	56.6	104.1
Gross energy	3543	1038.5	2153	7736
Dry matter	147.8	32.27	98.9	267.5
Water	267.5	32.72	190.6	343.1
Ash	24.7	4.69	15.1	39.5
Body size measurements (cm)				
Heart girth	195	9.3	176	223
Belly girth	231	12.0	200	261
Withers height	138	4.9	125	150
Length	154	8.1	134	170