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QUANTIFYING ENERGY BALANCE IN CROSSBRED DAIRY COWS

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SUMMARY

The aim of this study was to investigate the phenotypic relationships between milk production, traits indicating energy utilization, growth hormone (GH) and insulin-like growth factor-1 (IGF-1) in 793 lactating two year-old Friesian-Jersey crossbred dairy cows. Total milk volume and yield of milk components protein, fat and lactose were calculated as the sum of spline function predictions. Measures of energy intake, energy balance and efficiency of energy utilisation were calculated using metabolisable energy (ME) prediction equations derived from individual animal measurements of milk production, condition score and liveweight. There was considerable variation in the energy balance measures, with 2.5% of cows having less than 15 days in negative energy balance out of 100 days and 1% of cows being in negative energy balance for all 100 days. Higher producing cows had higher levels of GH and lower levels of IGF-1 and a greater amount of body tissue depletion compared to lower producing cows. Cows with higher ratios of milk ME over maintenance ME had lower circulating levels of IGF-1 and higher GH as well as greater body tissue depletion in the first 100 days of lactation. The relationship between energy balance, efficiency and IGF-1 with fertility and the impact of these relationships on economic efficiency require further investigation.
Keywords crossbreeding, energy balance, milk production, spline

INTRODUCTION

To be able to calculate energy intake and energy balance after accounting for maintenance and production demands, feed intake measurements per cow are required. Common methods to determine feed intake from pasture include; the use of a rising plate meter to quantify pre- and post-grazing herbage masses, alkane markers to estimate herbage throughput and predictive models based on live weight, milk production and pasture availability. The main limitation with the rising plate meter approach is that feed intakes are estimated for groups of animals, rather than individuals. Alkane markers allow feed intakes to be measured for individual animals, however intake measurements determined through alkanes are often reported to be inaccurate on pasture based systems (Waghorn *et al*, 2004), are expensive and time-consuming and are usually only measured over short periods of time. Predicting feed intake through characteristics of the cow is one way in which feed intake can be assessed over longer periods for individual cows. In the present study, adapted energy prediction equations for maintenance, milk production, pregnancy, growth and body condition score (BCS) change were used to calculate energy intake on a per cow basis.

Levels of growth hormone (GH) and insulin-like growth factor-1 (IGF-1) provide additional information on the energy status of dairy cows. Cows that are mobilising body tissue tend to have higher circulating levels of GH and lower circulating levels of IGF-1. Results from the Dexcel Holstein-Friesian strain trial (MacDonald *et al,* 2005) show that over the last 30 years, selection has resulted in higher levels of GH and lower levels of IGF-1 in early lactation cows managed in pasture based systems. GH induces the secretion of IGF-1from the liver. IGF-1 controls GH through a negative feedback mechanism. The result of high amounts of circulating GH is that adipose sensitivity to insulin is reduced and body tissue is mobilised. The aim of the study was to study the relationships between measures of energetic efficiency, GH, IGF-1, energy requirements and milk production in first lactation crossbred cows in order to identify a genetic basis for the modulation of these phenotypes in dairy cows. This paper explores the first stage of that process, the characterisation of phenotypes involved in the maintenance of positive energy balance.

METHODS AND MATERIALS

Data. The data was collected from an experimental population of New Zealand Friesian-Jersey crossbred dairy cows. The experiment consisted of approximately 800 F2 cows, which calved for the first time as two-year-olds and were monitored throughout their first lactation. This F2 population consisted of two cohorts, the first of which contained 352 cows calving between July and September 2002 and the second containing 441 cows calving across the same period in 2003. As far as possible animals in both cohorts were farmed in a common environment. A detailed description of the F2 experiment is given by Spelman *et al* (2004). Daily milk volumes (am and pm) were collected and every fortnight fat, protein, casein, and lactose yield was measured from a composite milk sample collected over 24hrs. The animals were also scored weekly for body condition and had live weight measured at least twice a week In the 2003-04 season an automatic weighing system was installed and on average over 80% of the animals had two live weights recorded each day though out lactation. Blood samples were collected in the first week after each cow calved and weekly thereafter until approximately 125 days of lactation. All blood samples where analysed by radioimmunoassay for IGF-1 and GH.

Methods. An iterative approach was used to fit a weighted generalized additive model using a penalized regression spline function (Wood 2004) to milk volume, milk composition yields, condition score and liveweight for each cow to remove environmental variation and to reduce the impact of errors in the data. For each data point a weight value was defined from a previous spline fit as an inverse function of the residual. The initial weights (iteration one) were set to one for all data points. The calculated weight was used in the subsequent weighted spline fit. This spline function converged after 2-4 iterations. The sum of the spline function predictions (SFP) were used to calculate the total yield measures for milk fat, true protein, lactose and milk volume for each cow. The average levels for GH, and IGF-1 over the sampling period were also calculated for each cow.

Metabolisable energy (ME) requirements for maintenance and activity were estimated from SFPs for liveweight, while ME requirements for milk production were calculated using the SFP for milk fat, true protein, lactose and milk volume yields. The calculation of energy yielded or gained from BCS change was based on the principles of BCS change from the NRC (2001). A detailed description of the equations used to calculate the energy requirements are given in Pryce *et al* (2005). The following two efficiency measures were calculated; (ME milk production)/(ME maintenance) (EFF1) and (ME milk production)/(ME maintenance + growth + BCS change) (EFF2). Two negative energy balance indicators were calculated for the first 100 days of lactation. The first was the number of days (DBR days) an animal was depleting body reserves and the second, was the total amount of ME depleted from body reserves (DBR total). The effects of cohort and age at first calving were removed from the hormone, ME and yield measures using a linear model where cohort was fitted as fixed effect and age at first calving was fitted as a linear and quadratic covariate.

RESULTS AND DISCUSSION

The mean and standard deviations for the energy and milk production measures are given in Table 1. The two negative energy balance indicators showed considerable variation, with 2.5% of the cows having less than 15 days in negative energy balance in the first 100 days of lactation and 1% of the cows being in negative energy balance for all 100 days of lactation.

Table 1. Phenotypic means and standard deviations for energy, milk production, GH and IGF-1 measures

	Milk Fat (kg)	Volume (l)	Protein (kg)	Lactose (kg)	GH Level (ng/ml)
Mean	164	4394	167	218	35.1
Std. Dev.	24.5	469	16.7	23.3	4.50
	DBR Total (MJ ME)	DBR Days	EFF1	EFF2	IGF-1 Level (ng/ml)
Mean	523	48.7	1.45	1.43	8.52
Std. Dev.	314	14.9	0.18	0.24	3.31

EFF1 = ME milk production/ME maintenance
EFF2 = ME milk production/(ME maintenance + growth and condition score change)
DBR = Depletion of body reserves

The correlations among the milk production traits were high ranging from 0.83 (milk fat and volume) to 0.92 (volume and protein). The correlations between mean GH level and the milk production traits were low, but all positive, with lactose and milk volume having the largest values of 0.12 and 0.13, respectively. Whereas, the correlations between mean IGF-1 level and milk production were moderate to low, but all negative, ranging from –0.17 to –0.30. The correlation between the two energy balance indicators was 0.58. The correlations between the two energy balance indicators and milk production were moderate to low but all positive ranging from 0.14 to 0.24 and 0.21 to 0.29 for DBR days and DBR total, respectively. There were moderate negative correlations of -0.34 and -0.45 between mean IGF-1 level and DBR days and DBR total, respectively. Whereas, the correlations between mean GH level and DBR days and DBR total were moderate to low, 0.07 and 0.23, respectively. The correlation between the two efficiency measures was 0.89. The correlations between the efficiency measures and milk production traits were moderate to high and all positive ranging from 0.46 to 0.67. Moderate negative correlations (-0.47 and –0.38) were found between IGF-1 level and the EFF1 and EFF2, respectively. Moderate to high correlations of 0.44 and 0.63 were found between EFF2 and DBR days and DBR total, respectively. Lower correlations of 0.27 and 0.30 were found between EFF1 and DBR days and DBR total, respectively.

Table 2 provides the mean values for IGF-1, GH, negative balance and efficiency measures for the top and bottom 5% of cows selected on milk solids yield. When contrasting the top 5% with the bottom 5% based on yield of on milk solids, the top 5% have nearly 60% greater efficiency, more days in negative energy balance, and twice the amount of energy depleted from body reserves, as well as higher GH levels and lower IGF-1 levels.

Table 2 Means for IGF-1, GH, negative balance and efficiency measures for the top and bottom 5% of cows selected on milk solids yield

	Milk Solids (Kg)	EFF1	EFF2	DBR Days	DBR Total (MJ ME)	GH Level (ng/ml)	IGF-1 Level (ng/ml)
Top 5%	347	1.60	1.63	54.1	703	11.24	8.11
Bottom 5%	174	1.06	1.02	41.2	327	8.95	12.04

EFF1 = ME milk production/ME maintenance
EFF2 = ME milk production/(ME maintenance + growth and condition score change)
DBR = Depletion of body reserves

The results support previous findings (Veerkamp *et al*, 2000), where higher producing cows had lower levels of IGF-1, higher levels of GH and greater amount of energy depleted from body reserves compared to lower producing cows. Both measures of efficiency essentially identify the same cows. The most efficient cows, that is cows with the highest ratio of ME for milk production over ME for maintenance, appear to have lower levels of IGF-1 and greater amount of energy depleted from body reserves during the first 100 days of lactation. They also have higher levels of production, although the relationship is not perfect due to a positive relationship between liveweight and production. The measures of efficiency used in this study are based on energy used for production over energy used for maintenance rather than an economic measure. It is conceivable that greater levels of energy depleted from body reserves during the first 100 days of lactation in more efficient cows could negatively impact on fertility. Also, body tissue has to be regained either later in lactation or in the dry period (when feed is sometimes more expensive), Veerkamp *et al,* (2000) showed a genetic correlation between commencement of luteal activity and energy balance of –0.49. Further research is required to study the relationships, including genetic relationships, among negative energy balance indicators, levels of IGF-1 and reproduction and also on the impact of fertility relationships on measures of economic efficiency in pasture-based systems.

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