PREDICTING ENERGY BALANCE IN LACTATING EWES AS A BASIS FOR QTL ANALYSIS

E. Jonas, P.C. Thomson, K.J. Fullard, D. McGill and H.W. Raadsma

ReproGen, Faculty of Veterinary Science, University of Sydney, Camden, NSW 2570

SUMMARY

Four different models (AFRC, CSIRO, CNCPS-s and body reserve change) were used to validate predicted energy balance, Residual Feed Intake (RFI) and Feed Conversion Ratio (FCR) of dairy ewes in a computerised self feeding system. Estimates derived from all models were in strong agreement and allowed an estimate of energy balance during lactation. Low to moderate positive phenotypic correlations (range 0.17 to 0.67) were observed between energy balance with milk yield, protein, and lactose content, moderate negative correlations (range -0.47 to -0.48) with energy balance and fat content in the milk. The repeatability of the energy models (AFRF, CSIRO, CNCPS-s) was between 0.16 and 0.46. The system was thought to be sufficiently accurate to predict energy balance, RFI, FCR in individual ewes as input traits for genetic parameter and QTL studies. A preliminary linkage analysis among chromosome 1, 5 and 23 could identify significant linkage regions for energy balance on OAR 1 around 330 cM, which was in a comparative region as described by Sherman *et al*. (2009) in cattle and for RFI at 117 cM on the same chromosome.

INTRODUCTION

Energy balance is a complex trait with relevance to the study of human obesity, and maintenance energy requirements of livestock (Moody *et al*. 1999). Achieving a better understanding of the factors predisposing for differential mobilization of body reserves is an important step in the development of strategies to reduce health and associated reproduction problems in dairy cattle (Friggens *et al*. 2007). It was concluded in different studies that an increased mobilization of body reserves in early lactation is associated with increased health problems and a reduction in reproductive performance in dairy cattle (Hansen 2000; Pryce *et al*. 2001) termed Negative Energy Balance (NEB) syndrome. On the other hand it was proposed that the cow is adapted to energy mobilization in early lactation if this is genetically driven and therefore this does not affect the health and reproduction as environmentally driven mobilization does (Friggens *et al*. 2007). A better understanding of the complexities of energy mobilisation requires the recording of energy balance as a routine phenotype to further estimate genetic correlations between energy balance, milk production, health and fertility and as a target trait for genetic marker studies. Until now only a few studies have identified quantitative trait loci (QTL) for component characteristics of energy balance and feed intake in cattle, with evidence for a genetic component for both (Harder *et al*. 2006, Nkrumah *et al*. 2007, Sherman *et al*. 2009). The aim of this study was to predict energy balance in lactating ewes, to test the repeatability of the parameters and to perform a linkage analysis for detection of QTL on three candidate chromosomes.

MATERIALS AND METHODS

The data used in this analysis were collected at the University Sydney research farm ‘Mayfarm’ at Camden, New South Wales, Australia as a subset of studies carried out between 2005 and 2009 using dairy sheep. Animals used for the experiment derived from an Awassi × Merino resource population (Raadsma *et al*. 2009). Information was collected on body weight and feed intake using an automatic feeder system without restriction of food on offer. The feeder experiments were performed across three experimental cohorts using 349 ewes between 2005 and

2007. In the present study observations from AMM backcross (BC) and AM_AMM (DBC) double backcross ewes were used. Data were collected before lambing (week -10 until 0), included the lambing date (week 0) and until a maximum of week 26.

Feed conversion (FCR) was calculated as the amount of feed consumed (in kg) per kg body weight gain or loss. Feed intake (in kg) as a ratio of absolute body weight and the residual feed intake (RFI) as the relation between observed and expected feed intake were also calculated (Koch *et al.* 1963). Energy balance was calculated based on the Input-Output models described by CSIRO (CSIRO 2007), the adapted formula of the CNCPS-s model (Cannas *et al.* 2004) and the advisory manual prepared by the AFRC (AFRC 1993). Using these three models, the difference in energy between energy intake (feed) and energy loss (maintenance plus pregnancy or milk energy) was calculated, the resulting variables are further defined as Energy Balance (EB). The three models differ slightly in the calculation of energy required for maintenance. Additionally the change in body reserve was calculated based on body condition score and body weight (Friggens *et al.* 2007), a formula which incorporates constants (universal constants and literature-derived estimates) to describe energy mobilisation (Sanson *et al.* 1993, Tolkamp *et al.* 2007, Lewis and Emmans 2007).

The repeatability of the parameters was calculated on a weekly basis using animal as a random factor, and season, experiment, reproduction stage, sire and genotype as fixed effect terms. A linkage analysis was performed in 100 backcross ewes of one half sib family using 26 markers on chromosome 1, 5 and 23. QTL methodology (maximum likelihood method) and marker design are explained in detail in Raadsma *et al.* (2009). Phenotypes used were the mean values of EB from the three models, body reserve change and RFI. QTL were calculated for phenotypes within five phases: phase I pregnancy, phase II week 1 & 2, phase III week 3 to 10, and phase IV week 11 to 20 of lactation.

RESULTS AND DISCUSSION

Table 1. Results of residual feed intake, energy difference between input and output (CSIRO, AFRC and CNCPS-s) [MJ], body reserve change [MJ]; number of animals (N), average (mean), standard deviation (std), minimum (min), maximum (max) for one experiment

Trait	N	mean	std	min	max
Feed conversion (feed intake / growth)	62	13.84	4.28	6.12	21.98
Feed intake / body weight*100	62	1.93	0.56	0.82	2.99
Energy balance (CSIRO)	58	5.92	2.51	1.15	11.39
Energy balance (CNCPS-s)	58	6.14	2.68	1.38	11.03
Energy balance (AFRC)	58	4.93	2.66	0.53	9.88
Body reserve change	58	3.97	2.93	-1.63	15.15
Residual feed intake	62	1.46	0.32	0.26	2.15

The weekly feed intake, body weight and lactation performances of 62 ewes from the Awassi × Merino population were analysed in a first cohort. Predicted dry matter intake, RFI and FCR indices were derived from the summarized feeder data. Using the estimates of RFI, slight differences between the estimated and measured feed intake were observed. The EB models of CSIRO, CNCPS-s and AFRC resulted in very similar parameters (Table 1) and an average was of all three was taken for further analysis of QTL effects. High (0.73 to 0.79) correlations were also observed between EB (CSIRO, CNCPS-s, AFRC) and RFI. Correlations between energy balance and lactation performance are shown in Table 2.

Table 2. Phenotypic correlation between the estimates of the energy balance, feed conversion rate and residual feed intake with the milk yield and composition traits

Trait	Energy balance			Body reserve change	FCR	RFI
	AFRC	CNCPS-s	CSIRO			
Milk yield	0.17	0.14	0.17	0.19	-0.40	0.65
Protein content	0.53	0.52	0.53	-0.09	-0.36	0.55
Fat content	-0.48	-0.47	-0.48	-0.34	0.31	-0.61
Lactose content	0.66	0.67	0.66	-0.12	-0.21	0.21
Repeatability	0.34	0.32	0.16	ne	0.004	0.46

Body reserve change was negatively correlated to fat content. FCR and RFI were correlated with milk yield. EB was highly correlated (>0.93) using the three models (CSIRO, CNCPS-s, AFRC), but lowly correlated to Body reserve change (0.19 to 0.2).The repeatability estimates of parameters describing energy balance parameters were comparable (0.16 [CSIRO] to 0.3 [AFRC]) within the three approaches (CSIRO, CNCPS, AFRC). The repeatability of the RFI was high (0.46), moderate for feed intake/body weight (0.26) and low for feed conversion (0.004).

Table 3. Results of the QTL analysis for energy balance calculated under three models and RFI

Trait	Phase	OAR	Position	LOD	sign	Effect
Energy balance (CSIRO)	I to IV	1	329.5	1.77	*	-3.04
	I		335.5	3.81	***	-4.82
	II,III,IV		-	no significant QTL		-
Energy balance (CNCPS-s)	I to IV	1	331.5	1.49		-2.90
	I		336.5	2.72	**	-3.69
	II,III,IV		-	no significant QTL		-
Energy balance (AFRC)	I to IV	1	328.5	1.42		-2.85
	I		333.5	2.85	**	-3.77
	II,III,IV		-	no significant QTL		-
Residual feed intake	I to IV	1	117.5	2.27	**	0.41
	I		118.5	2.2	**	0.32
	II,III,IV		-	no significant QTL	-	
Energy balance and Residual Feed Intake	all	5	-	no significant QTL	-	
		23	-	no significant QTL	-	

* suggestive QTL (LOD>1.7); ** significant QTL (LOD>2.0); highly significant (LOD>3.0)

The linkage analysis using QTL-MLE showed one significant QTL for RFI on OAR 1, which was located in a comparative region to BTA 1 (Table 3). The QTL for all three energy balance models were located in the comparative region to BTA 3, where Sherman *et al*. (2009) had describe a QTL for RFI in cattle (Table 3). Additional studies will need to be done to predict the EB for total milk take-off based on milk yield and milk composition data as previously described in cattle (Friggens *et al*. 2007). The results showed that the data derived from the different feed intake models can be further used to study the genetic background of these traits.

CONCLUSION

We could show that the application of input-output models to estimate the energy balances in ewes before and during lactation using a computerised feeding system yielded very similar estimates of energy balance. The traits were moderately repeatable and amenable for further genetic analysis. A targeted linkage analysis revealed one significant QTL for RFI on OAR 1 and also significant linkage for energy balance on the same chromosome, which were located in the comparative region to the identified QTL for RFI in cattle.

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