PREDICTING ENERGY BALANCE IN GROWING WETHERS AND ESTIMATION OF HERITABILITY FOR DERIVED PARAMETERS

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SUMMARY

The aim of this study was to characterize the energy balance of growing sheep for three different models (CSIRO, CNCPS-s, AFRC) using estimates of feed intake and individual animal weight in an automatic feeder system. Data from 610 wethers of seven cohorts from an Awassi-Merino resource population were used during feed intake experiments. Aspects of data analysis and handling from computerized systems are described to calculate growth, feed intake, residual feed intake (RFI), predicted dry matter intake (DMI) and feed conversion efficiency (FCR). Three models were used to calculate energy balance of 610 progeny from seven half sib families and as a basis for phenotypic correlation and heritability estimates. Two different prediction equations for EB were derived from each model, a preliminary energy balance describing the difference between energy intake and energy for maintenance (EB I) and an approach describing the energy surplus as the difference between feed intake, energy for maintenance and growth (EB II). All three models gave similar predictions for EB I with phenotypic correlations >0.9, whereas greater differences between the EB II models with phenotypic correlations of -0.87, -0.47 and 0.52 were observed. Heritability was estimated between 0.26 and 0.37 for the EB I, 0.17 to 0.52 for EB II, 0.51 for body weight, 0.45 for feed intake, 0.16 for RFI, 0.34 for DMI, and 0.55 for FCR. We conclude that EB I and FCR under either of the three models should be appropriate for QTL analyses in growing sheep under a computerized feed intake system. We also conclude that an exact determination of the energy for body mass gain must be reconsidered before variables calculated using this trait can be used as phenotypes for further genetic analysis.

INTRODUCTION

Sheep production is a major contributor to global food production and sheep meat one of the few sources of meat with no cultural and religious restrictions in consumption. Feed input costs represent a significant cost factor to sheep production enterprises and selection for improved feed and energy utilization or generally termed feed conversion efficiency, is potentially an attractive but complex avenue for improving sheep profitability. A fundamental requirement for consideration in genetic improvement systems is a clear definition of the phenotype for both research parameter estimation and application in profit functions.

A number of methods have been published to describe the energy balance in cattle, especially dairy cattle examples as reviewed by Brosh (2007), and Van Knegsel *et al.* (2005), however only few methods have been adapted for sheep, even though similar approaches can be used in both species. Traditionally there are two ways to measure the energy balance using the input-output measures and the calculation of changes in body tissue composition. The most detailed input-output method is described by the modification of the Cornell Net Carbohydrate and Protein System (CNCPS), a mechanistic model that predicts nutrient requirements and biological values of feed for cattle, and has been adapted for the application in sheep (Cannas *et al.* 2004). This system accounts for differences in feeds of diverse characteristics fed at different levels of intake across a wide range of animal physiological states and environmental effects. Alternative systems to predict the energy balance are the application of residual feed intake (RFI) (Sainz and Paulino 2004). The aims of this study were as follows: 1) to evaluate the energy balance in growing sheep using three different input-output models, 2) to calculate input components of residual feed intake, and 3) to calculate phenotypic correlations and heritability for energy balance estimates. In future, genome wide linkage and association studies for these traits will be performed using animals of the same population in an attempt to characterize the genetic architecture affecting these complex traits and identify genetic markers for marker assisted selection.

MATERIAL AND METHODS

The data used in this study were collected at the University Sydney research farm 'Mayfarm' at Camden, New South Wales, Australia between 2005 and 2009 using animals derived from an Awassi × Merino resource population (Raadsma *et al*. 2009). The information on body weight and feed intake were recorded using an automatic feeder system without any restriction of food available. The feeder experiments were performed during different growth phases at the time the animals entered the feeding system, ranging from 5 months till 2 years of age for a period of 70-90 days. To model the phenotype, the present study used observations from 610 animals. To stabilize the residual variances, estimates of the daily body weight and daily feed intake of each animal were summarized to weekly average values. Growth was calculated as the difference between two weekly averaged body weights.

Two different parameters describing energy balance were calculated based on the input-output model described by CSIRO (CSIRO 2007), the adapted formula of the CNCPS-S model (Cannas *et al.* 2004) and following the advisory manual prepared by the AFRC (AFRC 1993). The first main difference between the models is the calculation of the energy loss for maintenance, which is calculated as shrunken body weight in the model from CSIRO and as the sum of metabolism and activity energy using the CNCPS-S model. Difference between feed intake and energy loss for maintenance was further defined as energy balance I (EB I). The second greatest difference between the models is the estimation of energy requirements for growth, which is calculated using feed intake, full body weight and weight gain in the model of CSIRO, using body weight change, feed intake and maintenance energy in the model of CNCPS-s, and using body weight in the model of AFRC. Difference between feed intake and energy loss for maintenance and growth was further defined as energy balance II (EB II). The difference between the observed and predicted dry matter intake (DMI) was calculated following the description of CNCPS-S (Cannas *et al.* 2004). The residual feed intake (RFI) was calculated as the relation between feed intake and expected feed intake, which included here energy for growth (assuming 12.5 MJ ME required/kg weight gain) and energy for maintenance. Indices of feed conversion (FCR) were calculated as the amount of feed (kg) per kg body weight gain or loss and as additional feed (kg) required for each unit body weight.

All analyses were performed using the program R (version 2.6.0) and GenStat (10th edition). Mixed models were applied to the data to estimate the repeatability of each trait using animal as a random factor in SAS (version 9.2). Further the mean of the values of each animal were used to estimate heritabilities in ASREML using a sire model.

RESULTS AND DISCUSSION

To compare the energy balance models, data from 610 animals over a period up to 17 weeks (average 47 days) were used. Animals had an average body weight of 57 kg. During the experiment animals gained in average 9.5 kg. The summary of the data from the feeder experiment are shown in Table 1. Using the estimates of residual feed intake, slight differences between the predicted and the measured feed intake were observed, whereas the difference between the predicted and the observed dry matter intake were smaller. Observed feed intake for growth was in the expected range with a mean of 8 kg feed intake/kg body weight gain.

Table 1. Body weight [kg] and feed intake [kg] energy balance I and II (CSIRO, AFRC and CNCPS-s) [MJ], and feed conversation rates, shown are number of animals (N), minimum (min), maximum (max), average (mean), standard deviation (std)

Trait	N	min	max	mean	std
Body weight beginning (BWT0)	8152	29.42	101.84	50.59	11.27
Body weight end (BWTe)	8142	35.38	103.08	60.03	11.32
BWTe-BWT0 (Growth)	8142	-9.56	23.34	9.45	6.03
Mean body weight (BWT)	6750	29.20	103.22	57.27	11.62
Weekly body weight change (Growth rate)	5299	-3.00	5.00	0.98	1.76
Feed Intake (FI)	6691	0.021	2.98	1.14	0.50
Feed conversion (feed intake / growth)	4958	0.01	49.86	7.90	8.24
Feed intake / body weight (gross efficiency)	6691	0.30	960.8	133.9	76.02
Energy available for growth (CSIRO) (EB I)	6691	-7.87	28.03	6.85	5.53
Energy surplus (CSIRO) (EB II)	6691	-34.45	4.83	-18.55	5.62
Energy available for growth (CNCPS-s) (EB I)	6691	-6.32	27.58	7.21	5.42
Energy surplus (CNCPS-s) (EB II)	6691	-34.92	-0.02	-9.24	5.53
Energy available for growth (AFRC) (EB I)	6691	-8.48	27.69	6.41	5.53
Energy for surplus (AFRC) (EB II)	5275	-95.54	54.68	3.37	9.09
Observed dry matter intake / Predicted dry matter intake	6691	0.01	2.76	0.85	0.37
Residual feed intake	5147	-17.90	19.98	2.16	2.42

Table 2. Heritability (h^2), repeatability (t), and phenotypic correlations between of body weight (BWT), growth (GR), feed intake (FI), feed conversion rate (FCR) and feed intake/kg body mass (FI/BWT), dry matter intake (DMI), residual feed intake (RFI), energy balance I and II (EB I and EB II), DMI, and RFI; ne: not estimated

Trait	h^2	t	BWT	GR	FI	FCR	FI/BWT	DMI	RFI
BWT - mean	0.51	0.87	-	0.01	0.15	0.09	-0.19	-0.17	-0.12
Growth -GR	0.14	ne	0.01	-	0.43	0.06	0.32	0.39	0.04
FI	0.45	0.2	0.15	0.43	-	0.26	0.80	0.94	0.25
FCR	0.55	0.002	0.09	0.06	0.26	-	0.25	0.23	0.13
FI/BWT	0.55	0.24	-0.19	0.32	0.80	0.25	-	0.87	0.29
DMI	0.35	0.14	-0.17	0.39	0.94	0.23	0.87	-	0.30
RFI	0.16	0.02	-0.12	0.04	0.25	0.13	0.29	0.30	-
EB I CSIRO	0.32	0.16	-0.01	0.43	0.99	0.25	0.84	0.98	0.27
EB I CNCPS	0.26	0.17	0.05	0.43	0.99	0.25	0.83	0.96	0.27
EB I AFRC	0.37	0.16	-0.03	0.43	0.98	0.24	0.85	0.98	0.27
EB II CSIRO	0.34	0.13	-0.19	0.39	0.94	0.23	0.86	0.99	0.29
EB II CNCPS	0.18	0.14	-0.04	-0.39	-0.90	-0.21	-0.77	-0.88	-0.24
EB II AFRC	0.52	0.007	-0.11	0.07	0.49	0.35	0.50	0.53	0.45

Only slight differences between the energy balance models of CSIRO, CNCPS-s and AFRC were found for EBI, resulting in very similar parameters for predicted energy balance (Table 1). Prediction of EB II on the other hand showed a major difference for estimates from all three models (Table 1) Phenotypic correlations between derived EB I from the different models was high (> 0.99). The EB II showed greater differences with high negative phenotypic correlations (-

0.87) between the CSIRO and CNCPS-s model, moderate correlation (0.52) between the CSIRO and AFRC model, and moderate negative correlated (-0.47) between the CNCPS-s and AFRC model.

The repeatability of all traits taken on a weekly basis using 610 animals and 8267 observations are shown in Table 2. The phenotypic correlations and heritability estimates for all main traits are also shown in Table 2. The heritability for EB I and EB II was low to moderate (0.18 to 0.52). Cammack *et al.* (2005) estimated a slightly lower heritability of RFI (0.11), compared to our study (0.16). In another study, total feed intake, and feed conversion ratio were moderate heritable (0.39 and 0.26) (Snowder and Van Vleck 2003). In our study the estimate for feed intake and FCR was higher (0.45 and 0.55).

CONCLUSION

The application of three different models to estimate the energy balance in growing wethers using data from an automatic computerized feed intake and body weight system predicted similar levels of energy balance in sheep allowing for maintenance. But greater differences were seen in Energy balance among the models allowing for maintenance and growth. The data could be used to predict residual feed intake and indicators of feed conversion efficiency in sheep, and allow phenotypic and genetic analyses. Low to moderate heritability was shown for energy balance, FCR, DMI, and RFI. Furthermore it should be possible to use the data from these models for QTL mapping.

REFERENCES

AFRC (1993) "Energy and protein requirements of ruminants. An advisory manual prepared by the technical committee on response to nutrients". CAB international, Wallingford, UK.

Brosh A. (2007) *J. Anim. Sci.***85**:1213

Cammack K.M., Leymaster K.A., Jenkins T.G. and Nielsen M.K. (2005) *J. Anim. Sci.* **83**:777

Cannas A. (2004) *J. Anim. Sci.* **82**:149

CSIRO (2007) "Nutrient requirements of domesticated ruminants". CSIRO Publishing. Collingwood, Australia.

Raadsma H.W., Thomson P.C., Zenger K.R, Cavanagh C., Lam M.K., Jonas E., Jones M., Attard G., Palmer D. and Nicholas F.W. (2009) accepted in *Genet. Sel. Evol.*

Sainz R.D., Paulino P.V. (2004) eScholarship Repository, University of California. http://repositories.cdlib.org/anrrec/sfrec/2004 residual feed intake.

Snowder G.D. and Van Vleck L.D. (2003) *J. Anim. Sci.* **81**: 2704

Van Knegsel A.T.M., Van Den Brand, H., Dijkstra J., Tamminga S. and Kemp B. (2005) *Reprod. Nutr. Dev.* **45**:665