Idaho Agricultural
Experimental Station

Research Bulletin 84
April 1972

Gain Factors for Four Systems Of Measuring Energy Requirements Of Ram and Ewe Lambs

T. B. Keith, D. A. Price,
K. R. Frederiksen and D. O. Everson

UNIVERSITY OF IDAHO
College of Agriculture

Summary

Feed intake and body-weight data of 95 ram lambs and 131 ewe lambs were used to evaluate equations for all four systems of measuring energy requirements of sheep.

Gain factors for computing ADG of ram lambs were revised for TDN, DE, ME and NE systems of measuring energy requirements.

Gain factors for computing ADG of ewe lambs were revised for DE and ME systems of measuring energy requirements.

Maintenance allowances of feed for the four methods of measuring energy intake for the same ration were studied.

The variation in maintenance allowances of feed for the four methods warrant further studies of coefficients of metabolic weight ($W^{0.75}$) and the energy values assigned to feeds.

THE AUTHORS

Dr. T. B. Keith is professor emeritus, Department of Animal Industries, University of Idaho. **Dr. D. A. Price** is director and range nutritionist, U.S. Sheep Experiment Station, Sheep and Fur Animal Research Branch, ARS, USDA, Dubois, Idaho. **K. R. Frederiksen** is associate research professor of animal science, University of Idaho, headquartered at the U.S. Sheep Experiment Station, Dubois. **Dr. D. O. Everson** is professor and statistician, Idaho Agricultural Experiment Station, University of Idaho.

AGRICULTURAL EXPERIMENT STATION

University of Idaho | **College of Agriculture**

Moscow, Idaho | **SY 1.5M 4-72**

Gain Factors for Four Systems Of Measuring Energy Requirements Of Ram and Ewe Lambs

T. B. Keith, D. A. Price, K. R. Frederiksen, D. O. Everson

Equations have been formulated for all four systems of measuring energy requirements of growing ram and ewe lambs by Garrett, Meyers and Lofgreen (1959). The four systems measure energy at different stages of utilization and are referred to as TDN (total digestible nutrients), DE (digestible energy), ME (metabolizable energy) and NE (net energy).

This study attempts to evaluate these equations and revise those that give computed gains greatly different from the observed gains.

Experimental Procedure

Feed intakes, initial and final weights and ADG of 95 ram lambs and 131 ewe lambs were used to evaluate the accuracy of these equations (Keith et al., 1971). In one series, 95 rams and 91 ewes were fed a diet containing 87.5% alfalfa hay and 12.5% oats in individual stalls for 84 days (Price et al., 1965). In another trial, 40 ewe lambs were fed 5 different ratios of concentrate to alfalfa hay in individual stalls for 77 days (Davison, Keith and Hickman, 1950).

Concentrate mixtures with feed values for TDN, DE, ME, NE_m (net energy for maintenance) and NE_g (net energy for gain) of the 40 ewe lambs are presented in tables 1 and 2. TDN, DE and ME values for barley, oats, wheat bran, linseed meal and alfalfa hay are those presented by Crampton and Harris (1968).

The same feed values were used to calculate maintenance and gain for TDN, DE and ME systems.

Equations in table 3 were used to compute ADG shown in tables 4 and 5. All weight, gain and feed intake values were corrected by the method of least squares (Harvey, 1960).

Table 1. Concentrate mixtures and energy values of feeds.

Feed	% of ration	TDN[1]	DE[1]	ME[1]	NE_m[2]	NE_g[2]
Barley	40	76	3.38	2.77	1.93	1.27
Oats	29	67	2.94	2.41	1.66	1.12
Wheat bran	20	59	2.59	2.12	1.52	1.01
Linseed meal	10	71	3.13	2.56	1.61	1.08
Salt	1					
Average		69	3.04	2.49	1.72	1.15
Alfalfa hay, 29% fiber		50	2.20	1.80	1.23	.70

[1]Crampton and Harris (1968): barley 4-00-530; oats 4-00-309; wheat bran 4-05-190; linseed meal 5-02-048; alfalfa hay 1-00-063.

[2]Keith et al. (1971) and Lofgreen et al. (1968).

Table 2. Energy values of 5 diets differing in ratio of concentrate to alfalfa hay.

Ratio of concentrate to alfalfa hay	Value per kg				
	TDN	DE	ME	NE_m	NE_g
	%	Mcal	Mcal	Mcal	Mcal
2:3	58	2.55	2.12	1.43	0.88
1:1	60	2.64	2.18	1.46	0.93
3:2	62	2.73	2.25	1.52	0.97
2:1	63	2.78	2.32	1.54	0.99
5:2	64	2.80	2.34	1.58	1.01

Table 3. Equations used to estimate energy requirements for sheep for maintenance and weight gain.[1]

Energy category	Equation for maintenance and gain[2]
TDN	$.029\ W_{kg}^{0.75}\ (1 + 5.07\ g)$
DE	$137\ W_{kg}^{0.75}\ (1 + 5.29\ g)$
ME	$112\ W_{kg}^{0.75}\ (1 + 5.57\ g)$
NE	$63\ W_{kg}^{0.75}\ (1 + 3.97\ g)$

[1]Garrett et al. 1959.

[2]TDN and weight (W) are in kilograms, DE, ME and NE in kilocalories.

Computation of Gain Factors

Computed ADG for any energy system (TDN, DE, ME or NE) may be expressed as the ratio of energy available for gain to energy required for maintenance times a gain factor, X; e.g., for TDN:

$$\text{Computed ADG} = \frac{TDN_{ag}}{TDN_m \cdot X}$$

Conversely, when actual ADG and TDN consumption are established by experimentation, the gain factor, X, may be estimated as follows:

$$X = \frac{\overline{T}DG_{ag}}{TDN_m \cdot \text{Actual ADG}}$$

and the computed ADG of other animals fed given amounts of TDN may be computed from the first equation, where TDN_{ag} is TDN

Table 4. Observed and computed ADG, ratio of observed to computed ADG, maintenance and energy available for gain for ewe lambs fed 5 ratios of concentrate to alfalfa hay.

	Ratio of concentrate to alfalfa hay				
Items	**2:3**	**1:1**	**3:2**	**2:1**	**5:2**
No. lambs	8	8	8	8	8
Observed ADG, kg	0.10b	0.14a	0.16a	0.16a	0.17a
Computed ADG, kg					
TDN	0.11c	0.13bc	0.15ab	0.16a	0.17d
DE	0.08a	0.10a	0.12c	0.13a	0.14a
ME	0.09c	0.10b	0.12ab	0.13a	0.14a
NE	0.12c	0.14bc	0.16ab	0.17a	0.18a
Ratio of observed to computed ADG					
TDN	0.84c	1.09a	1.05ab	1.00b	1.03ab
DE	1.12d	1.43a	1.34ab	1.26c	1.30bc
ME	1.10c	1.42a	1.34ab	1.26b	1.30ab
NE	0.80d	1.02a	1.00b	0.96c	0.99b
Maintenance					
TDN, kg/day	0.48	0.49	0.50	0.50	0.50
DE, Mcal/day	2.27	2.33	2.38	2.36	2.36
ME, Mcal/day	1.85	1.90	1.94	1.92	1.93
NE, Mcal/day	1.05	1.08	1.10	1.09	1.09
Energy available for gain					
TDN, kg/day	0.27	0.33	0.38	0.42	0.43
DE, Mcal/day	1.02	1.25	1.48	1.66	1.71
ME, Mcal/day	0.88	1.07	1.26	1.41	1.46
NE, Mcal/day	0.49	0.58	0.68	0.75	0.77

[a,b,c,d] With comparison groupings, means not containing a common letter are significantly different ($P \leq 0.05$).

available for gain, TDN_m is TDN required for maintenance, X is the factor for converting the ADG to energy. Similar factors related to the energy requirement of ADG were derived for DE, ME and NE of both ram and ewe lambs.

With the data presented in tables 4 and 5, gain factors may be derived by regressing the dependent variable on the independent variable to obtain a slope with the regression line passing through the origin or $Y = bX$ where $b = \frac{\Sigma XY}{\Sigma X^2}$. Uncorrected sums of squares and cross products were used. For each sheep the dependent or Y variables (TDN_{ag}, DE_{ag}, ME_{ag} and NE_{ag}) were obtained by subtracting TDN_m, DE_m, ME_m or NE_m from the total TDN, DE, ME and NE intakes, respectively.

Table 5. Observed and computed ADG, ratio of observed to computed ADG, maintenance and energy available for gain of ram and ewe lambs.

	1957		1958		1959		1960	
Items	**Rams**	**Ewes**	**Rams**	**Ewes**	**Rams**	**Ewes**	**Rams**	**Ewes**
No. lambs	24	24	24	22	23	22	24	23
Observed ADG, kg	0.31a	0.20b	0.29a	0.17b	0.29a	0.18b	0.31a	0.19b
Computed ADG, kg								
TDN	0.27a	0.21e	0.22d	0.16g	0.24c	0.16g	0.25b	0.20f
DE	0.23a	0.17d	0.18c	0.13f	0.20b	0.13f	0.20b	0.16e
ME	0.23a	0.17d	0.18c	0.13f	0.20b	0.13f	0.20b	0.16e
NE	0.25a	0.19d	0.21c	0.16e	0.22b	0.16	0.22b	0.19d
Ratio of observed to computed ADG								
TDN	1.29a	0.96g	1.28a	1.04e	1.22c	1.11d	1.25b	0.97a
DE	1.34f	1.16h	1.55b	1.30g	1.47d	1.38e	1.50c	1.74a
ME	1.37b	1.18c	1.57a	1.30bc	1.49ab	1.39b	1.52ab	1.19c
NE	1.24b	1.02d	1.38a	1.08c	1.32a	1.14c	1.36a	1.02d
Maintenance								
TDN, kg/day	0.59	0.50	0.61	0.50	0.60	0.51	0.61	0.51
DE, Mcal/day	2.77	2.34	2.87	3.56	2.82	2.40	2.89	2.42
ME, Mcal/day	2.26	1.91	2.34	1.92	2.30	1.96	2.36	1.98
NE, Mcal/day	1.28	1.08	1.32	1.09	1.30	1.11	1.34	1.12
Energy available for gain								
TDN, kg/day	0.82	0.53	0.69	0.42	0.75	0.43	0.76	0.52
DE, Mcal/day	3.39	2.12	2.79	1.64	3.05	1.68	3.13	2.10
ME, Mcal/day	2.85	1.79	2.36	1.39	2.57	1.43	2.63	1.78
NE, Mcal/day	1.28	0.83	1.08	0.68	1.17	0.69	1.20	0.83
Feed/kg gain, kg	8.7b	10.0a	8.7b	10.0a	8.8b	10.3a	8.6b	10.0a
SD	±0.22	±0.22	±0.22	±0.23	±0.23	±0.23	±0.22	±0.23

[a,b,c,d] See footnote, table 4.

Results and Discussion

Equations (table 3) derived by Garrett, Meyers and Lofgreen (1959) gave computed ADG 22 to 29%, 34 to 55%, 37 to 52%, and 24 to 38% lower than the observed ADG for TDN, DE, ME and NE systems, respectively, for ram lambs.

DE and ME equations gave computed ADG 12 to 50% and 10 to 57% lower, respectively, than the observed ADG for ewes (tables 4 and 5).

Bull, Reid and Johnson (1970) have shown that ME was utilized more efficiently for body-energy gain in ewes than in rams. However, rams tended to be more efficient in feed conversion than ewes though this difference was not significant. The reason that rams tended to be more efficient is found by comparing final body composition. From 17 to 19% more energy was found in body composition of ewes than rams —the ewes had 30 to 35% more fat, 5 to 16% less water and 3 to 15% less protein than did the rams.

In this study, the average rates of feed conversion were 8.7 ± 0.11 and 10.3 ± 0.12 kg of feed per kg of weight gain by males and females, respectively. Differences between sexes were significant ($P \leq 0.01$).

Since a sex difference in efficiency of energy utilization has been established, a modification of equations for measuring energy requirements of rams and ewes is in order.

Calculating the metabolic rate from body weight raised to three-fourths power ($W^{0.75}$) has been considered to be the most accurate reference base for comparing metabolism of animals (Kleiber, 1965). Coefficients derived by Garrett et al. (1959) for determining maintenance requirements of lambs are .029 kg, 157, 112, and 63 kcal per kg of $W^{0.75}$ for TDN, DE, ME and NE, respectively. These values were used for rams and ewes in this study. Blaxter (1962) presented data to show that the basal metabolism of a steer 10 times the size of a lamb is 7.6 times as great. The coefficient of 63 kcal per kg of $W^{0.75}$ for NE_m presented by Garrett et al. (1959) was used in this study, since Lofgreen et al. (1968) has shown that the coefficient for NE_m of cattle is close to 77. This gives cattle weighing 10 times more than a lamb 6.8 times the maintenance allowance of sheep for NE.

Since computed ADG were lower than observed ADG for the four systems of measuring energy requirements of rams and two systems for ewes, gain factors were revised. Revised gain factors for rams were 4.00, 3.46, 3.56 and 2.86 for TDN, DE, ME and NE, respectively (table 6). Revised factors for ewes were 4.20 and 4.35 for DE and ME, respectively (table 6).

Table 6. Revised growth factors in equations for computing energy requirements of ram and ewe lambs for maintenance and weight gain[1].

Ram	Ewe
TDN = 0.029 $W^{0.75}$ (1 + 4.00 g)	TDN = 0.029 $W^{0.75}$ (1 + 5.07 g)
DE = 137 $W^{0.75}$ (1 + 3.46 g)	DE = 137 $W^{0.75}$ (1 + 4.20 g)
ME = 112 $W^{0.75}$ (1 + 3.57 g)	ME = 112 $W^{0.75}$ (1 + 4.35 g)
NE = 63 $W^{0.75}$ (1 + 2.86 g)	NE = 63 $W^{0.75}$ (1 + 3.97 g)

[1]TDN in kilograms; DE, ME and NE in Mcal.

Table 7. Liveweights and calculated feed required for maintenance for ewe lambs fed 5 ratios of concentrate to alfalfa hay.

	Ratio of concentrate to alfalfa hay				
Items	2:3	1:1	3:2	2:1	5:2
Initial wt. kg	39	38	39	38	38
Final wt. kg	46	49	51	51	51
Method					
TDN feed, kg/day	.83	.83	.82	.80	.79
DE feed, kg/day	.96	.98	.97	.95	.94
ME feed, kg/day	.89	.88	.87	.85	.84
NE feed, kg/day	.73	.73	.72	.70	.69
Total feed kg/day	1.30	1.37	1.42	1.45	1.45

Table 8. Liveweights and calculated feed required for maintenance of ram and ewe lambs.

Items	1957		1958		1959		1960	
	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes
Initial wt. kg	42	36	46	36	41	38	45	38
Final wt. kg	68	52	70	51	69	53	71	54
TDN, feed, kg/day	1.14	.96	1.17	.96	1.16	.98	1.18	.99
DE feed, kg/day	1.21	1.02	1.25	1.03	1.23	1.05	1.26	1.06
ME feed, kg/day	1.20	1.01	1.24	1.02	1.22	1.04	1.25	1.05
NE feed, kg/day	1.00	.84	1.03	.85	1.02	.86	1.04	.87
Total kg/day	2.70	1.95	2.48	1.75	2.57	1.78	2.63	1.98

Tables 7 and 8 give the maintenance allowance for lambs used in this study for all methods. If the coefficients for all four methods were accurate and the energy values of the feeds were representative of the categories of energy measurements, the feed allowances for maintenance would be the same for all methods.

Since there are two sets of factors (maintenance coefficients and values assigned to feeds) that affect the accuracy of the calculated feed needs for maintenance, it is difficult to determine which equation is the most accurate with the data presented in this paper.

The feed allowances for maintenance seem to be more consistent for the 4 categories of energy measurement of the rams and ewes fed alfalfa hay and oats (table 7) than with the ewe lambs fed 5 ratios of concentrate to alfalfa hay (table 6).

This study on the comparative maintenance allowance of feed by the four methods contributes to an evaluation of the maintenance coefficients and the values assigned to feeds.

References

Blaxter, Kenneth Lyon. 1962. The energy metabolism of ruminants. Charles C. Thomas, Springfield, Ill.

Bull, L. S., J. T. Reid and D. E. Johnson. 1970. Energetics of sheep concerned with the utilization of acetic acid. J. Nutr. 100:262.

Crampton, E. W., and L. E. Harris. 1968. Applied Animal Nutrition. 2nd ed. W. R. Freeman & Co., San Francisco, Cal.

Davison, D. N., T. B. Keith and C. W. Hickman. 1950. Concentrate and alfalfa hay ratios for growing and fattening lambs. Idaho Agr. Exp. Sta. Bul. 281.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative requirements of sheep and cattle for maintenance and gain. J. Animal Sci. 18:528.

Harvey, Walter R. 1960. Least-squares analysis of data with unequal subclass numbers. ARS 20-8, ARC, USDA, Beltsville, Md.

Keith, T. B., D. A. Price, K. R. Frederiksen and D. O. Everson. 1970. The energy requirements and energy values of feeding stuffs for growing lambs. Idaho Agr. Exp. Sta. Res. Bul. 83.

Lofgreen, G. P., and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. J. Animal Sci. 27:793.

Kleiber, Max. 1965. Metabolic body size, p. 428. *In* K. L. Blaxter (Ed.) Energy metabolism. Academic Press, New York.

Price, D. A., I. L. Lindahl, P. J. Reynolds and K. R. Frederiksen. 1965. Proc. Western Sect. Amer. Soc. Animal Sci. 16-XXXIX-1.