The efficiency of protein and fat deposition during growth in Dorper sheep

P.G. Marais*
Grootfontein Agricultural College, Middelburg, 5900 Cape Province, Republic of South Africa

H.J. van der Merwe and J.E.J. du Toit
Department of Animal Science, University of the Orange Free State, Bloemfontein 9301, Republic of South Africa

Received 16 March 1990; accepted 28 November 1990

Sixty Dorper lambs, comprising 30 ewe and 30 ram lambs, were divided into six groups of five ewe and five ram lambs each. Each group received, on an *ad libitum* basis, one of six diets consisting of a concentrate : roughage ratio of 30:70, 40:60, 50:50, 60:40, 70:30 or 80:20. The lambs were weaned at 120 days when the mean weaning masses were 22,07 ± 0,66 kg for ewes and 22,13 ± 0,39 kg for rams. The trial started at weaning and ended when animals reached a body mass of 40 kg. Values for feed intake and body composition were determined during the active growth period. Body protein and body fat were found to be exponentially related to cumulative ME intake as the independent variable. Partial efficiencies for protein and fat deposition were calculated from these relationships. Differences due to gender were found between the partial efficiencies of protein and fat deposition at a particular body mass. The efficiencies of protein deposition of both sexes decreased with an increase in body mass, while those of fat deposition increased slightly. Consequently, the validity of the hypothesis that efficiencies of protein and fat synthesis are constant is questionable. According to the energetic efficiency (MJ/kg), the cost of fat deposition is higher than that of protein.

Sestig Dorperlammers, bestaande uit 30 ooi- en 30 ramlammers, is in ses groepe van vyf ooi- en vyf ramlammers elk verdeel. Elk van die groepe het op 'n *ad libitum*-basis een van ses diëte, met 'n kragvoer : ruvoerverhouding van 30:70, 40:60, 50:50, 60:40, 70:30, of 80:20, ontvang. Die lammers is op 'n ouderdom van 120 dae gespeen met 'n gemiddelde liggaamsmassa van 22,07 ± 0,66 kg vir ooie en 22,13 ± 0,39 kg vir ramme. Die proef het vanaf speenouderdom tot die bereiking van 40 kg-liggaamsmassa geduur. Voerinname en liggaamsamestelling van individuele lammers is gedurende die aktiewe groeiproses bepaal. Liggaamsproteïen en -vet is loglineêr deur gewone regressie-analise met kumulatiewe ME-inname as x-veranderlike beskryf. Deur van hierdie verwantskappe gebruik te maak, is beramings van parsiële doeltreffendheid van energiebenutting vir beide proteïen- en vetneerlegging verkry. Geslagsverskille ten opsigte van die parsïele doeltreffendheid van proteïen- en vetneerlegging is by ooreenstemmende liggaamsmassas verkry. Die doeltreffendheid van proteïenneerlegging het by albei geslagte 'n afname in waarde getoon met 'n toename in liggaamsmassa, terwyl die doeltreffendheid van vetneerlegging 'n geringe toename getoon het. Gevolglik word die bestaan van 'n konstante doeltreffendheidswaarde vir proteïen- en vetsintese bevraagteken. Die energiekostes (MJ / kg) vir die deponering van vet was hoër as vir dié van proteïne.

Keywords: Deposition: protein and fat, efficiency, growth.

* To whom correspondence should be addressed.

Introduction

The efficiencies of energy utilization for protein and fat deposition are important factors affecting the economics of lean meat production. Consequently, many studies have been conducted in an attempt to quantify these parameters. Attention was focused on the comparative energetics of protein and fat synthesis in ruminants by Blaxter (1962), when he estimated the relative efficiencies of these processes, using biochemical procedures. Kielanowski (1965) used multiple regression analysis in an attempt to partition metabolizable energy (ME) intake between maintenance, and protein and fat deposition. These early estimates suggested a lower energetic cost for protein than for fat synthesis, but more recent estimates (Buttery & Boorman, 1976; Kielanowski, 1976; Rattray & Joyce, 1976; Pullar & Webster, 1977; Thorbek, 1977) have indicated that protein deposition is energetically less efficient (ME kilocalories required / kilocalories deposited) than fat synthesis.

The estimates for efficiencies of protein and fat deposition reported in the literature are quite variable. Fowler *et al.* (1980) reported estimates obtained by regression methods of 0,35 to 0,80 for protein and 0,70 to 0,91 for fat in pigs. The efficiencies for protein and fat deposition in ruminants have been found to be more variable (Ørskov & McDonald, 1970; Rattray *et al.*, 1974; Rattray & Joyce, 1976; Kielanowski, 1976; Rattray & Jagusch, 1977) than those of simple-stomached species. Caution must be exercised in attaching biological significance to partial regression coefficients when the independent variables are highly correlated (as are protein gain and fat gain). Other factors include the high degree of multi-collinearity between the independent variables and the inclusion of the other components which may introduce a large degree of instability in the estimates. For this reason, Roux *et al.* (1982) and Roux *et al.* (1983) proposed an alternate method for calculating efficiency estimates for fat and protein synthesis.

The objective of this study was to quantify the efficiency of energy utilization for protein and fat synthesis in the Dorper sheep.

Procedure

Design

Sixty weaned Dorper lambs, comprising 30 rams and 30 ewes, obtained from 120 Dorper ewes from the Grootfontein Agricultural College stud were used. Only single-born male and female lambs were included in the experiment. Mean weaning masses of 22,07 ± 0,66 kg and 22,13 ± 0,39 kg were recorded for ewe and ram lambs, respectively. The lambs were subdivided into six groups of five ram and five ewe lambs each. These groups were allocated to one of six different energy diets consisting of a concentrate: roughage ratio of 30:70, 40:60, 50:50, 60:40, 70:30 or 80:20 respectively. The diets were fed *ad libitum*.

During the trial, the lambs were fed individually from weaning to a body mass of 40 kg (approximately 70 days). Feed intake and live mass were measured weekly without prior fasting. Although this procedure is less reliable owing to differential gut-fill, a period of fasting could interfere with the measurement of 'true' *ad libitum* intake. By fitting a mathematical function to live mass data collected over a period of several weeks (Meissner & Roux, 1979), the effect of measurement error is reduced. A standard digestibility trial at *ad libitum* feed intake was used to estimate the digestible energy (DE) content of the diet. The ME intake of each lamb was computed as 0,82 of the DE intake (Blaxter, 1962). The cumulative ME intake of individual lambs prior to the commencement of the trial was calculated from the linear regression equation between ln(cumulative ME intake) and ln(body mass) of Mutton Merino lambs, as described by Meissner (1977). Body composition was estimated at two- to three-week intervals by the tritium dilution method (Meissner & Bieler, 1975).

Composition of diets

The ingredients used to compile the concentrate diet as well as the ME and crude protein (CP) content of the respective diets are shown in Table 1. All of the diets were pelleted. The lambs had free access to these diets and water. Fresh food was supplied three times daily to provide for *ad libitum* feed intake.

Table 1 The physical and chemical composition of the experimental diets on an air-dry basis

Components	Amount (kg / 100 kg)	
Concentrate diet		
Maize meal	89,6	
Fishmeal	5,9	
Urea	1,5	
Sodium chloride	2,9	
Roughage diet		
Lucern meal	100	
Diets[a]	HE (MJ / kg)	CP (%)
30:70	9,60 ± 0,32	15,75 ± 0,41
40:60	9,78 ± 0,33	15,50 ± 0,35
50:50	9,88 ± 0,20	15,44 ± 0,33
60:40	10,37 ± 0,35	15,69 ± 0,36
70:30	10,66 ± 0,28	16,00 ± 0,30
80:20	10,75 ± 0,25	16,31 ± 0,32

[a] Concentrate : roughage.

Theoretical considerations

Roux (1976) postulated a pattern of energy division during growth which follows from the pairwise log-linear relationships that were found between cumulative feed intake, cumulative heat production, protein and fat:

Let

$x_1 = \ln(\text{cumulative feed intake})$

$x_2 = \ln(\text{cumulative heat production})$

$x_3 = \ln(\text{body protein})$

$x_4 = \ln(\text{body fat})$

and

$x_i = a_i + b_i x_1$ for $i = 2, 3, 4$

be the linear relationship between x_2, x_3 and x_4 on the one hand and x_1 on the other hand.

In the present context, a feasible approach would be to define and calculate the efficiencies of protein and fat deposition from partial derivatives (Roux *et al.*, 1982). Formulae obtained from Roux *et al.* (1982) provide simple estimates and obviate the need for a formal principal component analysis. It is thus possible to calculate derivatives in which only protein or fat, as the case may be, are kept constant. The conversion ratios for protein and fat are then

$b_i y_1 / y_i (b_3^2 + b_4^2)$

and the partial efficiencies would be equal to

$$y_i (b_3^2 + b_4^2) / b_i y_1 \quad (1)$$

The gross efficiency could also be calculated in the same form as (1):

$$b_i y_i / y_1 \quad (2)$$

where $y_i = \exp(x_i)$; $x_i = \ln(\text{protein})$ (3) or $\ln(\text{fat})$ (4); y_1 = cumulative feed intake; b_i = slope of (3) or (4).

The technique therefore comprises a regression analysis with ln(cumulative ME intake) as independent variable and ln(body mass) or ln(components of body mass) as dependent variable. All other regression equations are then obtained by algebraic substitution (Marais, 1988).

Results and discussion

The relationships between ln(cumulative feed intake) and ln(body mass), ln(body protein), ln(body fat) and ln(cumulative heat production) describe a straight line when measured in temporal sequence on the same animal or group of animals (Roux, 1976; 1981; Meissner, 1977). The fit of these lines is usually extremely accurate. The respective relationships for ewe and ram lambs are given in Table 2. A fit of at least r = 0,989 was recorded in this trial.

By means of equations (1) and (2), efficiencies for protein and fat were computed within energy diets. Owing to the fact that no significant differences between diets could be detected (Marais,1988), a mean efficiency value for protein and fat deposition was calculated. These mean efficiency values are given in Table 3. The gross efficiency of energy may be calculated by adding the results obtained from equation (2) for protein to those for fat.

According to Table 3, the efficiency of protein deposition of ewe and ram lambs decreases with an increase in body mass from 0,38 to 0,25 and 0,53 to 0,33, respectively. On

Table 2 Regression relationship with ln(cumulative ME intake) as independent variable

	Ewe			Ram		
Diet (%)	Intercept	Slope	r	Intercept	Slope	r
ln(body mass) (kg)						
30:70	−0,5835	0,5800	0,9893	−0,3844	0,5657	0,9917
40:60	−0,5740	0,5798	0,9904	−0,2210	0,5488	0,9915
50:50	−1,0162	0,6423	0,9955	−0,4798	0,5838	0,9940
60:40	−0,6568	0,5879	0,9937	−0,7135	0,6232	0,9925
70:30	−1,2438	0,6774	0,9957	−0,7179	0,6224	0,9972
80:20	−0,7564	0,6005	0,9956	−0,4987	0,5867	0,9938
ln(body protein) (kg)						
30:70	−1,9530	0,4875	0,9873	−1,6782	0,4751	0,9909
40:60	−2,0292	0,5006	0,9900	−1,5059	0,4544	0,9915
50:50	−2,2457	0,5316	0,9948	−1,7275	0,4844	0,9938
60:40	−2,1332	0,5221	0,9937	−1,9223	0,5114	0,9866
70:30	−2,4482	0,5620	0,9961	−1,9273	0,5163	0,9974
80:20	−2,1320	0,5222	0,9956	−1,7069	0,4886	0,9938
ln(body fat) (kg)						
30:70	−6,0938	1,1367	0,9893	−6,0700	1,1102	0,9917
40:60	−6,0767	1,1364	0,9904	−5,6404	1,0611	0,9872
50:50	−7,0416	1,2747	0,9925	−6,2612	1,1462	0,9940
60:40	−6,2384	1,1524	0,9937	−7,0964	1,2765	0,9867
70:30	−7,4999	1,3445	0,9958	−6,7516	1,2241	0,9974
80:20	−6,5068	1,2893	0,9948	−6,2645	1,1672	0,9953

Table 3 The mean energetic efficiency of protein and fat deposition at different body masses

Body mass (kg)	Protein eqn. (1)[a] (MJ/MJ)	Protein eqn. (2)[a] (MJ/MJ)	Fat eqn. (1) (MJ/MJ)	Fat eqn. (2) (MJ/MJ)	Gross efficiency (MJ/MJ)
		Ewe			
22	0,38	0,06	0,31	0,26	0,32
24	0,36	0,06	0,31	0,26	0,32
26	0,34	0,05	0,32	0,27	0,32
28	0,32	0,05	0,33	0,27	0,32
30	0,30	0,05	0,33	0,28	0,33
32	0,29	0,05	0,34	0,29	0,34
34	0,28	0,04	0,35	0,29	0,34
36	0,27	0,04	0,35	0,30	0,34
38	0,26	0,04	0,36	0,30	0,34
40	0,25	0,04	0,37	0,31	0,35
		Ram			
22	0,53	0,08	0,26	0,22	0,30
24	0,49	0,07	0,27	0,23	0,30
26	0,46	0,07	0,27	0,23	0,30
28	0,43	0,07	0,28	0,23	0,30
30	0,41	0,06	0,28	0,24	0,30
32	0,39	0,06	0,29	0,24	0,30
34	0,37	0,06	0,29	0,24	0,30
36	0,36	0,05	0,29	0,25	0,30
38	0,34	0,05	0,30	0,25	0,30
40	0,33	0,05	0,30	0,26	0,31

[a] Partial efficiency (protein or fat).

the other hand, the efficiency of fat deposition of ewe lambs increases with an increase in body mass from 0,31 to 0,37 and that of ram lambs from 0,26 to 0,30. It therefore seems clear that differences between the efficiencies of protein and fat deposition were due to gender. Another conclusion which is inescapable is that the assumption that partial efficiencies are constant is not valid. The only rational basis for a constant cost of protein or fat synthesis lies in changing the dimension of the system by substituting heat production with maintenance. Since maintenance constitutes at least half of the heat production of homeotherms, it seems very likely that such an interchange would leave the dimensions of the relevant system unchanged. Partial support for this fact follows from the conclusion of Kotarbinski & Kielanowski (1969) that protein synthesis in older animals is less efficient than in younger ones.

If the data of Meissner (1977) on Karakul and Mutton Merino sheep on a concentrated diet (ME = 10,7 MJ/kg; CP = 17,3%) are subjected to the alternative calculated approach, the efficiency of protein deposition of Karakul ewes decreases with an increase in body mass from 0,55 to 0,25 and that of Mutton Merino ewes from 0,93 to 0,31. At the same time, this efficiency decreases from 0,51 to 0,26 in Karakul rams and from 0,89 to 0,34 in Mutton Merino rams. The efficiency of fat deposition of Karakul ewes increases from 0,24 to 0,28 and that of Mutton Merino ewes from 0,25 to 0,27. On the other hand, fat deposition efficiencies of Karakul rams increases from 0,24 to 0,28

Table 4 Estimated synthesis cost of protein and fat at different body masses

Components	Ewe	Ram
ME utilization for protein deposition		
22 kg		
MJ/kg protein	9,06	12,64
30 kg		
MJ/kg protein	7,15	9,77
40 kg		
MJ/kg protein	5,96	7,87
HE utilized for fat deposition		
22 kg		
MJ/kg fat	12,32	10,34
30 kg		
MJ/kg fat	13,12	11,13
40 kg		
MJ/kg fat	14,71	11,93

and that of Mutton Merino rams from 0,20 to 0,22. These results were obtained within the same body mass range as those shown in Table 3. These results support the findings of this study that gender differences in the efficiencies of protein and fat deposition are obtained. According to the protein and fat efficiencies of Meissner (1977), breed differences were found when sheep were fed the same diet. The data of this study agree with the results of Hofmeyr (1972).

The average gross efficiency for ewe and ram lambs varied between 0,30 and 0,35 (Table 3). Again, if the gross efficiencies of Meissner (1977) are calculated in the same manner, the efficiency of Karakul ewes increases slightly from 0,26 to 0,28 and that of Karakul rams from 0,27 to 0,28. The efficiency for Mutton Merino ewes decreases slightly from 0,30 to 0,27 and that of rams from 0,27 to 0,23. It therefore seems clear that gross efficiency is approximately constant over much of the growth cycle.

The energetic efficiencies (MJ/kg) of protein and fat deposition were calculated by multiplying the respective partial efficiencies by their combustion energy contents.

According to Table 4, gender differences were found. The cost of synthesizing protein in ram lambs was higher than that of ewe lambs, whereas the cost of synthesizing fat was lower. With the exception of ram lambs at 22 kg body mass, the energy cost (MJ/kg) of fat deposition is higher than that of protein. This agrees with the results of Kotarbinski & Kielanowski (1969), Ørskov & McDonald (1970), Thorbek (1970) and Hofmeyr (1972). As protein in lean meat is associated with three times its mass of water in terms of gain in body mass, efficiency should theoretically increase as protein content of gain increases. Therefore, animals with a high growth potential in lean meat, such as ram lambs, would be more efficient than animals with high fattening capacity (ewe lambs) in terms of body mass gain and gain in lean meat.

Conclusion

It seems clear therefore that different energy diets (concentrate: roughage diet) did not affect the efficiencies of protein and fat deposition within sexes. Owing to the fact that sex differences occurred between the efficiencies of protein and fat deposition, and to the curvilinearity of the data, it seems fair to conclude that a constant partial efficiency for protein or fat cannot be supported.

References

BLAXTER, K.L., 1962. The energy metabolism of ruminants. Hutchinson, London.

BUTTERY, P.J. & BOORMAN, K.N., 1976. The energetic efficiency of amino acid metabolism. In: Protein metabolism and nutrition. E.A.A.P. 16. Butterworths, London.

FOWLER, V.R, FULLER, M.F., CLOSE, W.H. & WHITTEMORE, C.T., 1980. Energy requirements for the growing pig. In: Energy metabolism. Ed. Mount, L.E., Butterworths, London.

HOFMEYR, H.S., 1972. Kwantifisering van faktore wat die bruto doeltreffendheid van energie-omsetting van voer by skape beinvloed. D.Sc.(Agric)-tesis, Universiteit van Pretoria.

KIELANOWSKI, J., 1965. Estimates of the energy cost of protein deposition in growing animals. Proc. 3rd. Symp. Energy Metab., Troon, 1964 E.A.A.P., 11, 13.

KIELANOWSKI, J., 1976. Energy cost of protein deposition. In: Proc 7th. Symp. Energy Metab., Ed. Vermorel, M. E.A.A.P. 19. Vicky. France. p. 137.

KOTARBINSKI, M. & KIELANOWSKI, J., 1969. Energy balance studies with growing pigs by the comparative slaughter technique. Proc. 4th Symp. Energy Metab., E.A.A.P., 12, 299.

MARAIS, P.G., 1988. Die invloed van energiepeile en kompensatoriese groei op liggaamsamestelling en doeltreffendheid van voerverbruik by Dorperlammers. Ph.D.(Agric.)-proefskrif, Universiteit van die Oranje Vrystaat, Bloemfontein.

MEISSNER, H.H., 1977. An evaluation of the Roux mathematical model for the functional description of growth. Ph.D. thesis, Dept. Zoology, University of Port Elizabeth.

MEISSNER, H.H. & BIELER, E.U., 1975. A note on the validity of using combinations of predictive equations for estimating body composition from tritiated water space. *S. Afr. J. Anim. Sci.* 5, 7.

MEISSNER, H.H. & ROUX, C.Z., 1979. Voluntary feed intake, growth, body composition and efficiency, in the sheep: quantification of between animal variation. *Agroanimalia*, 11, 9.

ØRSKOV, F.R. & MCDONALD, I., 1970. Utilization of dietary energy for maintenance and for fat and protein deposition in young growing sheep. In: Energy metabolism of farm animals. Ed. Schurch, A.S. & Wenk, C., Zuring: Juris Druck.

PULLAR, J.D. & WEBSTER, A.J.F., 1977. The energy cost of fat and protein deposition in the rat. *Brit. J. Nutr.* 37, 355.

RATTRAY, P.V., GARRETT, W.M., HINMAN, N. & EAST, N.E., 1974. Energy cost of protein and fat deposition in sheep. *J. Anim Sci.* 38, 378.

RATTRAY, P.V. & JAGUSCH, K.T., 1977. Energy cost of protein in the preruminant and young ruminant lamb. *N.Z. Soc. Anim. Prod.* 37, 167.

RATTRAY, P.V. & JOYCE, J.P., 1976. The utilization of metabolizable energy for fat and protein deposition in sheep. *N.Z. J. Agric. Res.* 19, 299.

ROUX, C.Z., 1976. A model for the description and regulation of growth and production. *Agroanimalia* 8, 83.

ROUX, C.Z., 1981. Animal growth in the context of time series and linear optimal control systems. *S. Afr. J. Anim. Sci.* 11, 57.

ROUX, C.Z., HOFMEYR, H.S. & JORDAAN, EILENE, 1983. The problem of multi-collinearity in the estimation of partial efficiencies of protein and fat by regression methods. Proc. 9th Symp. Energy Metab., Lillehammer, Norway. E.A.A.P., 19, 138.

ROUX, C.Z., MEISSNER, H.H. & HOFMEYR, H.S., 1982. The division of energy during growth. *S. Afr. J. Anim. Sci.* 12, 1.

THORBEK, G., 1970. The utilization of metabolizable energy for protein and fat in growing pigs. In: Energy metabolism of farm animals. Eds. Schurch, A. and Wenk, C., E.A.A.P. 13, 129.

THORBEK, G., 1977. The energetics of protein deposition during growth. *Nutr. Metab.* 21, 105.