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SIMILAR EFFICIENCY AT TWO FEEDING LEVELS IN SHEEP

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OPSOMMING: TWEE VOEDINGSPEILE LEWER DIESELFDE DOELTREFFENDHEID BY SKAPE

Twaalf Vleis-Walrichmerinokruis hamellammers is ewekansig in twee groepe van 6 verdeel na speen by 8 weke ouderdom. Die een groep het 'n hoë kragvoerrantsoen teen 'n voedingspeil net onder *ad libitum* en die ander groep 80% van hierdie berekende *ad libitum* tot op 'n ouderdom van 36 weke ontvang. Die inname en massa van elke lam is weekliks gemeet en die hoeveelheid vet en proteïen in die liggaam is elke 14 dae afgelei van die tritiumruimte. Ofskoon die *ad libitum* groep meer gevreet, meer gegroei en meer vet en proteïen tot op 36 weke ouderdom gedeponeer het, was daar geen verskille indien die twee groepe by dieselfde massa-interval vergelyk is nie. Die resultate in die massa-interval 15 tot 45 kg vir die *ad libitum* en 80% *ad libitum* groepe onderskeidelik was soos volg: MF benodig: 1 881 ± 129 en 1 884 ± 219 MJ, massatoename: 174 ± 25,5 en 157 ± 18,5 g dag^{-1}, vet toename: 7,84 ± 1,61 en 6,68 ± 1,43 kg, proteïentoename: 3,90 ± 0,51 en 4,00 ± 0,69 kg en aantal dae benodig: 176 ± 31,5 en 193 ± 21,0. Geeneen van die verskille was betekenisvol by die 5% betekenispeil nie, tog wou dit voorkom asof die *ad libitum* groep meer vet en minder proteïen gedeponeer het as die 80% *ad libitum* groep. Uitgedruk in terme van vet- of proteïendeponering per eenheid massatoename het die *ad libitum* groep dan ook deurgaans meer vet en minder proteïen as die 80% *ad libitum* groep gedeponeer, alhoewel slegs die data bokant 35 kg massa statisties betekenisvol was ($p < 0,05$). Die gevolgtrekking is gemaak dat dié verandering in liggaamsamestelling verantwoordelik is daarvoor dat die 80% *ad libitum* groep dieselfde doeltreffendheid in terme van MJME kg^{-1} massatoename gehad het as die *ad libitum* groep.

SUMMARY:

Twelve Mutton-Walrich Merino cross wether lambs were randomly allotted to two groups of 6 at 8 weeks of age after they were weaned. The one group received a high energy diet just below *ad libitum* and the other 80% of this calculated *ad libitum* until 36 weeks of age. Intake and mass gain of all lambs were measured every week, while body fat and protein were derived from fortnightly measurements of tritiated water space. Although the *ad libitum* group consumed more and gained more in body mass, fat and protein until 36 weeks of age, there were no differences when the two groups were compared within the same body mass interval. The results between 15 and 45 kg body mass for the *ad libitum* and 80% *ad libitum* groups were respectively: ME required: 1 881 ± 129 and 1 884 ± 219 MJ, mass gain: 174 ± 25,5 and 157 ± 18,5 g day^{-1}, fat gain: 7,84 ± 1,61 and 6,68 ± 1,43 kg, protein gain: 3,90 ± 0,51 and 4,00 ± 0,69 kg and days required: 176 ± 31,5 and 193 ± 21,0. None of these differences were significant at the 5% level of probability. Yet, it was observed that the *ad libitum* group tended to deposit more fat and less protein than the 80% *ad libitum* group. In terms of fat or protein deposition per unit mass gain it was in fact found that the *ad libitum* group gained consistently more fat and less protein than the 80% *ad libitum* group, although the data was only statistically significant ($p < 0,05$) above 35 kg body mass. It was concluded that this change in body composition was responsible for the fact that the 80% *ad libitum* group exhibited the same efficiency (MJME kg^{-1} mass gain) as the *ad libitum* group.

Efficiency of growing animals in terms of kg feed per kg gain is closely related to their body composition. For example, decreased efficiency with growth is closely associated with increased fat relative to protein deposition. Also, it was recently shown that differences in efficiency among different breeds of sheep can mostly be attributed to differences in body composition (Hofmeyr, 1972; Meissner, Roux & Hofmeyr, 1975; Meissner, De la Rey, Gerhard & Van der Westhuizen, 1976).

Feeding level also influences efficiency – generally the higher the level of feeding (above maintenance) the higher the efficiency achieved (Blaxter, 1964). The question arises if feeding level also influences efficiency by altering body composition.

Existing information on the effect of feeding level on body composition is equivocal. A number of authors indicated body composition of ruminants to be rather uniform at a particular body mass and independent of feeding level (Tulloh, 1963; Reid, Bensadoun, Bull, Burton, Gleeson, Han, Joo, Johnson, McManus, Paladines, Stroud, Tyrell, Van Niekerk & Wellington, 1968; O'Donovan, 1974; Basson, 1975). On the other hand a number of other publications convincingly showed that body composition in the ruminant can be altered by feeding level (Pálsson & Verges, 1952; Elsley, McDonald & Fowler, 1964; Andrews & Orskov, 1971; Searle, Graham & O'Callaghan, 1972; Black, 1974; Craddock, Field & Riley, 1974; Meissner *et al*, 1976).

With regard to body composition being influenced by feeding level, Black (1974) in his review concluded that provided protein intake is adequate, high feeding levels should promote higher fat deposition than lower ones. In general, this was supported by Meissner *et al* (1976). Since high fat deposition is associated with poor efficiency, it follows that very high feeding levels do not necessarily assure maximum efficiency, since the beneficial effect to growth of high energy intake (above maintenance) might be counteracted by excessive fat deposition.

To test this hypothesis, an experiment was designed to determine if a feeding level of 80% of *ad libitum* can achieve similar or better efficiency than one at *ad libitum*.

Procedure

Design

Twelve Mutton-Walrich Merino cross wether lambs were randomly allotted to one of two dietary treatments at 8 weeks of age. The two dietary treatments were respectively just below *ad libitum* feed intake and 80% of this calculated amount. They will be referred to as the *ad libitum* and 80% *ad libitum* groups respectively. Individual feed intakes and body masses were measured weekly, whereas body composition was determined every fortnight until 36 weeks of age.

Experimental procedure

Lambs were individually raised on slatted floors from 2 days of age until the end of the experiment. During the period prior to commencement of the trial treatment was as follows: from 2 days of age until 7 weeks the lambs received cow's milk according to the schedule described by Meissner *et al* (1975). They also had access to the experimental diet which was the same as that used by Meissner *et al* (1975). The composition of the diet is shown in Table 1.

Table 1

Composition of the diet on an air dry basis

	%
Corn and cobmeal	66,0
"Voermol" molasses	13,0
Fish meal	19,0
Bone meal	1,0
Salt	0,9
*Vitamins and minerals	0,1

*A commercial mixture was used.

At 7 weeks of age lambs were weaned and allowed one week to adapt to receiving no milk before the start of the trial at 8 weeks.

Intake of milk and feed until 8 weeks was recorded for individual lambs and the cumulative intake of metabolisable energy thus obtained plus a calculated amount of ME intake before birth (see Meissner *et al*, 1975) was used as starting point of intake in the trial.

From 8 weeks onwards the *ad libitum* group was fed according to the *ad libitum* feed intake of Mutton Merino ewes used by Meissner *et al* (1975). These intakes were calculated by differentiating the Gompertz equation between cumulative ME intake and time at weekly intervals. From these calculated amounts 10% was deducted to ensure complete consumption. The 80% *ad libitum* group received 80% of the latter allowance.

Metabolizability of the diet was determined about halfway through the experiment using all lambs in both groups. Feed intake, faeces and urine production were collected and analysed according to standard procedures. Methane production was calculated from the equation $CH_4 = 6{,}05 + 0{,}02\mathbf{A}$, where CH_4 is kcal CH_4/100 kcal feed and **A** = apparent digestibility of feed at maintenance (%) (A.R.C., 1965). The metabolizability of the diet at 80% *ad libitum* intake was slightly higher (11,6 MJME/kg DM) than at *ad libitum* intake (11,2 MJME/kg DM) which could be expected in view of the depressing effect of higher intakes on dietary metabolizability (e.g. Blaxter, 1961). Although not significantly different, this difference was taken into account when the ME intakes of the two groups were calculated.

Body composition estimation

Body protein and fat were calculated from TOH space measurement using the equations of Meissner & Bieler (1975). These equations together with correlation coefficient and Sy.x are given in Table 2.

Table 2

*Prediction equations for body protein and body fat from TOH space measurement (**X**)*

Y	b	a	r	Sy.x
Protein (kg)	0,222	0,915	0,94	0,417 (kg)
Fat (%)	–0,960	80,562	–0,90	1,886 (%)

Statistical analysis

The linear form of the allometric and the Gompertz equations (Roux, 1974 & 1976) fitted the data extremely well. Regression equations for individual lambs were calculated between ln body protein and ln body fat. Differences between the two groups at comparable points of interest were established with the aid of Student's one-tailed t-test, since it was postulated that the two groups should have been different from one another unidirectionally. This condition was not applicable for the test for differences in various characteristics at 8 weeks of age (Table 1) since no directional differences were expected.

Results

At the start of the trial the *ad libitum* and 80% *ad libitum* groups were not significantly different with regard to cumulative ME intake to 8 weeks, body mass, body protein and body fat. This is shown in Table 3.

Meissner *et al* (1975) found a sharp break in slope of regression lines between ln cumulative ME intake and ln body mass at 13 weeks of age and therefore applied two sets of equations to the data, one prior to 13 weeks of age and one from 13 weeks of age. Accordingly two sets of equations were fitted for individual sheep in this study, one for data between 8 and 13 weeks and

Table 3

Total intake, body mass, protein and fat at 8 weeks of age

	ad libitum mean ± SD	80% ad libitum mean ± SD	Significance of difference in mean
Cumulative ME (MJ)	284,3 ± 35,3	284,9± 45,8	NS
Body mass (kg)	14,81± 1,15	15,87± 1,07	NS
Body protein (kg)	3,04± 0,28	3,25± 0,32	NS
Body fat (kg)	0,96± 0,20	1,02± 0,10	NS

one between 13 and 36 weeks. The mean and standard deviation of slope, intercept and correlation coefficient for equations relating ln cumulative ME intake to respectively ln body mass, ln body protein and ln body fat are presented in Table 4.

Evidently equations between 8 and 13 weeks fitted the data less well than equations fitted between 13 and 36 weeks (correlation column, Table 4), especially those involving body protein and body fat. This was obviously due to fewer points of measurement before 13 weeks than after – 6 versus 24 in the case of ME intake and body mass and 3 versus 12 in the case of ME intake and body protein or body fat.

Under the usual statistical assumptions **a** and **b** are sufficient statistics, that is, all the information from the data is contained in these statistics. This means that **a** and **b** can be used in statistical analysis in place of the data. Hence t-tests between the means of the **a**-s and **b**-s of the different groups are applicable.

Prior to 13 weeks the mean slope and intercept of regression equations between ln cumulative ME intake and ln body mass differed significantly ($p < 0,05$) between the *ad libitum* and 80% *ad libitum* groups but not after 13 weeks. Ln cumulative ME intake and body protein equations did not differ significantly between the two groups before 13 weeks but were nearly significantly different ($0,05 < p < 0,10$) after 13 weeks. Ln cumulative ME intake and body fat equations were not significantly different prior to 13 weeks but were significantly different ($p < 0,05$) with regard to both slope and intercept after 13 weeks. The results suggest that before 13 weeks the *ad libitum* group tended to gain more body mass per unit ME intake but not after 13 weeks. There were no differences in body protein and body fat before 13 weeks but after 13 weeks the *ad libitum* group tended to deposit less protein and more fat per unit ME intake.

Table 5 shows feed intake, growth and efficiency of the two groups in relationship to age and body mass. It was assumed that the experimental animals would consume all feed (See Procedure). The standard deviation in Table 5 showed that this was not achieved, the percentage refusal being between 2 and 4. However, the major objective of the trial namely that one group should consume 80% of the feed intake of the other was not influenced.

When compared within the same body mass range the *ad libitum* group required about the same ME and DM per unit gain, although their body mass gain was about 10% higher (not significant). They also deposited about 3% less protein and about 17% more fat between 15 and 45 kg body mass (not significant). In addition it

Table 4

Mean slope (b), intercept (a) and correlation coefficient (r) of regression equations relating ln cumulative ME intake (X) to respectively ln body mass, ln body protein and ln body fat (Y)

Y	Ad libitum			80% ad libitum		
	$\bar{b}$ ± SD	$\bar{a}$ ± SD	$\bar{r}$ ± SD	$\bar{b}$ ± SD	$\bar{a}$ ± SD	$\bar{r}$ ± SD
8 to 13 weeks:						
ln body mass	0,55 ± 0,09	-0,39 ± 0,56	0,99 ± 0,004	0,44 ± 0,07	0,29 ± 0,43	0,97 ± 0,018
ln body protein	0,51 ± 0,19	-1,77 ± 1,11	0,91 ± 0,136	0,44 ± 0,22	1,32 ± 1,29	0,96 ± 0,045
ln body fat	0,82 ± 0,46	-4,68 ± 2,61	0,84 ± 0,149	0,50 ± 0,23	2,82 ± 1,32	0,76 ± 0,296
13 to 36 weeks:						
ln body mass	0,53 ± 0,03	0,27 ± 0,21	0,99 ± 0,002	0,53 ± 0,04	-0,28 ± 0,25	0,99 ± 0,005
ln body protein	0,32 ± 0,05	0,47 ± 0,33	0,97 ± 0,009	0,38 ± 0,07	-0,91 ± 0,42	0,98 ± 0,007
ln body fat	1,28 ± 0,06	-7,67 ± 0,41	0,99 ± 0,004	1,11 ± 0,13	-6,47 ± 0,94	0,98 ± 0,012

Table 5

Feed intake, growth and efficiency between 8 and 36 weeks of age and between 15 and 45 kg body mass

	ad libitum mean ± SD	80% ad libitum mean ± SD	Significance of difference in mean
8 to 36 weeks:			
Total ME intake (MJ)	2 159 ± 76	1 725 ± 32	p < 0,001
Body mass gain (kg)	33,20 ± 2,16	28,03 ± 2,96	p < 0,01
Protein deposition (kg)	4,25 ± 0,68	3,91 ± 0,92	NS
Fat deposition (kg)	9,16 ± 0,69	6,24 ± 0,83	p < 0,001
15 to 45 kg:			
No. of days to 45 kg	176 ± 31,5	193 ± 21,0	NS
Body mass gain (g day^{-1})	174 ± 25,5	157 ± 18,5	NS
Total ME intake (MJ)	1 881 ± 129	1 884 ± 219	NS
Protein deposition (kg)	3,90 ± 0,51	4,00 ± 0,69	NS
Fat deposition (kg)	7,84 ± 1,61	6,68 ± 1,43	NS
Calculation of energy balance and efficiency between 15 and 45 kg			
Energy expenditure (MJME):			
Maintenance	1 205	1 259	
Protein deposition*	282	289	
Fat deposition	394	336	
Efficiency:			
kg feed kg^{-1} gain	5,60	5,41	
MJME kg^{-1} gain	62,7	62,8	

* Partial efficiencies of protein and fat are assumed constant over the body mass range 15 to 45 kg and equal to 0,33 and 0,79 respectively (Ørskov & McDonald, 1970)

Table 6

ME intake, protein deposition and fat deposition per 5 kg body mass gain at different body mass intervals

	Body mass kg	Ad libitum mean ± SD	80% ad libitum mean ± SD	Significance of difference in mean
ME intake (MJ)	15–20	208 ± 38	236 ± 48	All N.S.
	20–25*	216 ± 35	220 ± 29	
	25–30	294 ± 19	288 ± 30	
	30–35	341 ± 25	335 ± 40	
	35–40	388 ± 33	380 ± 51	
	40–45	434 ± 42	425 ± 61	
Protein deposition (kg)	15–20	0,95 ± 0,34	1,00 ± 0,47	NS
	20–25	0,90 ± 0,41	0,58 ± 0,16	0,05 < p < 0,10
	25–30	0,56 ± 0,08	0,65 ± 0,10	0,05 < p < 0,10
	30–35	0,53 ± 0,07	0,62 ± 0,11	0,05 < p < 0,10
	35–40	0,50 ± 0,08	0,59 ± 0,11	0,05 < p < 0,10
	40–45	0,47 ± 0,07	0,57 ± 0,11	p < 0,05
Fat deposition (kg)	15–20	0,55 ± 0,34	0,39 ± 0,24	NS
	20–25	0,60 ± 0,51	0,89 ± 0,14	NS
	25–30	1,18 ± 0,20	1,03 ± 0,16	NS
	30–35	1,49 ± 0,28	1,24 ± 0,24	0,05 < p < 0,10
	35–40	1,83 ± 0,38	1,46 ± 0,34	p < 0,05
	40–45	2,20 ± 0,51	1,68 ± 0,44	p < 0,05

* 20–25 kg body mass coincided with 13 weeks of age approximately

can be calculated that they required approximately 4% less ME for maintenance than the 80% *ad libitum* group. Furthermore, although not significant, the *ad libitum* group required 17 days less to grow from 15 to 45 kg.

Table 6 presents the amount of ME required and the protein and fat deposition per 5 kg body mass gain at different body mass intervals. It must be stressed again that due to poorer fit of regression lines before 13 weeks (about 20–25 kg body mass), calculations for body mass intervals up to 25 kg are less reliable than afterwards.

Table 6 reveals that ME required per 5 kg body mass gain was very similar between the *ad libitum* and 80% *ad libitum* groups, the *ad libitum* group being slightly more efficient during early growth and the 80% *ad libitum* group during late growth (not significant). Apart from the initial stages, the *ad libitum* group deposited consistently less protein and consistently more fat per 5 kg body mass gain than the 80% *ad libitum* group, the difference between 35 and 45 kg body mass being significant ($p < 0{,}05$). It is also evident with regard to both groups, that rate of protein deposition declined and fat deposition increased with body mass.

Discussion

Manipulation of body composition by feeding level

Although differences were small they were consistent* and indicated that body composition with regard to both protein and fat deposition was altered by feeding level (Table 6). The effect of a 20% (80% *ad libitum*) reduction in intake on total protein deposited between 15 and 45 kg body mass, however, was negligible and even the change in total fat deposited, although greater, was not significant (Table 5). This result suggests that one of the main reasons of controversy on the subject of manipulation of body composition by nutritional means or not, arises from experimental design. The effect of feeding level with adequate protein intake is small: Black (1974) put the maximum differences in fat deposition at 5 to 8% of body mass and in this study (also having adequate protein) it was only about 3% of body mass at 45 kg. Detection of effect of feeding level on body composition would therefore probably be more difficult in experiments which do not cater for sequential determinations of body composition, a conclusion also previously drawn by Fowler (1967) and others.

The model used by Black (1974), based on principles established in experiments on liquid-fed lambs, predicts body fat deposition to respond, following a moderate reduction in energy intake but adequate protein intake, as follows: initially, as energy intake is decreased in a lamb of about 24 kg body mass, the amount of fat in the body relative to that in a continuously growing animal progressively decreases. With continued growth however, the amount of fat increases again so that at 40 kg there is little difference due to treatment. If the restriction is made earlier (19 kg body mass) body fat in the restricted lamb remains lower throughout. In this experiment the restriction was made even earlier, at about 15 kg body mass, and differences in body fat content were seen to increase progressively, the most pronounced effect being at 45 kg. Admittedly, this work is not completely comparable because the lambs were weaned and restricted within one week and it is known that weaning may have dramatic effects on body composition (Searle *et al*, 1972; Kellaway, 1973). The changes are associated with either a loss of or little change in body fat, but an increase in body lean. Searle *et al* (1972) for example, observed a greater fat loss when intake was restricted after weaning, a result which is contradictory to the one found here, where differences in body fat content only became substantial from about 30 kg body mass. It is clear from the above discussion that the influence of feeding level on body composition is complicated and is dependent on the growth stage where restriction is applied, weaning, type of diet and presumably also on severity of restriction (Black, 1974).

Influence of body composition on efficiency

By depositing more protein and less fat the 80% *ad libitum* group converted dietary ME with similar efficiency into body mass gain (Table 5) as the *ad libitum* group. The effect of body composition change was clearly so substantial that it completely offset the beneficial effect to efficiency (kg feed per kg gain) of the higher feeding level and (less important) the possible slightly lower maintenance requirement of the *ad libitum* group (Table 5). Both Hofmeyr (1972) and Meissner *et al* (1975) previously showed the effects of body composition differences to be more important than feeding level and differences in maintenance requirements in determining differences in efficiency between breeds of sheep.

Most information in parallel to this study comes from pig data. In their study of the response of the growing pig to variation in dietary energy intake, Davies & Lucas (1972b) fed pigs in the body mass range 21 to 92 kg 0,8, 0,9, 1,0 and 1,05 times the recommended ARC allowances. They found percentage lean (protein) in the carcass to decrease, % fat to increase and daily body mass gain to increase, and feed conversion ratio to be rather invariant (slight increase) with increasing feeding level – results which generally agree with the findings in this study.

Comparable work with ruminants in relation to variation of feeding level is scanty. Altering feeding

*It can be argued that due to differences in digestive tract contents between the two groups, body protein and body fat calculations in the 80% *ad libitum* group may have included a systematic error. This is admitted. However, if corrections are made to constant fill (digestive tract), differences in protein and fat between the two groups would have been accentuated.

level by changing energy density of the diet within limits does not seem to affect body composition mainly because the ruminant responds by eating more or less depending on concentration (Craddock, Field & Riley, 1974; O'Donovan, 1974). Yet, the work of Blaxter (1976) indicates that although sheep eat more of a less nutritive diet, compensation is not complete. Furthermore, his data show similar growth rates on two diets differing 12% in nutritive value. DM intake compensation on the lower energy diet was only 5% . Thus, his data suggest sheep on the lower energy diet to be fractionally more efficient than those on the higher energy diet. However, on the other hand, Craddock *et al* (1974) and O'Donovan (1974) presented convincing evidence to indicate sheep to be most efficient on the diets with highest energy density.

The work of Davies & Lucas (1972b) suggests the result of similar efficiency at a particular body mass interval not to be necessarily unique. They found similar feed conversion ratios between as low as 80% to as high as 105% of ARC ME allowances, although the latter allowance seems to impose a slightly poorer feed conversion ratio. Davies & Lucas (1972a) and Vanschoubroek, De Wilde & Lampo (1967) also showed feed conversion ratio to vary little between 2,6 and 3,4 multiples of maintenance (DE), but their work implicates an optimum feeding level of about 2,7 times maintenance for pigs which coincides with a dietary feed restriction of about 25%.

The conclusions to be drawn from the above discussion relevant to ruminant production are:

1. Feeding level influences body composition.
2. By manipulating body composition by nutritional means similar efficiences to those achieved with maximum intake can be obtained with lower intakes.
3. Maximum efficiency can possibly be attained at a lower level of intake than *ad libitum*.

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