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CHANGES IN WHOLE BODY AND CARCASS COMPOSITION IN YOUNG SHEEP DURING WEIGHT LOSS AND SUBSEQUENT REGROWTH

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SUMMARY

Crossbred wether lambs were used to measure the effects of severe feed restriction (loss of 25% empty body weight (EBW)) and re-feeding on the body and carcass composition of immature sheep. Sheep re-fed from 26 kg EBW (after losing 25% EBW) contained, at 45 kg EBW, more body water and protein and less fat and energy than continuously fed animals of the same EBW. The treatment effect was greater in the carcass and had little effect on the composition of the non-carcass EBW. The carcass from a 45 kg EBW re-fed sheep was 700 g heavier and contained 1200 g less fat than that from a continuously grown sheep of the same EBW. Body fat did not fall during underfeeding until the loss in EBW was more than 10%, but fat levels continued to fall during the first 5 kg of weight gain in the re-feeding period.

INTRODUCTION

Animals subjected to a period of under-nutrition often exhibit a very high growth rate when later given access to an adequate feed supply (Wilson and Osbourn, 1960; Meyer and Clawson, 1964; Keenan and McManus, 1969; McManus *et al.*, 1972). This compensatory growth phenomenon has led to an examination of the composition of the gain with conflicting results. Some data have shown an acceleration of protein deposition and water accumulation after realimentation (Reid *et al.*, 1968; Keenan and McManus, 1969; Barnard *et al.*, 1969; McManus *et al.*, 1972) while Meyer and Clawson (1964) and Wilson and Osbourn (1960) concluded that the accelerated growth was high in fat content.

The present experiment was designed to study the effects of imposing a 25% weight reduction on immature sheep followed by realimentation.

EXPERIMENTAL

Management

Thirty-two 2-month-old lambs (Western ewe (U.S.A.) × Hampshire ram) were grown according to the plan in Fig. 1 on a 50:50 pelleted lucerne/corn mixture. The ration dry matter was 17.15% protein. Each slaughter group is shown by a number. With the exception of group 10 (2 sheep) the groups consist of 3 or more animals.

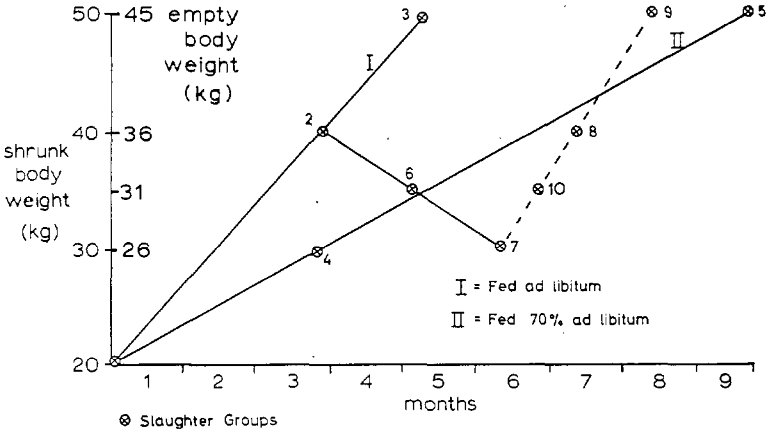

FIG. 1: *Experimental design. Shrunk body weight = liveweight after a 24-hour fast. Empty body weight = shrunk body weight — gut contents.*

Groups 2 and 3 were fed *ad libitum* and groups 4 and 5 at 70% *ad libitum*. Groups 6 and 7 were progressively underfed to lose an estimated 12% and 25% empty body weight (EBW*) respectively, while groups 10, 8 and 9 were re-fed to appetite up to their indicated EBW after losing 25% EBW. The "target" EBWs for the groups were 26 kg for groups 4 and 7; 31 kg for groups 6 and 10; 36 kg for groups 2 and 8; 45 kg for groups 3, 9 and 5.

Feed intakes were adjusted during the weight loss phase, so that lambs dropped about 1 kg liveweight per week, taking approximately 10 weeks of sub-maintenance feeding to lose approx. 25% EBW. The daily feed ration was given in 5 equal amounts from 8 a.m. to 4 p.m. Re-feeding to appetite was accomplished gradually over 7 to 8 days when some feed was refused.

BODY COMPOSITION

After slaughter, half of each carcass was ground into a fine mince for chemical analysis. The other half was dissected into lean, fat and bone and each of these components was freeze dried, ground into a powder and subsequently analysed for nitrogen, fat and ash. Concurrent samples of the "non-carcass" or "remainder" (head, feet, hide, blood, empty gut and offal) were minced separately and analysed. Standard A.O.A.C. methods (1955) were used to measure protein, fat and ash.

*EBW = Liveweight after 24-hour fast — gut contents.

Statistical Procedures

Comparative regression analyses of body components (water, protein, fat and energy) against EBW were used for continuously fed versus realimented sheep. When comparing the means from the equations covariance correction was made to equal EBW.

Since the EBWs of the sheep were very close to the "target" weights, all tissues were corrected to the exact "target" weight. This was done by using the regression coefficients from the regression analyses to distribute the weight difference between actual and "target" EBW among the tissues. With two exceptions, body weight corrections were less than 5%. The corrected means were compared across equal EBW by a one-way analysis of variance.

RESULTS

Regression and Covariance Analysis of Body Composition and EBW

The body components of water, protein, fat, energy and ash are related to EBW for continuously fed sheep and for realimented animals in Table 1. Curvilinear relationships using the logarithmic form of the allometric equation were examined but failed to improve the r^2 value over that of linearity in any parameter. This is almost certainly because the comparative data fall into a restricted EBW range (25 to 45 kg) and below

TABLE 1: THE REGRESSION OF BODY COMPONENTS ON EBW IN CONTINUOUSLY FED SHEEP AND IN REALIMENTED ANIMALS

Feeding Regime*	*Body Component (Y)*	*Equation (X = EBW (kg))*	*Sy.x (kg or Mcal)*	r^2
Continuous	Water	$Y = 0.413X + 5.321$	1.003	0.93
Realimented	(kg)	$Y = 0.415X + 6.527$	1.002	0.85
Continuous	Protein	$Y = 0.108X + 1.309$	0.264	0.93
Realimented	(kg)	$Y = 0.115X + 1.229$	0.267	0.86
Continuous	Fat	$Y = 0.444X - 7.012$	1.202	0.91
Realimented	(kg)	$Y = 0.448X - 8.629$	1.260	0.80
Continuous	Energy	$Y = 4.796X - 57.706$	10.64	0.94
Realimented	(Mcal)	$Y = 4.947X - 77.102$	10.55	0.87
Continuous	Ash	$Y = 0.027X + 0.336$	0.067	0.93
Realimented	(kg)	$Y = 0.017X + 0.825$	0.116	0.41

*Continuously fed sheep = groups 2 to 5.
Realimented sheep = groups 8 to 10.

the level of higher fat accretion. Hence, all comparisons were made using linear regression. None of the regression coefficients for the paired equations in Table 1 differed significantly ($P > 0.10$).

A comparison of the means from the equations in Table 1 is shown in Table 2. The sheep which had lost 25% EBW and were then re-fed showed significantly more water, less fat and less energy ($P < 0.01$) than continuously fed animals.

TABLE 2: COMPARISONS OF BODY COMPONENT MEANS FROM REGRESSION EQUATIONS FOR CONTINUOUSLY FED SHEEP AND REALIMENTED ANIMALS[1]

Body Component (kg)	*Continuously Fed (groups 2-5)*	*Realimented (groups 8-14)*	*Difference (R — C)*
Water	20.91	22.65	+1.74**
Protein	5.39	5.70	+0.31
Fat	9.75	8.76	—0.99**
Energy (Mcal)	123.2	115.1	—8.1**
Ash	1.37	1.49	+0.12*

[1] In determining significance levels, covariance analysis was used to adjust the means to an EBW of 37.7 kg.
* $P < 0.05$, ** $P < 0.01$.

ANALYSIS OF VARIANCE OF BODY COMPOSITION AT SPECIFIC "TARGET" EBWs

Since there were no differences in whole body composition between groups 3 and 5 the data have been combined for testing against that from group 9.

When re-fed sheep at 36 kg (group 8) were compared with the continuously fed group of the same weight (group 2) no significant differences in any body components were found, partly because of the large variability in group 8.

On a total body basis at 45 kg EBW the re-fed sheep had more water and protein and less fat and energy than continuously fed sheep of the same EBW (Table 3). On partitioning EBW into carcass and "remainder", the whole body differences were found to be due to changes in the carcass. Nutritional treatment did not affect the composition of the "remainder" although it did lower the fresh weight. Some of the differences may be due to the significantly heavier carcasses from the re-fed sheep but even on a "percentage of carcass weights" basis the differences still exist.

During the first 5 kg of weight loss, water and protein were mainly affected although fat rose by 0.24 kg (Table 4). Fat

TABLE 3: COMPARISON OF THE CARCASS, "REMAINDER" AND TOTAL BODY COMPOSITION OF CONTINUOUSLY FED AND REALIMENTED SHEEP

(Means adjusted to 45 kg EBW)

	Carcass		*Remainder*		*Total EBW*	
	C	*R*	*C*	*R*	*C*	*R*
Fresh weight (kg)	27.46	28.14*	16.92	16.24*	45.00[1]	45.00[1]
Dry weight (kg)	14.49	13.68	6.68	6.13	21.17	19.81†
Water (kg)	12.98	14.46**	10.24	10.11	23.82[1]	25.19†[1]
Protein (kg)	3.63	3.97**	2.53	2.44	6.16	6.41†
Fat (kg)	9.60	8.42†	3.49	3.10	13.09	11.52†
Ash (kg)	1.12	1.16	0.45	0.44	1.57	1.60
Energy (Mcal)	111.40	101.39†	48.07	43.51	159.47	144.90†

[1] The carcass and remainder do not add up to the total by the small amount of evaporative loss at slaughter.
C = continuously fed sheep (groups 3 and 5)
R = Re-fed sheep (group 9).

† $P < 0.10$, * $P < 0.05$, ** $P < 0.01$.

tissue was the main component lost during continued underfeeding to 26 kg EBW. The first 5 kg of regain was almost the reverse of the first 5 kg loss in weight in changes of body tissue. There was continued fat loss as the body regained 5 kg of lean tissue. Body water proved to be the main dynamic component during early underfeeding and weight regain.

Dissecting half carcasses from each sheep into lean, fat and bone as shown in Table 5 substantiated the results of chemically analysing minced carcass. The re-fed sheep at 45 kg EBW had more carcass lean and less fat than continuously grown sheep. Group 10 sheep had much less dissectable carcass fat

TABLE 4: THE CHANGES IN BODY TISSUE OF SHEEP SUBJECTED TO A 25% LOSS OF EBW FOLLOWED BY THE REGAIN OF THAT WEIGHT

Weight change intervals (kg EBW)

	Weight Loss			*Weight Regain*		
	36 to 31	*31 to 26*	*36 to 26*	*26 to 31*	*31 to 36*	*26 to 36*
Water	—4.22	—1.55	—5.77	+4.48	+1.96	+6.44
Protein	—0.71	—0.55	—1.26	+0.71	+0.62	+1.33
Fat	+0.24	—2.91	—2.67	—0.39	+2.30	+1.91
Ash	—0.07	—0.03	—0.10	+0.10	+0.12	+0.22
Total	—4.76	—5.04	—9.80	+4.90	+5.00	+9.90

and this was still true when expressed as a percentage of the half carcass weight.

TABLE 5: DISSECTABLE HALF-CARCASS COMPONENTS (kg)

	31 kg EBW		*36 kg EBW*		*45 kg EBW*	
Group	*6*	*10*	*2*	*8*	*3 + 5*	*9*
Half-carcass	9.90	9.29*	11.25	10.92	13.74	14.01
Lean	5.08	5.51	6.02	6.09	6.52	7.24**
Fat	2.98	1.97*	3.31	2.73	4.92	4.38†
Bone	1.70	1.60	1.78	1.87	2.03	2.09

† $P < 0.10$, * $P < 0.05$, ** $P < 0.01$.

DISCUSSION

The present work not only showed that re-fed animals were leaner than continuously fed animals of the same weight, but also that the re-fed sheep grew at a much faster rate than their continuously fed counterparts. From 30 to 50 kg the re-fed sheep grew at 270 g/day, while the *ad libitum* continuously fed sheep grew at 130 g/day. Morgan (1972) suggested that the more mature an animal when deprived of feed, the greater would be the compensatory growth when feed restriction was removed. It is not clear whether this is an age or weight effect, but sheep in the present experiment, at 40 kg when underfeeding commenced, would be getting close to mature weight although quite young at about 6 months of age.

An important finding in the present work was that during compensatory growth it was the carcass component of the EBW that changed in composition towards more lean and less fat and not the "remainder" fraction. At 45 kg EBW, in fact, the re-fed sheep had significantly more carcass and less "remainder". There would therefore be more lean meat from a re-fed sheep than a continuously well fed animal of the same weight not only because of a change in body composition, but also because a greater percentage of the animal weight would be in the form of carcass.

Large losses of lean tissue during underfeeding were measured in this experiment and these were very rapidly reversed upon re-feeding. Conversely fat mobilization was not substantial until there had been a drop of more than 10% in body weight. Barnard *et al.* (1969) were surprised to find that obese women, after long periods of starvation, continued to lose fat on re-feeding (although not fed to appetite) while rapidly regaining the substantial quantity of water and protein lost during starvation. Sheep in compensatory growth were found by McManus *et al.* (1972) to lay down "substantially less body fat, more protein and retained more water in their bodies than did control sheep". These authors measured endocrine functions in an attempt to define some mechanism of accelerated lean tissue growth after submaintenance feeding. It was suggested, on the basis of nucleic acid measurement, that the anterior pituitary gland in the compensating sheep was in a state of marked hypertrophy when compared with underfed or continuously well-fed animals. Plasma growth hormone levels were depressed in compensating sheep probably because utilization was faster than the rate of production. The fact that sheep in the present experiment re-fed to 36 kg EBW did not show treatment effects on body composition may indicate that a period of enzyme adaptation is needed after a major change in nutrition to produce a measurable effect. Alternatively it may indicate an abnormal extension of the growth phase of lean tissue before rapidly increasing fat deposition occurs as suggested by Howarth and Baldwin (1971) from their work with rats. Inspection of a graph from the re-fed sheep showing body fat with increasing EBW does not suggest curvilinearity with increasing EBW.

Butterfield (1966) reported muscle : fat ratios of 1.71 during continuous growth, and 2.80 during recovery of lost weight in cattle. Comparable figures from this experiment were 1.08 and 2.49, respectively, indicating broad general agreement that, during compensatory growth, lean tissue is laid down at the expense of fat. It is therefore unlikely that periods of forced undernutrition occurring naturally in a pastoral situation will adversely affect muscle : fat ratios in the meat-producing animal. Whether or not the extra lean and less carcass fat from a 50 kg sheep is important to the consumer is a matter for conjecture.

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