Changes in Body composition and Maintenance efficiency during periods of restricted and maintenance feeding in immature and mature sheep.

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Declaration:

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Alexander Ball

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Abstract

Improvements in production and quality can occur, without the need for increased inputs, through the use of *Compensatory growth* or by reducing the maintenance requirements during growth and at maturity. A series of studies were used to examine the changes in body composition that occurred during weight loss and realimentation in immature and mature sheep. The effect of variations in body composition, induced through manipulation of nutrition, on estimates for equilibrium maintenance efficiency of mature sheep was examined. Statistical methods developed, tested for seasonal cycles in body composition in an attempt to determine the impact that any endogenous pattern in tissue deposition has on estimates of efficiencies for growth and maintenance.

Maintenance efficiency

Differences in maintenance requirements between genotypes selected for variation in body composition when compared at the same weight were shown to be a function of response of body components to selection. No reduction in the true energetic costs of maintaining the various body tissues was achieved through selection for changes in body fatness. These results indicate that differences in body composition do contribute to variation in maintenance requirements observed both within and between breeds. Improvements in biological efficiency gained by selection for proportionally fatter animals are diminished by a proportional reduction in the final product (muscle mass) from the dam/offspring unit. Sex differences in maintenance requirements at the same weight are not explained by differences in body composition.

The implications of previous nutritional history on estimates for equilibrium maintenance efficiency were examined in mature sheep.. Utilisation of CT-scanning allowed estimates for maintenance efficiency to be adjusted for differences in retained energy over the test period. A period of severe weight loss resulted in higher maintenance requirements during a realimentation period relative to that recorded prior to the weight loss period, when expressed per kilogram of body weight. In contrast, less severe

restriction resulted in no deviation in the relationship between equilibrium feed intake and equilibrium weight. After realimentation, the maintenance costs per kilogram of body weight remained higher in those sheep that had previously lost greater weights of body tissues. Higher maintenance requirements may be a cause or an effect of the inability to completely recover empty body weight during the realimentation period. It appears that prior nutritional history can affect estimates of maintenance requirements for mature sheep. The assumption that energy costs for protein and fat deposition and depletion are constant was proposed as a limitation to attempts to estimate true maintenance costs. Equilibrium body weight and body composition at the end of a realimentation period differed for immature sheep that had undergone a previous period of weight loss. Higher body weights were maintained after immature sheep had gained weight and been restricted back to an equilibrium feeding level. This suggests that maintenance requirements do decrease with age or maturity.

Body composition and Compensatory growth

More precise methods of describing the magnitude of fixed treatment effects and random animal variation were developed using random effects models with cubic splines. This technique, combined with accurate estimates the weights of body components *in vivo* via CT-scanning, removed some of the previous confounding effects of differences between animals and biases in allocation of animals to treatment groups. The novel description of the treatment effects using this combination of techniques enhanced the level of understanding of the dynamics of body tissues.

In mature sheep, it was evident that two phases for tissue depletion (that is muscle followed by fat depletion) existed during weight loss. Depletion of carcass fat was used by both sexes to meet the major part of a net energy deficit. Relative to total fat depletion, lean tissues of the body were conserved during the weight loss phase. Changes in endocrine levels were proposed as mechanisms that enabled protein to be conserved during weight loss. Catabolism of lean tissues or muscle from the carcass, that was observed in

the initial phase of weight loss, may be part of a mechanism that protects the animal from ketones formed during lipolysis.

The sheep that were faced with a milder nutritional restriction were able to conserve greater levels of adipose tissue and visceral organs. There was a difference between rams and ewes during weight loss, although unexpectedly it appeared as though females adapted to the energy deficit by reducing metabolic requirements of the tissues rather than mobilising higher levels of lean tissue. There was no effect of fatness genotype (as examined by comparing sheep from lines that differed in backfat thickness) on the patterns of tissue mobilisation during weight loss. Mature sheep fed at a previously defined level for weight maintenance, demonstrated a clear priority for the deposition of carcass fat, whilst carcass muscle remained at depleted levels. A shift to a fat biased metabolism during realimentation appears to be a response of mature sheep that have experienced a period of weight loss.

The patterns of tissue depletion observed for immature sheep clearly differed from those obtained for mature sheep. No hierarchy for tissue depletion in the immature sheep was identified as similar weights of fat and muscle tissue were mobilised from the carcass. Lean conservation was much more pronounced during weight loss in the immature rams when compared to the immature ewes. Elevated levels of growth hormone during feed restriction in the male may contribute to the level of lean conservation that was observed. A distinct sex effect was also observed for the priority for tissue deposition during restricted gain in immature sheep. Females gained greater weights of total fat, whilst males deposited higher weights of carcass muscle as total body weight increased. Differences in priorities for reproductive function as sheep mature may be associated with this result. Clear differences due to sex, were apparent for the proportions of tissues that were deposited during realimentation. Carcass muscle was fully recovered by immature rams, whilst total fat was recovered by both sexes. The influence of elevated growth hormone levels was suggested as a mechanism that promoted lean tissue deposition in the male. Clearly the severity of the nutritional limitation and the stage of maturity at which the restriction was enforced were identified as critical factors that contribute to variation in

the final body composition of sheep from different growth paths. For sheep, it appears as though the sexual dimorphism that exists for body tissue responses to nutritional manipulation, diminishes with maturity.

Seasonality

After adjusting for differences in body composition attributable to growth using an allometric function, seasonal oscillations for total body fat and carcass muscle were apparent in growing sheep.. The magnitude and phase of the sine oscillations for fat and carcass muscle suggested that seasonal cues affect the priorities for tissue deposition. Seasonal oscillations where present for mature sheep that had been fed at a constant feed level. However a more precise method of describing the patterns of change in body tissues using random effects models and cubic splines did not reveal the presence of any time based deviation in total fat, carcass muscle or visceral lean. Nevertheless, the possibility of oscillations in body composition must be considered when estimating the efficiency of growth and maintenance or when evaluating the effects of nutritional manipulation on tissue development in immature and mature sheep.

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