

## Chapter 7

### Summary and Conclusions.

Economic and social pressures demand improvements in efficiency of conversion of inputs to outputs from meat production enterprises. Chapter 2 outlined two approaches, where improvements in production and quality can be made without the need for increased inputs. Firstly, through utilisation of *Compensatory Growth* (Wilson, 1960), the efficiency of liveweight gain can be increased, whilst patterns of tissue deposition can be altered so that specific market specifications are fulfilled. Secondly, through decreasing the feed required for maintenance, particularly for the breeding female during non-productive periods (Thompson and Barlow, 1986), significant improvements in both biological and production efficiency can be achieved. The studies presented in this thesis have examined changes that occur in body composition as they affect aspects of both maintenance efficiency and compensatory growth. The concept of seasonality in body composition was studied with reference to the impact that any endogenous pattern in tissue deposition had on the efficiencies of growth and maintenance.

The ability to accurately estimate the weights of body components *in vivo* via CT-scanning using the procedures outlined by Thompson and Kinghorn (1992) and more recently by Jopson *et al.* (1995), removed some of the previous restrictions that had been faced by researchers when attempting to describe the magnitude of fixed treatment effects and random animal variation. Although the use of CT-Scans to predict body composition *in vivo* in a longitudinal design does allow discrimination between treatment and animal effects, there is still the possibility of type II errors occurring through the physical restrictions of using low numbers of animals within each treatment cell. However, as the precision of estimation was increased through obtaining repeated measurements on individual animals, new challenges emerged with the data analysis due to the effects of correlation between measurements and the domination of random animal effects within treatments. The statistical approach adopted for the analysis of the CT-data, that used random effects models with cubic splines (Græn and Silverman, 1992; Cullis *et al.*, 1996)

was novel for experiments involving body composition of animals. The description of the treatment effects that this technique offers is without parallel and clearly continual development of these procedures will enhance the level of understanding of the dynamics of body tissues.

### **7.1 Compensatory growth**

The review of compensatory growth presented in Chapter 2, examined the changes in body composition that occur in animals during periods of interrupted growth and during the compensatory growth phase as feed supply is increased. The severity of the restriction and the stage of maturity at which the restriction is enforced were identified as critical factors that contributed to the variation in the published results for the final body composition of compensating and normally grown animals, compared at either immature or mature weights. Several studies indicated that an increased understanding of the priorities for tissue mobilisation during weight loss and tissue regain during realimentation within individual animals was required, so that the mechanisms responsible for compensatory growth could be identified (see Ryan, 1990; Carstens, 1995).

Chapter 3 investigated the effects of severity of feed restriction and sex on the patterns of depletion of body tissues in mature sheep fed below maintenance levels. In mature sheep it was evident that phases or steps (Robinson, 1948) for tissue depletion existed during weight loss. Overall, as expected, depletion of carcass fat was utilised by both sexes to meet the energy deficit. Changes in endocrine levels during weight loss, particularly growth hormone, have been proposed as a mechanism that enabled protein to be conserved (Hart *et al.*, 1985; Waghorn *et al.*, 1987). This appeared to be consistent with the results for the mature sheep. However, during the initial phase of weight loss, catabolism of lean tissues or muscle from the carcass was observed. Wolker *et al.* (1994a) suggested that lean tissues may be mobilised as a mechanism to protect the animal from excess ketones formed during lipolysis. The energy associated with the loss of carcass muscle in the mature sheep was only minor when compared to the energy loss from total fat mobilisation.

The severity of the restriction influenced the proportions of tissues that were depleted during the weight loss phase, conservation of adipose tissue and visceral organs was evident for those animals that had lower rates of weight loss. Jopson *et al.* (1996) demonstrated an ability of entire males to preferentially conserve body lean during weight loss at the expense of body fat when compared to castrates. They and others (Onischuk and Kennedy, 1990; Claus and Weiler, 1994), suggested that androgen levels and more specifically testosterone, were responsible for the mechanism that separated males from castrates and females. The results in chapter 3 showed a difference in the absolute loss of tissue weight between rams and ewes during weight loss. Unexpectedly it appears as though females adapted to the energy deficit by reducing metabolic requirements of the tissues rather than mobilising greater levels of lean tissue. Interestingly there was no effect of initial fatness (as examined by comparing sheep from lines that differed in backfat thickness; Morris *et al.*, 1996) on the patterns of tissue mobilisation during weight loss.

Many studies have shown that when compared at a constant weight which is approaching maturity, little difference existed between animals that had been previously restricted and animals that had been grown without interruption (see review by Ryan, 1990 and chapter 2). In chapter 3 mature sheep that were realimentated 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. Two mechanisms which may have contributed to the result observed were discussed. Firstly, it was suggested that there was a shift in the metabolism of animals undergoing weight loss which favoured the deposition of adipose tissue during realimentation (Greef *et al.*, 1986b; Dulloo and Girardier, 1993; Rozen *et al.*, 1994). Secondly, the absence of any recovery of muscle tissue for the mature animal may be related to an inability to increase protein synthesis above that required for the maintenance of the existing mass of muscle tissue (Kreienbring *et al.*, 1994; Schadereit *et al.*, 1995; Mosoni *et al.*, 1996).

The effect of maturity on the response of animals during weight loss and regain has been studied extensively, although significant variation still existed in responses

documented in the literature. The results from chapter 3, suggested that mature sheep differed in their response from that expected from the literature for immature sheep, during both weight loss and regain. The results presented for immature sheep in this thesis (Chapter 5) also clearly differed from those obtained in chapter 3. The steps (Robinson, 1948) of weight loss were not apparent for the immature sheep, with similar weights of fat and muscle tissue mobilised from the carcass. A comparison of the results for the immature rams versus the immature ewes supported the hypothesis of Claus and Weiler (1994) and Jopson *et al.* (1996) that lean conservation is more pronounced for the entire male. A distinct sex effect was also observed for the priority for tissue deposition during a restricted gain in immature sheep. As expected (see Butterfield, 1988), females gained greater weights of total fat and males deposited higher weights of carcass muscle as total body weight increased. It was suggested that differences in priorities for reproductive functions (Fennessy *et al.*, 1991; Weber, 1996) may be associated with this result.

The ability of the immature rams to recover carcass muscle during the realimentation phase, contrasted with results obtained for mature sheep and immature ewes. A proposal that the compensation expressed by the immature rams was related to the elevation of plasma GH levels, as shown by Onischuk and Kennedy (1990), requires further investigation. Evidence for a fat biased metabolism for females as they approach maturity, was strengthened by the observed increase in internal and carcass fat for the immature ewes fed at equilibrium feeding levels after the period of restricted gain. The results of Chapter 5 identified combinations of sex and nutritional manipulation, that produced marked differences in the body composition of sheep at similar live weights. Further investigation of the interrelationships between feeding level, growth rate and sex, using the procedures outlined in this thesis, will enhance the development of models (see Sainz and Wolf, 1990; Baldwin, 1995) that are constructed to predict the effect of feeding regimes on body tissue development. Hopefully these studies, and those which follow, will provide the framework for the development of a mechanistic dynamic model that provides producers with management tools that combine different backgrounding experiences and genotypes to meet specific market goals.

## 7.2 Maintenance efficiency

From the literature it was clear that changes in body composition, particularly the proportion of metabolically active visceral tissues, effected estimates for maintenance requirements. Genetic selection for animals that varied in body composition was expected to have an effect on maintenance costs through changes in the ratio of muscle to fat (Olthoff *et al.*, 1989). Specifically selection for increased fatness may be used to improve maintenance efficiency. Differences in maintenance requirements between genotypes selected for variation in body composition, were shown to be a function of responses in body components using preliminary results from chapter 3 (Ball *et al.*, 1995). They showed no real improvements in terms of the energetic costs of the body tissues had been achieved through selection for backfat depth. The removal of line differences in calculated maintenance requirements by adjusting for body composition, highlights the importance of the relationship between maintenance estimates and body composition. Attempts to improve maintenance requirements through selection must be coupled with techniques that can reliably adjust for variations in body composition.. Ball and Thompson (1995) further showed that any improvements in biological efficiency that could be gained by selection for proportionally fatter animals were diminished by a proportional reduction in the final product from the dam/offspring unit. However, differences in maintenance requirements between sexes could not be explained by differences in body composition at the same weight. Identification of the mechanism(s) that contribute to different maintenance requirements of rams and ewes, for example variation in protein turnover within the muscle, may provide an opportunity to reduce maintenance costs whilst output levels are maintained.

Attempts to estimate maintenance requirements, or that component which is considered to be associated with non-productive essential metabolic processes, has seen the development of numerous techniques of measurement. The majority of these techniques are dependent on either measuring the heat production or a respiratory coefficient, or from partial regressions of changes in energy in the body to energy consumed, (Klieber, 1975; Webster, 1978; Baldwin and Bywater, 1984; Baldwin, 1995).

Taylor and Turner (1968) and later Taylor *et al.* (1981) pioneered the development of the concept of *Equilibrium Maintenance Requirements* ( $T_0$ ) for animals, that could be estimated from the relationship between equilibrium weight and equilibrium feed intake. Taylor and Turner (1968) showed that estimates for equilibrium maintenance requirements were constant as animals matured, suggesting that the exponent of the relationship between weight and feed intake did not differ from unity. One area that concerned Taylor and Turner (1968) was whether or not a constant  $T_0$  was applicable for animals that were forced to a near equilibrium weight by restricted feeding below an equilibrium level.

The results from Chapter 3, indicated that a different equilibrium weight and body composition was achieved by mature sheep that had experienced a period of weight loss and were returned to original equilibrium feeding levels. This finding contrasted with evidence presented by Parks (1982) from results of Clapperton and Blaxter (1966) which suggested that a constant relationship existed between weight and feed intake in animals that were losing weight. Recently Luiting *et al.* (1995) and Kolstad and Vangen (1996) suggested improvements in the interpretation of maintenance requirements, as predicted by the design of Taylor and Turner (1968) were achieved by correcting for the changes that occurred in body composition over the period where animals were maintaining weight.

Chapter 4 examined the implications for maintenance efficiency after adjusting calculated maintenance requirements for energy retained in the body over the test period (see Kolstad and Vangen, 1996). Following a period of weight loss, maintenance requirements were the same as those estimated prior to the restriction period, when expressed per kilogram of body weight. However, when expressed per kilogram of total body lean, maintenance requirements were lower at the end of the restriction period for animals that had lost weight. Clearly, the biological parameter against which maintenance costs were compared, affected the interpretation of the results. After realimentation, the maintenance costs per kilogram remained higher in those sheep previously fed at 60% of maintenance, although the maintenance requirements for sheep fed at 80% of maintenance did not differ from those estimated prior to the restriction period. These results indicate

that estimates for equilibrium maintenance requirements will be effected by the previous nutritional history of the animal. However, the techniques used to adjust maintenance requirements for differences in energy retained in the body over time, highlighted the inadequacy of assumptions that energy costs for protein and fat deposition and depletion are constant. Any attempt to estimate true maintenance costs are restricted by these assumptions. Future improvements in estimating maintenance requirements must be coupled with improved estimates of the efficiencies for protein and fat deposition (Tess and Greer, 1990), through the use of CT-scanning and other techniques that enable repeated and accurate estimates of body composition to be obtained. The results for chapter 5, contributed to the investigation of maintenance requirements, by confirming that equilibrium body weight and body composition differed for immature sheep that had undergone weight loss. In addition, the increased weight maintained at an equilibrium feeding level after immature sheep had gained weight over a treatment phase, suggests that maintenance requirements do decrease with age or maturity. Further experimentation is required to understand why this apparent improvement in efficiency was achieved.

### **7.3 Seasonality.**

Blaxter and Boyne (1982), Argo and Smith (1983) and Walker *et al.* (1991) indicated that seasonal oscillations existed in the energy metabolism of sheep. If these oscillations were part of an endogenous rhythm of metabolic activity and energy utilisation it was likely that seasonal oscillations also existed in body composition. Previously a number of studies had demonstrated that seasonal oscillations existed in body components of temperate deer species (Adamczewski *et al.*, 1987; Parker *et al.*, 1993; Verme, 1988; Worden and Perkins, 1995; Weber and Thompson, 1995) and cattle (Laurenz *et al.*, 1992). After adjusting for differences in body composition attributable to growth, seasonal oscillations in the body components were also apparent in growing sheep (Chapter 6; Ball *et al.*, 1996). Clearly seasonal oscillations in body components will affect the relative energy costs for both growth and maintenance efficiency, this may influence procedures that attempt to characterise efficient animals for genetic selection. The magnitude and phase of the sine oscillations for fat and carcass muscle suggested that priorities for tissue

deposition based on seasonal cues were present and that these priorities may impact on fatness/weight specifications for finishing animals.

Previous studies that had demonstrated seasonal oscillations in body composition (Ball *et al.*, 1996; Weber, 1996) for both immature and mature deer were confounded by variations in feed intake. Seasonal oscillations in mature sheep that had been fed at a constant feed level (Chapter 6) were found using an identical statistical technique as used by those studies. However, further analysis of the data using a more precise method of random effects models and cubic splines (Cullis *et al.*, 1996) failed to identify any presence of time based deviations in body components which could be described as a seasonal cycle. In order to satisfy requirements for estimating spline deviations, further studies are required where more intensive measurements of body composition are made over an annual period.



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## **Appendix**

The following papers were submitted to conferences during the course of the Ph.D. candidature. These two papers summarise the results and highlight the implications of the first estimates of body composition (Scan 1) of Chapter 3.

## **Feed requirements for maintenance of mature rams and ewes from lines selected for differences in body composition.**

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### **Keywords**

Body composition; maintenance requirements; sex; sheep.

### **Abstract**

A total of 24 mature rams and ewes (>2.5yrs) from a line selected for high backfat thickness and a unselected control line were used to investigate the relationship between maintenance efficiency and body composition in mature sheep. Over a 6 week period the sheep were fed daily a pelleted ration at levels to maintain liveweight. At the end of this period the weights of total fat, carcass lean, viscera and of the empty body (fleece free) were estimated from X-ray computed tomographic images. After adjustment for empty body weight the control line required 5% more feed to maintain liveweight ( $P<0.05$ ) than sheep from the fat line and males required 19% more feed ( $P<0.05$ ) than females. After adjustment for differences in either total fat or carcass lean weight, there were no significant difference ( $P>0.05$ ) in feed requirement between the lines. This indicated that although a genetic change in body composition did alter maintenance feed requirements at maturity, the efficiency of maintaining a unit weight of either fat or carcass lean remained the same. After adjustment for differences in total fat and carcass lean weight, rams still required 11% more feed than ewes to maintain liveweight. Adjusting for visceral weight had no effect on feed requirements to maintain the mature sheep. It was proposed that differences in the turnover rates of adipose tissue or carcass lean contributes to the higher maintenance feed cost observed for the mature male.

### **Introduction**

Selection for an increase in the proportion of lean during body growth will allow both beef and sheep producers to provide carcasses that satisfy consumer requirements for a leaner product (Thompson, 1990). A change towards leaner body composition resulting from selection for decreased fatness (see Fennessy *et al.*, 1987), has been shown to alter the gross food efficiency of the growing animal (Webster, 1989; Thompson, 1990). However, in a number of species, leaner animals have higher maintenance energy requirements (Thompson *et al.*, 1983; Hofstetter and Wenk, 1985; Stephens, 1991; DiContanzo *et al.*, 1991), which is consistent with the hypothesis that lean tissue is more expensive to maintain than fat (Webster, 1989; Olthoff *et al.*, 1989). Thus at the enterprise level, genetic improvement in growth efficiency and product suitability, may be mitigated by a correlated increase in maintenance requirements of the breeding female. Therefore the implications of selection for a change in body composition on feed requirements to maintain mature animals warrant investigation.



It is widely accepted that maintenance requirements for entire males are in the order of 1.15 times that of females in both cattle (ARC, 1980) and sheep (Corbett, 1990). Despite this large difference, the mechanisms which contribute to the sex effect are not clearly defined. A higher proportion of the empty body weight as lean in bulls, compared with cows or steers (Russel and Wright, 1983), together with higher fasting heat production of rams compared with ewes and wethers (Graham, 1968), have been suggested as factors that contribute to the sex effect.

A number of authors have indicated that lean body mass may be more appropriate for the estimation of maintenance requirements than metabolic body weight (Pullar and Webster, 1977, McCracken, 1992). Quantifying the relationship between body components and the feed requirements for maintenance at a variety of physiological states, will assess whether an adjustment factor for body composition is necessary in feeding standards that estimate maintenance requirements. This experiment attempts to quantify the effect of body composition differences on feed requirements for maintenance by examining the relationship between the feed required to maintain liveweight and the proportions of body components in mature rams and ewes from genotypes which differ in body composition.

## **Materials and methods**

### Animals and experimental design

The experiment was a 2x2 factorial design, examining the effects of sex and genotype on the feed intake required to maintain a constant liveweight in sheep. The sheep were from a high backfat selection line and a randomly bred control flock developed at AgResearch Invermay in New Zealand (Fennessy *et al.*, 1987). The high backfat line was a result of selection for ultrasonic backfat depth at the 12th rib (C) site, adjusted for liveweight. A total of 24 mature sheep (12 rams and 12 ewes older than 2.5 yrs of age) from the fat and control lines were used.

The sheep were run on pasture and 2 weeks prior to the commencement of the experiment they were shorn, vaccinated, drenched with anthelmintics prior to being placed into individual indoor pens (3x3 metres). They were weighed after a 24 hour fast and the metabolisable energy required to maintain liveweight for each sheep was estimated as a function of metabolic weight, age and sex using equation 1.21 from the SCA (1990). The sheep were fed a pelleted ration (Thompson *et al.*, 1985), once daily at 0800 hours and water was provided *ad libitum* during the experiment. For the first 2 weeks sheep were weighed at 3 day intervals and feeding levels were adjusted when animals had a deviation of  $\pm 2$  kg from their initial liveweight. When feed intakes had stabilised (2 weeks), these levels were fixed for the next 6 weeks. Thereafter sheep were weighed after a 24 hour fast and randomly moved to pens within the shed weekly.

### CAT-scanning procedure

The sheep were scanned using a CAT-Scanner (Hitachi CTW-430 X-ray Computed Tomography system) following the procedure defined by Thompson and Kinghorn (1992). When necessary the sheep were sedated with Acepril® (0.1mg / 10kg liveweight; Troy Laboratories, Australia) to improve image quality. From each sheep, 2-dimensional

sagittal cross-sectional scans were made of the whole body from a point behind the rump (distal to the proximal hind limb muscles) to the 3rd/4th cervical vertebrae, at 40 mm intervals. On average, 25 scans were taken for each sheep.

To estimate the weight of body components, each scan was divided into total fat (fat tissue in the subcutaneous, intermuscular, internal and udder/scrotal depots), carcass lean (all lean of the musculature from the carcass), viscera (the alimentary tract, abdominal and thoracic organs, trachea, aorta, and udder or scrotal lean tissue) and bone using the program CATMAN (Thompson and Kinghorn, 1992). Contents of the rumen, reticulum, omasum, abomasum, caecum, colon and bladder were excluded from the images. Total tissue area from each slice was also recorded. Tissue areas from each scan were numerically integrated to estimate tissue volume, which were then corrected for density to provide an estimate of tissue weight. Total tissue weight, which comprised total fat, carcass lean, viscera and bone, was used as an estimate of fleece-free empty body weight (EBW).

### Statistical analysis

Data on weekly feed intakes, body components and empty body weight were transformed to  $\log_{10}$  to minimise the correlation between the mean and variance. Individual feeding levels (kg/week) needed to maintain liveweight were analysed by a least squares model (model 1) which contained terms for sex, genotype and empty body weight. First order interactions were tested and found to be non-significant ( $P>0.05$ ). To determine the effects on the feed required to maintain liveweight, additional covariates for the weights of  $\log_{10}$  total fat (model 2),  $\log_{10}$  carcass lean (model 3) and  $\log_{10}$  viscera (model 4) were included as separate terms in the above model. Again all first order interactions were tested and found to be non-significant ( $P>0.05$ ).

### **Results**

Mean component and empty body weights for line and sex combinations are presented in Table 1. Rams were significantly heavier than ewes ( $P<0.05$ ), whilst line and the line x sex interaction was not significant ( $P>0.05$ ).

Sex, line and  $\log_{10}$  empty body weight all had significant effects on the feed required to maintain liveweight (Model 1, Table 2;  $P<0.05$ ). The antilog of the least square difference between sexes indicated a multiplicative sex difference, whereby the rams required 1.19 times more feed to maintain liveweight than the ewes. Similarly the line effect indicated that the sheep from the control line required 1.05 times more feed to maintain liveweight than sheep from the fat line.

After inclusion of fat weight as a covariate, the line effect was no longer significant (Model 2, Table 2;  $P>0.05$ ), and the multiplicative sex difference was reduced to 1.11 ( $P<0.05$ ). The regression coefficient for fat weight was -0.12 showing that an increase in fat weight at the same EBW results in a decrease in feed intake. After inclusion of a covariate for carcass lean, line was again not significant (Model 3, Table 2;  $P>0.05$ ), and the sex difference was reduced to 1.10. The regression coefficient for carcass lean was 0.34 which indicates that an increase in carcass lean at the same EBW results in an increase in feed requirements. Although not shown in Table 2, the addition of visceral weight to

model 1 did not account for a significant component of the variance ( $P>0.05$ ) and had no effect on the significance or magnitude of the regression coefficients for line, sex and EBW.

## Discussion

This study showed that sheep from the control line, which had a higher proportion of lean and a lower proportion of fat, required 5% more feed when compared to sheep from the fat line (Table 1). This supports the work of Olthoff *et al.*, (1989), where fatter sheep had lower maintenance requirements, due to the higher metabolic activity of lean tissue (Webster, 1989). However in the present study, after adjustment to the same total fat weight, or carcass lean weight, there was no difference between the lines in liveweight maintenance requirements. This suggests, that while selection altered gross body composition, the energy requirement per unit of fat, or carcass lean weight, for the two lines remained the same.

After adjusting for differences in EBW, males required 1.19 times more feed to maintain liveweight than females. Therefore equations to estimate maintenance requirements of mature animals require the inclusion of a scaling factor to account for the sex difference (ARC 1980; SCA, 1990). Unlike the line effect, which appeared to be largely a function of differences in body composition, this study showed that when adjusted to the same total fat or carcass lean weight, males still required 1.11 times more feed than females to maintain liveweight. That is, it is energetically more expensive to maintain a unit of lean or fat respectively, in males than in females. Because of the high negative correlation between fat and lean it is not possible to separate which tissue is having the greater effect.

Webster (1985) showed that males had a higher metabolic heat production than castrates and indicated that the protein synthesis and turnover may be responsible for the difference in maintenance requirements between males and castrates. Adeola *et al.*, (1990) observed that muscle turnover rate was higher in male than female pigs and suggested that differences in the partitioning and turnover of protein within the carcass lean depot would contribute to a higher feed requirement of the male when compared to the female. In contrast Sinnet-Smith and Woolliams (1988) showed that there was no sex effect on the metabolic activity of adipose tissue in sheep from several breeds differing in body composition. Overall these results indicate that a higher turnover rate of protein within the carcass lean depot was probably the major contributing factor to the higher feed requirements of the rams in this experiment. It is interesting to note that Loblely *et al.*, (1990) could not generate a difference in muscle turnover rate when infusing testosterone into wethers, suggesting that the presence of anabolic steroids alone are not responsible for the increase in metabolic energy demands of the entire male.

The work of Afonso and Thompson (unpublished data) who compared maintenance requirements of similar sheep at an earlier stage of growth (22-31 weeks of age) found no difference in the feed requirements between rams and ewes, even after adjusting for the small differences in total fat weight. This contrasts with the present experiment, where significant differences in feed requirements between rams and ewes were identified and these remained after adjustment for differences in body composition. This indicates that as

sheep mature, the feed requirements to maintain liveweight become progressively higher in males than in females and that stage of maturity influences the magnitude of the contribution of body components to feed intake requirements

Metabolic activity of the viscera is regarded as a major factor contributing to differences in maintenance efficiency observed both within and between strains of sheep and cattle (Ferrell and Jenkins, 1984; Koong *et al.*, 1985; Solis *et al.*, 1988). In the present experiment visceral mass had no effect on the feed required to maintain liveweight. However it must be noted that the estimates for visceral weight, using the CAT-Scanner, are not as accurate as estimates for the other components *in vivo*. As the technique used to estimate body components was independent of bias (Afonso, 1992), the comparisons made between sexes and lines were still valid. Therefore this result suggests that the visceral mass differences have no effect on the variation in feed requirements of mature animals when fed at maintenance levels.

## Conclusion

An understanding of the components that contribute to the efficiency of feed utilisation by mature animals is fundamental to the improvement of, or the manipulation of efficiency in animal production (Olthoff *et al.*, 1989). This study showed that selection for an increase in body fatness reduced the feed requirements for maintenance of liveweight in mature sheep. However after adjustment for line differences in carcass lean or fat weight, differences in maintenance requirements were no longer apparent. This indicated that genetic selection for body fatness changed maintenance requirements per unit of EBW at maturity, but had no effect on the maintenance cost per unit of lean, or fat weight, within the body. In contrast to the line effect, the higher energy requirements of the mature ram, cannot be entirely explained by differences in composition, indicating that the energy cost of maintaining a unit weight of either fat or carcass lean in a ram was higher than in the ewe. Further work is required to establish the factors that contribute to this difference, which may lead to techniques that enable modification of maintenance requirements for breeding animals.

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**Table 1:** Mean fleece free empty body weight (EBW), carcass lean, viscera and total fat weights ( $\pm$ s.e.m.) at the end of the experimental period for control and fat rams and ewes.

	Line			
	Control		Fat	
	Rams	Ewes	Rams	Ewes
<b>Number</b>	6	6	6	6
<b>Total Fat (kg)</b>	9.30	16.34	15.29	16.71
s.e.m.	1.00	1.47	2.84	1.11
<b>Carcass Lean (kg)</b>	25.15	19.27	24.74	17.10
s.e.m.	1.82	0.62	1.22	0.55
<b>Viscera (kg)</b>	7.84	5.74	6.98	4.64
s.e.m.	0.31	0.27	0.33	0.16
<b>Empty body weight (kg)</b>	47.94	45.64	52.24	42.00
s.e.m.	3.17	1.95	3.83	1.40

**Table 2:** The effects of line, sex and body components on the feed required to maintain liveweight ( $\log_{10}$  kg of feed/week), in rams and ewes from the control and fat selection lines

Source of Variation		Regression Coefficients ( $\pm$ s.e.m.)		
		model 1 (***)	model 2 (***)	model 3 (***)
Constant		-0.155 (0.113)	-0.404 (0.157)	-0.218 (0.096)
Line	Control	0.011 **	0.005	0.006
	Fat	-0.011 (0.004)	-0.005 (0.005)	-0.006 (0.004)
Sex	Male	0.038 ***	0.022 *	0.021 **
	Female	-0.038 (0.004)	-0.022 (0.008)	-0.021 (0.006)
$\log_{10}$ fat weight		-	-0.119 * (0.056)	-
$\log_{10}$ carcass lean weight		-	-	0.341 ** (0.109)
$\log_{10}$ EBW		0.568 *** (0.068)	0.798 *** (0.126)	0.334 ** (0.093)

\*  $P < 0.05$ , \*\*  $P < 0.01$ , \*\*\*  $P < 0.001$

## **The effect of selection for differences in Ultrasonic Backfat depth on the feed utilisation for maintenance and Biological Efficiency in sheep.**

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### **SUMMARY**

Selection for increase in backfat thickness reduced maintenance requirements for both immature and mature sheep. In both immature and mature sheep the change in maintenance efficiency was a function a change in the relative proportions of the body tissues, with no alteration to the fundamental metabolic costs of the tissues. The improvement in maintenance efficiency for the fat line increased biological efficiency, although after adjusting for the penalties associated with a lower carcass lean proportion, leaner sheep were more biologically efficient.

### **Introduction**

Selection for leaner body composition is one of the options that is available to producers to provide edible product that meets consumer demands. In a number of species, animals that have comparatively more lean have a higher fasting heat production (FHP) and (or) higher maintenance energy requirements ( $Me_m$ ), which are usually of the magnitude of between 5 and 20% (Pullar and Webster 1977; Tess *et al.*, 1984). Most of these differences have been attributed to the higher costs associated with protein turnover rates in both the carcass, and more importantly in the visceral organs (Koong *et al.*, 1985; Webster 1989). Therefore, although an increase in leanness at the same market weight will reduce the above-maintenance costs for growth (Olthoff and Dickerson 1989; Thompson 1990), if this selection leads to a correlated response in the mature females, then there will be an associated increase in the feed requirements for maintenance. The costs of both inputs and outputs will determine whether the producer gains from selection for leaner growth. In order to assess the net benefit of selection for leanness, the changes to both inputs and outputs needs to be evaluated at the enterprise level.

This paper describes the results from two experiments that were designed to evaluate the effect of selection for an increase in weight adjusted backfat thickness on the feed requirements of sheep held at equilibrium liveweights during growth (J.J.M. Afonso and J.M. Thompson, unpublished data) and at maturity (Ball *et al.*, 1995). The paper uses these results in a model that examines the effect of the change in body composition on biological efficiency.

### **Experimental review**

The sheep used in the experiments were from the Coopworth backfat selection lines (Fennessy *et al.* 1987). Briefly the lines were the result of selection for and against a weight adjusted backfat thickness, and a randomly bred control line. The sheep were fed a high quality pelleted ration (Thompson *et al.*, 1985) once daily and housed indoors under a natural photoperiod in individual pens. The weights of carcass lean, viscera, total body fat and empty body weight were estimated using a CAT-Scanner (Hitachi CTW-430 X ray Computed Tomography system) following the procedure described by Thompson and Kinghorn (1992).

(i) Experiment 1: Feed requirements for lambs at 21-34 weeks of age.

Materials and methods used in this experiment were given by Afonso (1992). Briefly rams and ewes from the three lines were fed to maintain liveweight from the ages of 21 to 34 weeks. Sheep were CAT-scanned at 21, 25 and 34 weeks of age. A repeated measures analysis of the individual feed levels (kg/wk) required to maintain liveweight over the 10 week period was used. The model contained terms for the effects of sire, sex, mean empty body weight over the maintenance period and sires within line. Additional covariates of total body fat, carcass lean and viscera were included in the above model to determine the effect of body composition on feed requirements for maintenance.

The results from this experiment (J.J.M Afonso and J.M. Thompson unpublished data), showed that there was a significant line effect on feed requirements for maintenance ( $P < 0.05$ ), with sheep from the fat line requiring 20% less feed to maintain liveweight than sheep from the control and lean lines. There was no sex effect, indicating that there was no difference in the amount of feed required to maintain liveweight of rams and ewes, at this age. There was no time interaction between sex or line with the feed required to maintain liveweight, indicating that the magnitude of these effects was constant over the experimental period. When body components, of carcass lean, viscera and total fat were included as separate covariates in the model, the line effect was no longer significant, whereas the sex effect was still significant ( $P < 0.05$ ).

(ii) Experiment 2: Feed requirements at a mature age (>2.5 yrs).

Materials and methods used in this experiment are outlined in Ball *et al.* (1995). Briefly mature rams and ewes from the fat and control lines were fed a constant amount of feed to maintain liveweight for a period of 6 weeks. At the end of this period, the sheep were CAT-scanned. Individual feeding levels (kg/week) were analysed in a least squares model that contained terms for sex, line and empty body weight. Additional covariates for total body fat, carcass lean and viscera were included as separate terms in above model.

The results showed that at a mean EBW of 45kg, control sheep required 6.23 kg/wk and a fat sheep required 5.98 kg/wk to maintain liveweight, whereas rams required 1.11 kg/wk more feed to maintain liveweight than ewes. After the addition of total fat or carcass lean as additional covariates, the line effects were not significant and the sex effect, although still significant ( $P < 0.05$ ) was reduced, so that when compared at the same proportions of fat or carcass lean, rams required 0.44 kg/wk and 0.55 kg/wk more feed respectively to maintain liveweight.

**Discussion.**

(i) Line effect

Sheep from the control line required more feed to maintain liveweight than sheep from the fat line in both experiments. When compared at the same EBW, immature sheep from the fat line required 20% less feed than control or lean sheep at the same EBW, whilst at maturity, when compared at a mean EBW, control sheep required 5% more feed per week to maintain liveweight. After adjustment to the same proportions total body fat, carcass lean or viscera at the same EBW, the line effects were not significant, indicating that the differences in the maintenance requirements observed for the lines were a function of the differences in body composition at both an immature age and at maturity. Overall



these experiments support Olthoff *et al.* (1989) who concluded that selection for an increase in fatness will result in a decrease in maintenance requirements, if  $Me_m$  is expressed on a weight basis. It is noteworthy that although selection for an increase in fatness increased maintenance efficiency at equilibrium weights, there was no line effect on the feed efficiency free of the maintenance component (AB; Afonso, 1992).

#### (ii) Sex effect

At the age of 21-34 weeks there was no difference in the amount of feed required to maintain liveweight of rams and ewes, whilst at maturity rams required 19% more feed to maintain liveweight than ewes at the same EBW. The absence of a sex effect on maintenance requirements at an immature age (21-34 weeks; prior to puberty) and its presence at maturity indicated that there was a divergence in maintenance requirements with physiological maturity, even after adjustment to the same body composition. This result may indicate that the relative decline in protein turnover rates observed with age by Waghorn and Wolff (1984), may differ with sex, the decline being greater in ewes. It is unlikely that the sex effect is a function of differences in adipose tissue turnover rates as Vernon (1981) showed that the rate of lipolysis of both sexes was relatively constant with age. However forcing immature animals to maintain an equilibrium weight may have severe compositional and metabolic effects (Tess *et al.*, 1984), thus the relationship between stabilised intakes and  $Me_m$  may be questionable in immature animals and could be affecting any differences due to sex at immature ages.

In contrast to the line effect, adjusting for differences in either total fat, carcass lean or viscera at the same EBW did not remove the sex effect at maturity, although the effect was reduced when the covariates for total fat and carcass lean were included. These results suggest that at maturity rams have a higher metabolic cost for maintaining body tissues. Clearly identification of the physiological mechanisms that contribute to the sex differences at maturity, may provide criteria that aid in the selection of sheep that have lower maintenance requirements, without altering body composition.

#### **Implications for biological efficiency.**

The impact of a change in maintenance requirements, as a result of selection for body composition, on biological efficiency, was examined using a model described by Thompson and Barlow (1986). The model calculates biological efficiency over the lifetime production of a ewe as a function of the predicted outputs and inputs for the ewe and her progeny. Parameters used in the model were mature ewe weight (A) 55kg, an exponential change in food intake to body weight of 0.23 (kg weight / kg feed intake), an annual lambing percentage 150% and the productive life of a ewe, 5 years. Other feeding parameters were assessed to be directly proportional to mature weight. The initial estimates for biological efficiency (g lean/MJ of ME) were obtained for the control and the fat lines using the assumption that ewes from the fat line required 5% less feed to maintain liveweight at maturity. Estimates were then obtained for biological efficiency from the model with the addition of the condition that fat sheep contained ca. 5% less lean than sheep from the control line (McEwan *et al.*, 1990; Ball *et al.*, 1995; J.C. McEwan unpublished data).

The results from the biological efficiency model (Figure 1) indicate that the maximum biological efficiency for the fat line ewe would be 3% higher than maximum biological efficiency of the control line ewe. The maximum efficiencies for the two lines occur when progeny are slaughtered at same proportion of their mature weight respectively. When changes in body composition were also included in the model the difference in biological efficiencies between the two lines diverged, with the control line being 17% more efficient than the fat line.

The reduction in maintenance requirements of the ewe resulting from selection for increased body fatness did not alter biological efficiency greatly. However this observed increase assumed that there is no associated change in body composition of the progeny and breeding female at slaughter. Adjusting for a 5% increase in body lean in the control line, showed that there would be a significant increase in biological efficiency through selection of leaner females even though maintenance requirements are higher. The small disadvantage gained in maintenance efficiency was offset by the increase in the lean proportion of the carcass of slaughtered progeny over the lifetime of the ewe and of the ewe at culling.

### **Conclusion**

These results indicate that for the Australian lamb industry, where lambs are slaughtered from a 35kg (trade lamb) to 50kg (elite lamb), there would be little change in efficiency by selecting for fatter sheep with lower maintenance requirements. However when consideration of the increase in carcass fatness were taken into account fatter sheep were less efficient. Therefore if selection for an increase in maintenance efficiency of the breeding ewe was associated with a corresponding increase in the proportion of the carcass fat of corresponding progeny, then the industry will be penalised in terms of both biological and economic efficiency.

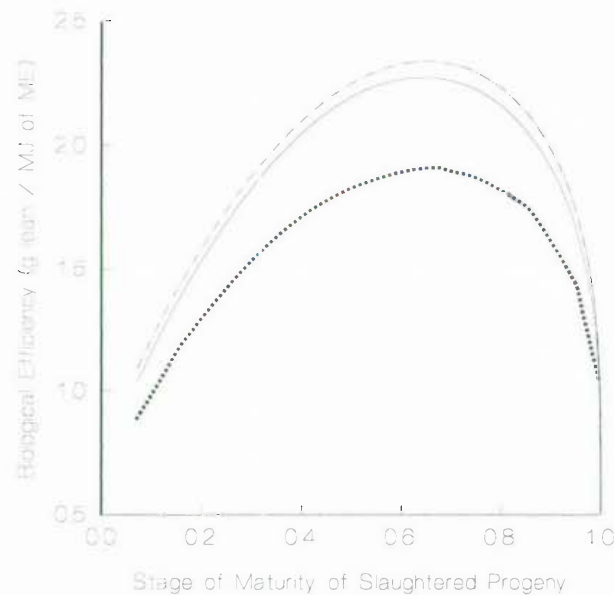


Figure 1. Biological Efficiency as a function of stage of maturity for a control ewe (—), a fat ewe with 5% lower  $Me_m$  (---) and a fat ewe with 5% lower  $Me_m$  and 5% less carcass lean (- - -).

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