# final report


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Prepared by: Dr Hutton Oddy and Dr Brad Walmsley

NSW Department of Primary Industries



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# A scoping study to explore the limitations on productivity of meat sheep due to nutrient supply


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# Abstract

This project was initiated to examine the basis of claims that the growth rate of some modern meat lambs had potentially increased to 500 g/day and industry concerns that nutrient supply was constraining lambs from achieving such growth rates. The phenotypic increases in live weight, eye muscle depth and fat over the last 20-25 years were examined in some major breeds of meat sheep. There has been an increase in rate of growth and large changes in fat and lean composition of lambs over that period. Modelling systems were used to demonstrate that nutrient demands have consequently increased to support this increase in production. Analysis of growth rates in the Cowra and Trangie flocks within the Sheep CRC Information Nucleus Program was conducted. Average postweaning growth rates were well short of potential (predicted using models of growth and nutrient requirements). In the rare cases where reported post weaning growth rates exceeded 400 g/day, it could be shown that this was more likely due to errors in measurement than actual lamb performance. However, the **general finding was that current postweaning growth rates were consistently less than potential**; suggesting that if practical measures to increase nutrient (feed) availability were implemented lamb growth rates could be expected to increase.

This project supports the idea that the potential of high performance lambs (achieved through genetic selection/improvement) is constrained by the intake of nutrients post-weaning. Some suggestions about how this maybe further examined are presented.

# Executive summary

Continued genetic improvement in meat sheep breeds has resulted in increased carcass weights at younger ages. This has been achieved in direct response to selection criteria within the terminal sire index [weight gain (60%), lean (20%) and fat (-20%)] with an increasing movement to selection on weaning weight at 100 days of age. Such selection will potentially lead to increased mature size. In light of producer observations that some lambs had growth rates in the order to 400-500 g/day, this project was commissioned to explore the capacity of present day production systems to provide the nutrients required to exploit such superior genetics.

This project quantified the realised changes in growth, fat and lean measures that have occurred over the past 20 years in the Australian lamb industry. It used a modelling approach to determine the extent to which change in animal phenotypes has been influenced by nutrient supply.

The project found:-

- Selection (of sires) has certainly increased growth rate and decreased fat and increased lean content of the body of lambs over the past 20-25 years.

- However, the extent to which this translates to improvement in production is variable. Analysis indicates that it is normal for growth to be less than expected based on genetic potential (modelled using anticipated changes in mature size). This exaggerates the differences in fat and lean deposition in the body of the lambs due to selective breeding. From a production efficiency perspective having growth rate (and consequent effects on body composition) less than maximum is not desirable.

- The evidence suggests that lambs are most often nutrient deprived after weaning (i.e. growth rate is less than before weaning). Growth after weaning is less than anticipated based on models of nutrient requirements adjusted for anticipated increases in mature size. Modelling suggests composition of specific nutrients in the feed are alone unlikely to be responsible for the growth rate being less than expected, unless they have direct effects on feed intake. It seems that failure to achieve lamb growth potential is due to the failure of lambs to eat sufficient feed to maximise growth. The results strongly suggest that lamb performance could be improved by increasing the quality of feed (essentially energy density, with sufficient protein to ensure rumen function is not impaired) available to lambs after weaning and before slaughter. It is recognised that other factors (e.g. social, diet induced subclinical acidosis) also affect intake by lambs, and attention to these is warranted.

- The limited data available for this study from lambs with known ASBVs finished on pelleted and high grain diets suggested that even when presented with unlimited amounts of high energy density feed, lambs do not always respond as anticipated. This may be because ASBVs overestimate the anticipated phenotypic differences in growth rate, and hence mature size leading to higher performance expectations than those achievable. Alternatively, the management of lambs and their feed supply in these studies was not appropriate. This in turn restricted growth potential so that the overall performance was much less than potential even though the relativity in performance of lambs with different ASBVs was on average as expected.

The following recommendations are offered for research to be undertaken to better understand the basis of and overcome this shortfall in expectations of lamb growth.

It seems that lambs are less well suited to feedlotting than cattle, and traditionally feedlotting of lambs has been on an opportunistic basis. The development of systems for year round feedlotting has rarely been successful due to the seasonal nature of lamb production. Accordingly it is believed that the by addressing the following issues it is more likely practical solutions to improve lamb performance will emerge:

1. Developing pastures that allow lambs to maximise nutrient intake for 8-12 weeks postweaning.

2. Managing these pastures to maximise growth and minimise the detrimental impact of GINs, and nutrient density, e.g. rotational grazing, perhaps by incorporating other species and/or stock classes.

3. It is strongly suggested that a research project be conducted to establish:

    a. Maximum growth rate of lambs on pastures managed to provide different levels of nutrient supply,

    b. This is extended to include the use of supplement to maximise nutrient intake. If it is demonstrated pasture management practices can be used to maximise lamb nutrient intake this information be provided to industry as a matter of urgency along with recommendations on how to manage pastures to achieve maximum lamb growth.

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# 1 Background

The continued genetic improvement of meat sheep has resulted in increased carcass weights at younger ages. This has been achieved in direct response to selection criteria within the terminal sire index [weight gain (60%), lean (20%) and fat (-20%)] with an increasing movement to selection on weaning weight at 100 days of age. Selection of this nature will potentially lead to increased mature size. The capacity of present day production systems to provide the nutrients required to exploit such superior genetics is not clear.

This study was initiated following advice from Sheep Genetics that producers were at times reporting lamb growth rates of 500g/day or more. This raised several concerns, first about veracity of the claims and second about the capacity of current production systems to meet nutrient demands of such fast growing sheep if indeed they existed.

To address these issues several lines of enquiry were followed:

1. Sheep Genetics records of phenotypic data (weight, scanned fat and eye muscle depth) were obtained for a number of major sheep breeds over the past 20-25 years.

2. Data from selected flocks within the Sheep CRC Information Nucleus was used to investigate growth and other phenotypic traits.

3. A discussion was conducted with selected industry practitioners concerning their experience and sought data on growth of lambs of know genetic background fed grain or high quality feed during finishing.

4. The theoretical nutrient requirements for both energy and protein, of different genotypes, were explored using the above data as a base.

5. A strategy was formulated to explore the nature of theoretically potential nutrient limitations.

This report describes the results of these analyses, summarises what are believed to be the issues and provides some guidelines for further work in this field.

# 2 Project objectives

**1.** Undertake desktop study of nutrient requirements of modern (and post-modern; projected) sheep genetics. The study will explore potential energy and protein/amino acid requirements of sheep to achieve high rates of weight and lean (muscle) gain. To achieve this outcome the study will rely heavily on the biological lessons learned from previous studies of selection for weaning and yearling weight in both sheep and cattle.

**2.** Using outcomes from 1, potential pasture based production systems will be explored. Nutritional limitations to reaching potential productivity will be identified and where possible, suggestions made as to potential solutions. The methodology used to explore possible nutrient limitations was:

a) Compare genetic and phenotypic trends,

b) Model these against known nutrient requirements, and

c) Prepare scenarios with different nutrient densities to illustrate the short fall between current and theoretical performance. The examples used were representations of an improved pasture, a high quality pasture (ryegrass and white clover) and a feedlot diet.

**3.** Recommendations will be made about what can be implemented using current knowledge. Where insufficient knowledge is obvious, suggestions of potential research activities will be made.

# 3 Methodology

## 3.1 Phenotypic and Genetic Data

### 3.1.1 LAMBPLAN

Data was sourced from the LAMBPLAN database for 6 breeds; Merino, Border Leicester, Poll Dorset, Texel, Suffolk and White Suffolk. This data consisted of phenotypic means for live weight, GR fat depth (FAT) and eye muscle depth (EMD) for each stage (birth, weaning, etc), year and sex (ram and ewe) over the past 20-25 years (depending on breed).

Linear regression analysis has been conducted using the linear model procedure in the R statistical package (R Development Core Team 2011) on a stage basis (e.g. weaning, postweaning, yearling, etc) to describe the phenotypic trends across years in live weight as well as FAT and EMD expressed relative to live weight for each breed by sex combination. These trends have been used to explore how mean growth rates between stages have changed across years and between breeds. The trends also demonstrate how body composition has also changed due to management and breeding decisions.

### 3.1.2 Information Nucleus Flock

Data including both phenotypic and genetic (ASBV) information was sourced from the Trangie and Cowra flocks within the Sheep CRC Information Nucleus Program (van der Werf et al. 2010). This information has been incorporated into the study in an attempt to find higher growth rates than those expressed in the phenotypic means taken from the LAMBPLAN database. The Trangie and Cowra flocks were identified from within the INF as flocks which achieved very high growth rates during the INF. This data has been analysed to describe growth rates within breed (BRDX in database) groupings (i.e. Merino matings, maternal matings (Border Leicester x Merino) or terminal matings (e.g. Poll Dorset x 1$^{st}$ cross ewe)). This analysis has been conducted across sexes. This data also allows individual animal growth rates at different points in time and over different lengths of time to be explored.

The modelling system (described below) used to explore the theoretical nutrient requirements of achieving realised growth rates in the LAMBPLAN data was also used to compare realised growth rates at different stages in the Cowra flock from the INF with expected growth rates when production conditions were non-limiting. In this instance the model was used to describe expected changes in growth rate as animals aged without estimation of nutrient requirements. This exercise was conducted in Merino and Terminal x Maternal lambs with the results displayed in Figures 5 and 6, respectively. Given growth rates were determined across sexes at different growth stages mature weight was estimated as an average of females and castrates. The mature size of Merinos (77 kg) was estimated from the Cowra INF data by multiplying the average adult ewe weight of animals born in 2007, 2008, 2009 and 2010 by 1.1 (average of mature size ratios for females and castrates; CSIRO 2007). The mature size of Terminal x Maternal animals (98 kg) was estimated by multiplying the average adult ewe weight of Maternal (1st cross) animals born in 2007, 2008, 2009 and 2010 by 1.1 (average of mature size ratios for females and castrates; CSIRO 2007) and then multiplying this value by 1.1 again to take account of the effect Terminal breeds have on mature size.

## 3.2 Theoretical Nutrient Requirements

Theoretical nutrient requirements (energy and protein) to realise the growth rates found in both the LAMBPLAN and INF data were explored using the growth modelling approach described by Amer and Emmans (1998). This modelling system predicts bodyweight as a function of the four chemical components; protein, fat, water and ash. Unconstrained growth of these components is expressed as a function of the degree of maturity of protein, represented by the following form of the Gompertz function:

$$u_t = \exp\left(-\exp\left(G_o - \left(B * t\right)\right)\right)$$

where $u_t$ is the degree of maturity of protein in the body, $t$ is time, $G_o$ is the initial condition and $B$ is the rate parameter scaled in metabolic time. The value assigned to the rate parameter was the interspecies value of 0.023 estimated by Emmans (1997) and used in sheep by Jones et al. (2004). A multiplier factor ($M_x$, takes a value between 0 and 1) was incorporated to adjust the rate parameter to achieve realised growth rates in non-limiting conditions.

The relationships between protein and the other chemical components are defined using allometric relationships, as detailed in Emmans (1988). The effective energy (EE) scale (Emmans 1994) is used for determining the quantity of energy required to achieve the growth rates calculated from the LAMBPLAN and INF datasets. This system includes estimation of maintenance requirements in proportion to mature protein scaled to 0.73 ($P_m^{0.73}$) following Brody's (1945) rule for scaling mature maintenance needs as well as the energy costs of protein and lipid deposition. The protein requirements to support this rate of growth have been incorporated by dividing protein deposition rate by the efficiency of using protein available to the small intestines for growth (0.7; CSIRO 2007) with maintenance needs being proportional to $P_m^{0.73}$. It is also assumed at this point that available protein supplies meet the amino acid needs for lean tissue deposition. The following equation is used to relate the metabolisable energy (ME) content of a diet to the EE content of the diet (Emmans 1994):

$$EE = 1.15ME - 3.84 - 4.67DCP \text{ (MJ/kg DM)}$$

where DCP is digestible crude protein percent of the diet. A standard diet of 10 MJ ME/kg DM, 140 g/kg DM crude protein and a DM digestibility of 72% was used to demonstrate the feed intake required to satisfy the estimated nutrient requirements.

The data obtained from the LAMBPLAN database are used to estimate mature weights for each breed and sex combination. For each stage of growth (weaning to postweaning, postweaning to yearling), weight at the beginning of that stage and realised growth rate are used to estimate energy and protein requirements. These estimated requirements will be used to demonstrate how nutrient supply has needed to change to support the change in rate of growth and body composition that have occurred over the last 20-25 years.

A hypothetical exercise was undertaken based on the live weight trends modelled from the LAMBPLAN data. In the Suffolk and Poll Dorset breeds trends found in ram weaning, postweaning and yearling live weights were used to extrapolate live weight at each stage to the year 2030. This information was used to estimate growth rates required between stages to realise such live weights and in turn the nutrients required to achieve this performance. This exercise was extended to examine the nutritional requirements of anecdotal postweaning growth rates in excess of 400 g/day reported from within the Australian lamb industry. The nutrient requirements to achieve the highest postweaning growth rate in the Trangie and Cowra flocks of the INF were evaluated against modelled estimates. The highest postweaning growth found in the Trangie and Cowra flocks of the INF was achieved by a Terminal x Maternal ram lamb. In order to conduct the theoretical nutrient modelling the mature weight (132 kg) of this animal was estimated from the Cowra INF data by multiplying the maximum recorded adult ewe weight of Maternal ($1^{st}$ cross) animals born in 2007, 2008, 2009 and 2010 by 1.2 (mature size of castrates compared to ewes; CSIRO 2007) and then multiplying this value by 1.1 to take account of the effect Terminal breeds have on mature size.

In order to add real world utility to this exercise all estimates of nutrient requirements were expressed relative to three defined diets that are commonly found in southern Australian sheep production systems. These diets were based on: 1) an improved pasture system, 2) a highly productive ryegrass and white clover mixed pasture, and 3) a high energy feedlot ration. The assumed nutrient composition of each diet is given in Table 1.

**Table 1:** The assumed nutrient composition of 1) an improved pasture, 2) a highly productive ryegrass and white clover mixed pasture, and 3) a high energy feedlot ration.

| Diet Composition | Diet | | |
|---|---|---|---|
| | Improved Pasture | Ryegrass/ White Clover | Feedlot Ration |
| Dry Matter (%) | 37.0 | 22.0 | 88.7 |
| DM Digestibility (%) | 68.0 | 76.0 | 80.3 |
| Metabolisable energy (MJ/kg DM) | 9.5 | 11.0 | 12.5 |
| Crude protein (% DM) | 12.0 | 15.0 | 15.0 |

# 4 Results

## 4.1 Phenotypic Data

### 4.1.1 LAMBPLAN

The average phenotypic trends between 1990 and 2010 for postweaning and yearling live weight in Merino, Suffolk and Poll Dorset rams and ewes are demonstrated in Figures 1 and 2, respectively. Both figures also demonstrate the postweaning and yearling phenotypic trends in FAT and EMD expressed relative to live weight between 1990 and 2010 (where available) for these breeds.

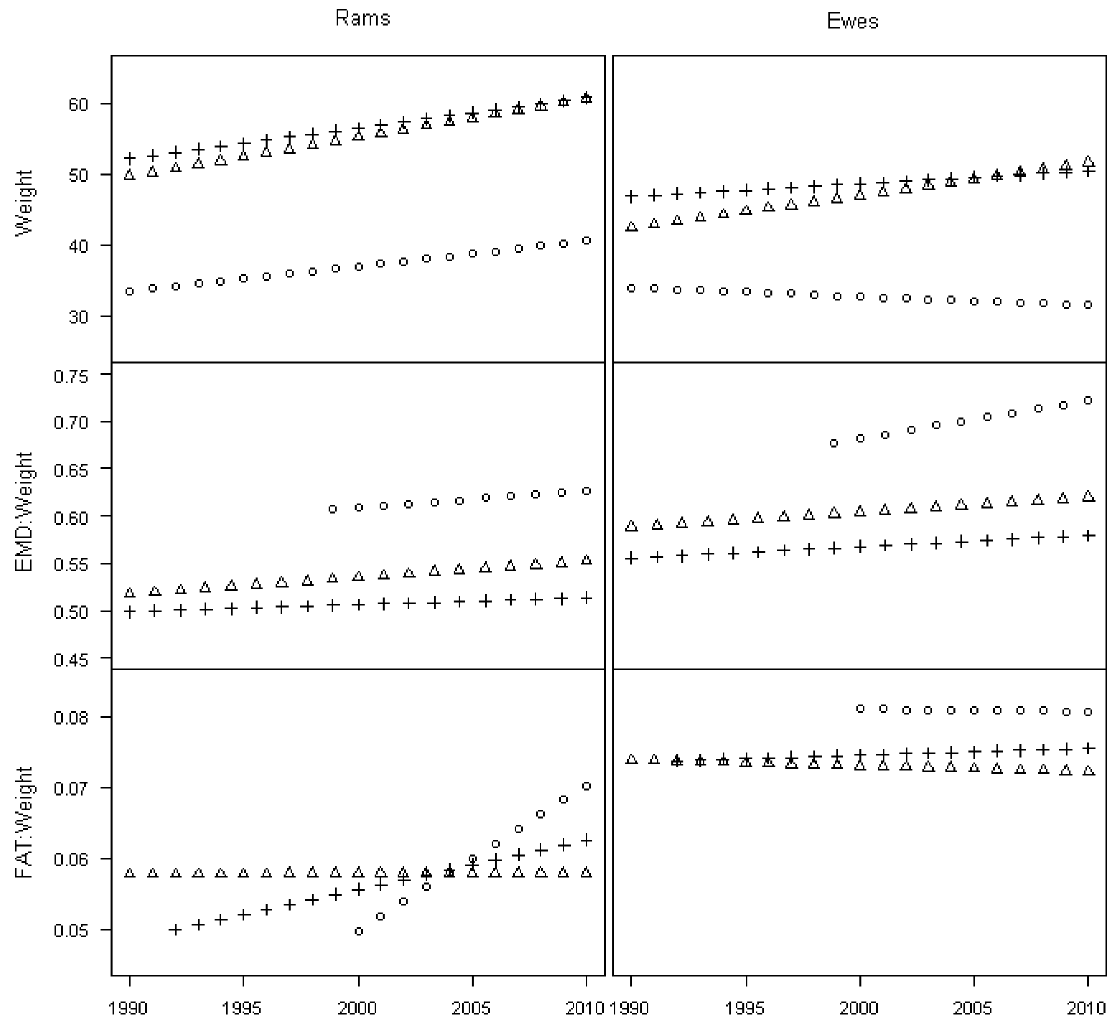


**Figure 1:** Postweaning phenotypic trends in live weight in conjunction with EMD and FAT expressed relative to live weight taken from the LAMBPLAN database for Merino (o), Suffolk (+) and Poll Dorset (Δ) rams and ewes between 1990 and 2010.

The phenotypic trends in Figure 1 for Merinos, Suffolk's and Poll Dorset's demonstrate that in rams of all breeds postweaning live weight has increased between 1990 and 2010 while increases have occurred in Poll Dorset and Suffolk ewes and a decrease has occurred in Merino ewes. During the same period the ratio of EMD to live weight has generally increased in both sexes for all breeds although this increase is not as evident in some breed x sex combinations as others. The trends in FAT relative to live weight have been much more variable between 1990 and 2010. The trends in Poll Dorset rams and Suffolk ewes have been relatively static during this period. A strong upward trend has occurred in both Merino and Suffolk rams particularly Merino rams while a downward trend is evident in both Poll Dorset and Merinos ewes.

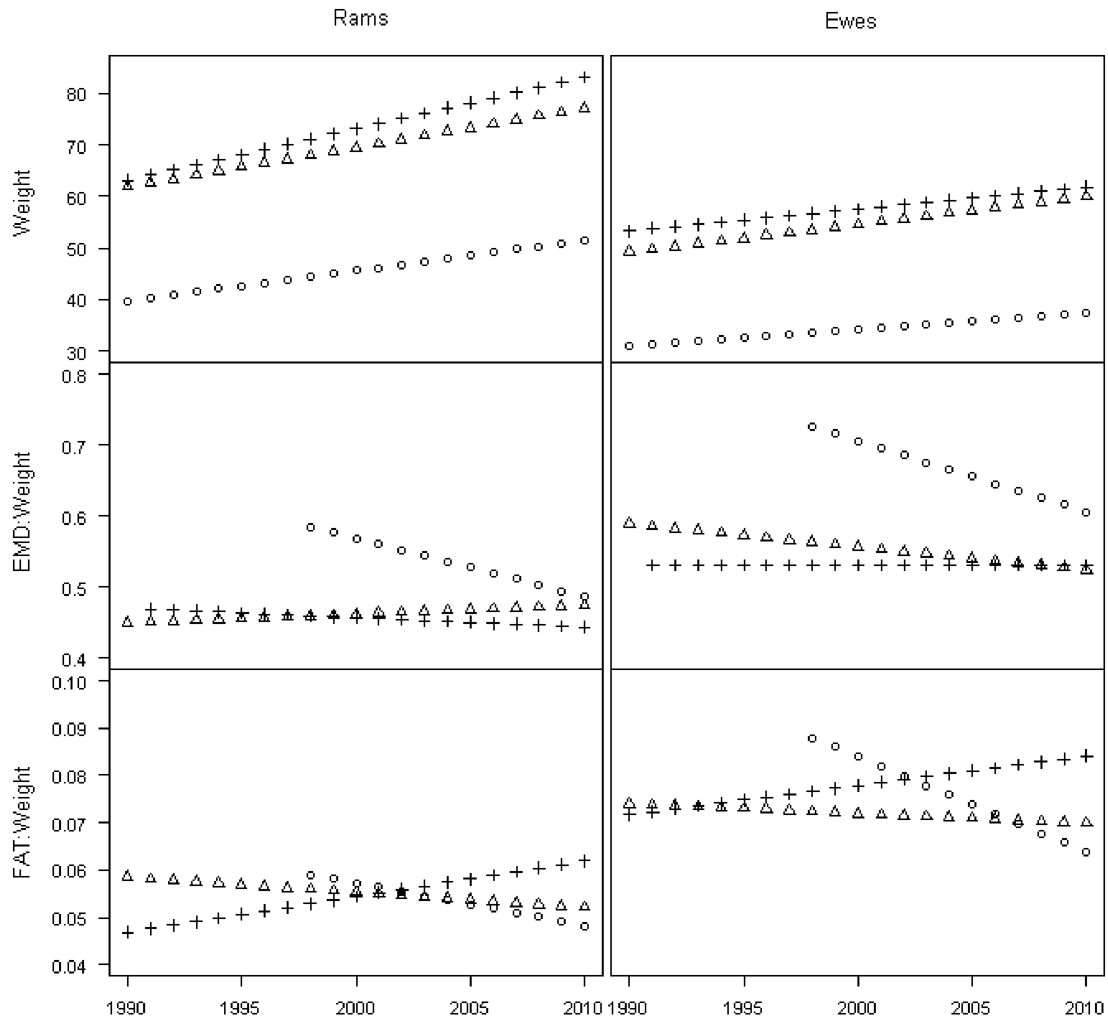


**Figure 2:** Yearling phenotypic trends in live weight in conjunction with EMD and FAT expressed relative to live weight taken from the LAMBPLAN database for Merino (o), Suffolk (+) and Poll Dorset (Δ) rams and ewes between 1990 and 2010.

The phenotypic trends in Figure 2 for Merinos, Suffolk's and Poll Dorset's demonstrate that between 1990 and 2010 yearling live weight has increased in both sexes for all three breeds which supports the trends seen in postweaning live weight presented in Figure 1. The trends in EMD and fat elative to live weight in Figure 2 contrast with those in Figure 1. There has generally been a decrease in EMD relative to live weight all breeds and sexes with a slight upward trend occurring in Poll Dorset rams and a static trend in Suffolk ewes. Fat relative to live weight has trended down in both Merino and Poll Dorset rams and ewes while upward trends have been evident in Suffolk rams and ewes. The strong downward trends in the Merino breed in particular for EMA and FAT ratios maybe a consequence of inadequate nutrition during the period after postweaning prior to yearling measurements being recorded.

The realised rates of growth from weaning to postweaning and postweaning to yearling from the LAMBPLAN data for each breed by sex combination for 1990, 2000 and 2010 are summarised in Tables 2 and 3.

**Table 2:** Realised growth rates (g/day) of rams from the LAMBPLAN database for the weaning to postweaning and postweaning to yearling periods of Merino, Border Leicester, Poll Dorset, Texel, Suffolk and White Suffolk breeds for 1990, 2000 and 2010.

| Breed | Stage | Year | | |
|---|---|---|---|---|
| | | 1990 | 2000 | 2010 |
| Merino | W to PW | 77 | 84 | 92 |
| | PW to Y | 45 | 62 | 78 |
| Border Leicester | W to PW | 102 | 106 | 111 |
| | PW to Y | 106 | 101 | 95 |
| Poll Dorset | W to PW | 120 | 146 | 173 |
| | PW to Y | 87 | 103 | 118 |
| Texel | W to PW | 119 | 114 | 109 |
| | PW to Y | 69 | 93 | 117 |
| Suffolk | W to PW | 94 | 130 | 166 |
| | PW to Y | 78 | 119 | 160 |
| White Suffolk | W to PW | 107 | 128 | 148 |
| | PW to Y | 67 | 101 | 134 |

In 1990, the mean growth rate of rams between weaning and postweaning was less than 125 g/day for all breeds with Merinos only achieving 77 g/day (Table 2). Ram growth rates between postweaning and yearling stages were less than 110 g/day in all breeds with Merinos only achieving 45 g/day. In 2010, mean growth rates for these two stages generally increased in all breeds with the highest growth rate being 173 g/day during the weaning to postweaning period in Poll Dorset's. However, Border Leicester growth rates decreased during the postweaning to yearling period from 106 g/day in 1990 to 95 g/day in 2010. The weaning to postweaning growth rate of Texel's also decreased from 119 g/day in 1990 to 109 g/day in 2010.

**Table 3:** Realised rates of growth (g/day) in ewes from the LAMBPLAN database for the weaning to postweaning and postweaning to yearling periods of Merino, Border Leicester, Poll Dorset, Texel, Suffolk and White Suffolk breeds for 1990, 2000, and 2010.

| Breed | Stage | Year | | |
|---|---|---|---|---|
| | | 1990 | 2000 | 2010 |
| Merino | W to PW | 98 | 71 | 44 |
| | PW to Y | -20 | 11 | 43 |
| Border Leicester | W to PW | 62 | 70 | 78 |
| | PW to Y | 65 | 64 | 64 |
| Poll Dorset | W to PW | 88 | 106 | 124 |
| | PW to Y | 49 | 54 | 60 |
| Texel | W to PW | 85 | 82 | 79 |
| | PW to Y | 44 | 59 | 73 |
| Suffolk | W to PW | 84 | 99 | 114 |
| | PW to Y | 47 | 64 | 82 |
| White Suffolk | W to PW | 80 | 92 | 104 |
| | PW to Y | 28 | 53 | 79 |

In 1990, the mean growth rate of ewes between weaning and postweaning was less than 100 g/day for all breeds with Border Leicesters only achieving 62 g/day (Table 3). Ewe growth rates between postweaning and yearling stages were less than 65 g/day in all breeds. In 2010, mean growth rates for these two stages varied between breeds with the highest growth rate being 124 g/day during the weaning to postweaning period in Poll Dorsets. Border Leicester growth rates remained relatively unchanged during the postweaning to yearling period between 1990 and 2010 (~ 64 g/day). The weaning to postweaning growth rate of Merinos decreased from 98 g/day in 1990 to 44 g/day in 2010.

### 4.1.2 Information Nucleus Flock

The realised growth rates from the INF data are expressed within breed (BRDX) groupings (e.g. Merino, maternal and terminal matings) as a comparison to the information retrieved from the LAMBPLAN database. Analysis of individual animal growth rates revealed individuals were capable of expressing growth rates up to and in excess of 680 g/day over short intervals (e.g. 20 days) (Figure 3). This analysis also revealed the same animals expressed low growth rates (100 g/day) and even negative growth rates (-133 g/day) over similarly short intervals (6 - 16 days). This variation in growth rate during the postweaning period as demonstrated in Figure 3 is typical of that seen throughout both the Cowra and Trangie datasets. The animal depicted in Figure 3 expressed an average growth rate of 336 g/day over the whole postweaning period (119 days) which was higher than those found in the Suffolk and Poll Dorset LAMBPLAN data. The highest growth rate found during the whole postweaning period was 416 g/day for a Terminal x Maternal ram lamb born in 2010 in the Trangie flock.

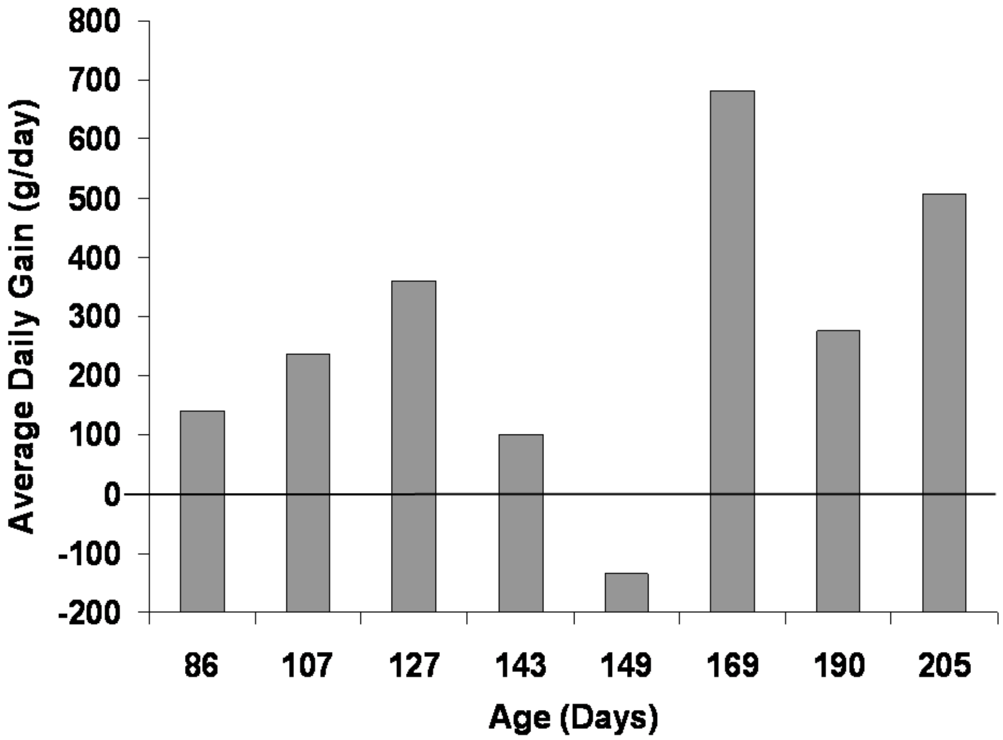


**Figure 3:** Variation in realised growth rates between the weaning (86 days of age) and postweaning (107 to 205 days of age) stages for an individual animal born in 2008 from the Trangie flock in the INF.

Realised postweaning growth performance of lambs in the Cowra and Trangie flocks were compared to their genetic potential represented by weaning weight ASBV. Caution needs to be used when interpreting these relationships as the live weights plotted against weaning weight ASBV were included in the LAMBPLAN analysis that generated the ASBVs. However, Figure 4 demonstrates that a positive relationship exists between weaning weight ASBV and postweaning weight measured at approximately 150 days of age in both Merino and Terminal x Maternal lambs. The regression coefficients were 2.13 and 3.00 ($P$<0.001) for the Merino and Terminal x Maternal lambs, respectively indicating that those lambs with higher weaning weight ASBVs were achieving higher weights at the postweaning stage. The $R^2$ values of the regressions between weaning weight ASBV and postweaning weight were 0.40 and 0.34 for Merino and Terminal x Maternal lambs, respectively.

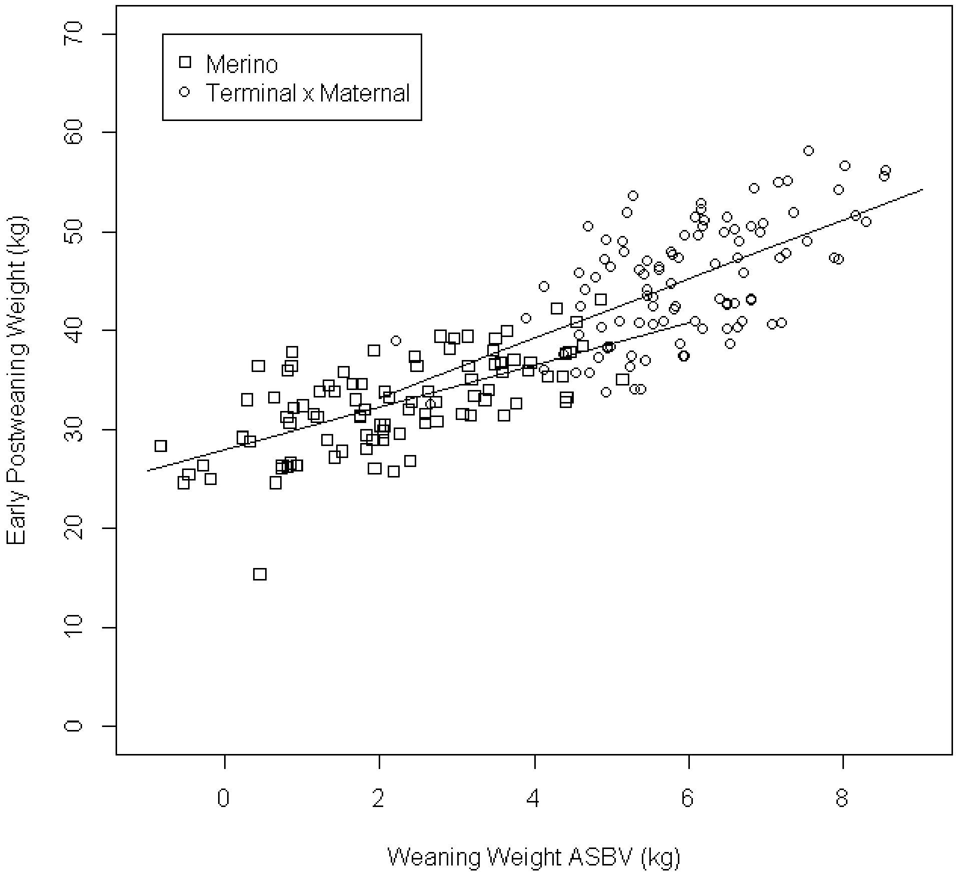


**Figure 4:** Relationship between weaning weight ASBV and early postweaning weight (~150 days of age) for Merino and Terminal x Maternal lambs born in 2010 from the Cowra site in the INF.

Figure 4 suggests the relationships between ASBV and postweaning live weights are as would be expected. This was explored further by comparing realised postweaning growth rates with growth rates that would be expected based on growth modelling in non-limiting conditions. **This comparison suggested lambs in the INF were not realising their full growth potential.** A comparison is shown between expected and realised growth rates of Merino lambs born in 2010 from the Cowra flock of the INF in Figure 5. The average growth rate to weaning (94 days) agrees with that expected in non-limiting conditions, however following weaning the mean growth rate is on average lower than the expected growth rate at all time points up to 300 days of age. Large variation in growth rate exists between time points as animal's age, and most importantly there are substantial short falls in actual growth compared to that expected based on the theoretical growth curve for that breed when nutrient supply matches requirements.

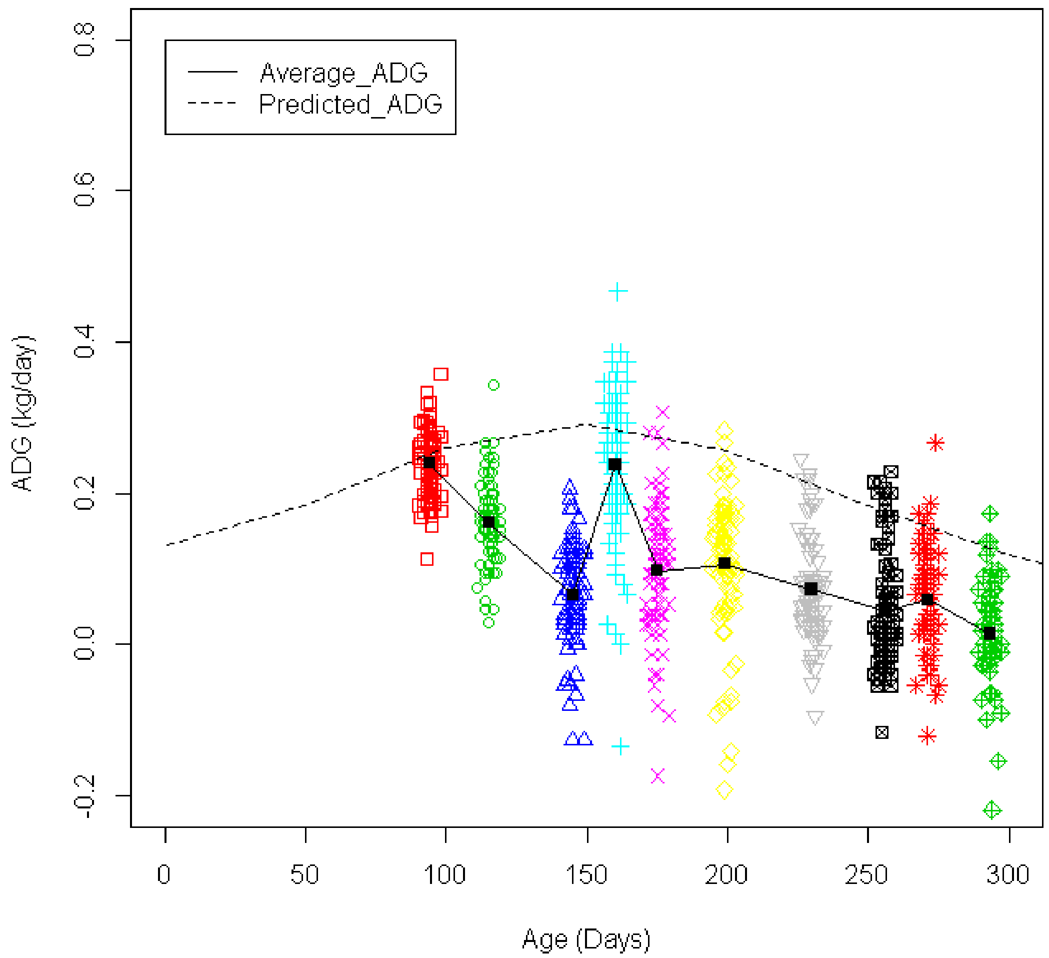


**Figure 5:** Realised average daily gain of Merino lambs born in 2010 between 94 and 293 days of age from the Cowra site of the INF in comparison to projected daily growth rates (dashed line) modelled when nutrition is non-limiting.

A similar pattern is evident in Figure 6 for Terminal x Maternal lambs born in 2010 from the Cowra flock of the INF. Again the average growth rate to weaning (97 days) agrees with that expected in non-limiting conditions and the mean growth rate following weaning is lower than the expected growth rate at all time points up to 230 days of age.

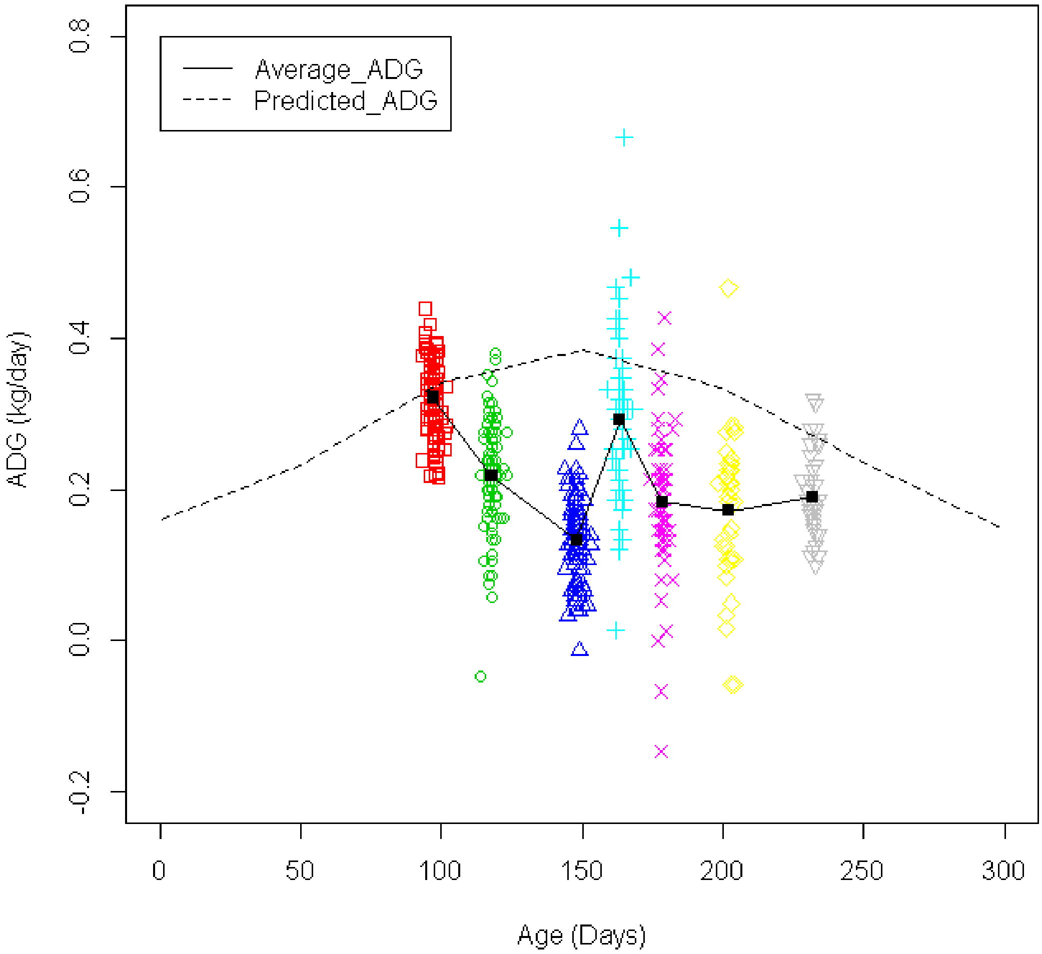


**Figure 6:** Realised average daily gain of Terminal x Maternal lambs born in 2010 between 97 and 232 days of age from the Cowra site of the INF in comparison to projected daily growth rates (dashed line) modelled when nutrition is non-limiting.

## 4.2 Theoretical Nutrient Requirements

LAMBPLAN data from Merino, Border Leicester, Poll Dorset, Texel, Suffolk and White Suffolk breeds was used to estimate theoretical nutrient requirements for the growth rates reported above (Tables 2 and 3). The nutrient requirements of only Poll Dorset's and Suffolk's are presented given these breeds were found to have the highest growth rates during the weaning to postweaning and postweaning to yearling growth stages, respectively. Data from all breed groupings in the INF database were also used to estimate theoretical nutrient requirements for achieving realised growth rates. The highest growth rates during the weaning to postweaning stage of growth were found in rams in the Terminal x Maternal grouping. The lamb with the highest growth rate between the weaning and postweaning stages in 2010 from the Trangie flock was used to illustrate nutrient requirements to achieve the highest growth seen in the Cowra/Trangie flocks of the INF. Unfortunately this animal did not have any live weight measurements taken between the postweaning and yearling stages and thus no nutritional requirements can be presented for this period. As an exercise the nutrient requirements to express predicted growth rates when the multiplier factor

($M_x$) was given a value of 1 are also tested. These nutrient requirements are presented in Table 4.

**Table 4:** Estimated energy (MJ EE/day) and protein (g DCP/day) requirements to achieve realised rates of growth found in the LAMBPLAN data for the weaning to postweaning and postweaning to yearling periods of Poll Dorset's in 1990, 2000 and 2010.

| | | Year | | | |
|---|---|---|---|---|---|
| Sex | Stage | 1990 | 2000 | 2010 | 2010 ($M_x$=1) |
| Energy (MJ EE/day) | | | | | |
| Ram | W to PW | 10.57 | 11.76 | 12.88 | 17.53 |
| | PW to Y | 11.19 | 12.41 | 13.59 | 16.20 |
| Ewe | W to PW | 9.01 | 10.01 | 11.05 | 13.53 |
| | PW to Y | 8.65 | 9.40 | 10.13 | 11.46 |
| Protein (g DCP/day) | | | | | |
| Ram | W to PW | 32.78 | 38.83 | 45.16 | 61.08 |
| | PW to Y | 28.28 | 32.04 | 35.69 | 43.32 |
| Ewe | W to PW | 25.70 | 29.21 | 32.72 | 40.17 |
| | PW to Y | 20.90 | 22.70 | 24.46 | 28.02 |
| Standard Diet (kg DM/day) | | | | | |
| Ram | W to PW | 1.47 | 1.64 | 1.79 | 2.44 |
| | PW to Y | 1.56 | 1.73 | 1.89 | 2.25 |
| Ewe | W to PW | 1.25 | 1.40 | 1.54 | 1.88 |
| | PW to Y | 1.20 | 1.31 | 1.41 | 1.59 |

In order to obtain the data presented in Table 4 for the realised growth rates in the Poll Dorset LAMBPLAN data the multiplier factor ($M_x$) used to restrict expression of the base rate parameter ($B$) was within the range 0.4-0.6. These results demonstrate that the increases in growth rate in Poll Dorset's between 1990, 2000 and 2010 for the weaning to postweaning and postweaning to yearling stages have increased the requirements for both energy and protein. The percentage increases in requirements have generally been higher for protein and for rams. The protein requirement in rams for the weaning to postweaning stage increased 18.5% between 1990 and 2000 with a further 16.3% increase between 2000 and 2010. Over the same period ewe protein requirements increased 13.3% and 12.0%, respectively. The corresponding changes in energy requirements in rams were 11.3% between 1990 and 2000 and 9.5% between 2000 and 2010. In ewes these changes were 11.1% and 10.4%, respectively. The percentage changes in nutrient requirements for the postweaning to yearling stage have been lower than those seen in the weaning to postweaning period but follow the same general pattern. When the base rate parameter is expressed fully, (i.e. $M_x$ = 1) for the 2010 data, nutrient requirements need to be higher to achieve such performance. To realise this level of performance for rams, energy and protein requirements would increase by 26-27% during the weaning to postweaning period and by 16-17% during the postweaning to yearling period. The corresponding increase for ewes would be 18-19% and 12-13%, respectively. The percentage increases in feed intake of the standard diet parallel the percentage increases in energy demand indicating energy demand drives feed intake.

The theoretical nutrient requirements for the growth rates realised in the Poll Dorset LAMBPLAN data (Table 4) have been transformed to feed intakes required to achieve this performance (Table 5) of three diets differing in nutrient densities which have been described in Table 1. As a test against reality these predicted intakes were compared to those presented for growing sheep in the updated Australian feeding standards for ruminant animals (CSIRO 2007). As an example in 1990 Poll Dorset and Suffolk rams were estimated to have mature weights of approximately 70 kg, their respective weaning weights were 35 kg and 40 kg and their predicted intakes of an improved pasture with a digestibility of 68% are 1.58 kg (Table 5) and 1.54 kg (Table 7). The feed intake of a growing sheep estimated in Table 6.3 of the updated Australian feeding standards for ruminant animals (CSIRO 2007) with a mature weight of 70 kg, weighing 40 kg and eating a diet with a digestibility of 70% is 1.56 kg.

These results demonstrate that the increases in nutrient demand in Poll Dorset's have as expected increased the feed intake required to achieve the realised performance. Irrespective of the diet considered the percentage increase in feed intake required to achieve the realised changes in growth rate are identical between 1990 and 2000 and between 2000 and 2010. The percentage changes are in strong agreement with the percentage changes in demand for energy seen above in Table 4. For example the percentage increase in feed intake for the weaning to postweaning period seen in Poll Dorset rams is 11.3% similar to that seen for energy demands in Table 4. These findings indicate all three diets presented in Table 1 are not protein limiting but rather energy demand is the driving force behind intake of these diets, as evident for the standard diet in Table 4.

**Table 5:** Daily intake (kg DM/day) of different diets required to realise rates of growth found in the LAMBPLAN data for the weaning to postweaning and postweaning to yearling periods of Poll Dorset's in 1990, 2000 and 2010.

| | | Year | | | |
|---|---|---|---|---|---|
| Sex | Stage | 1990 | 2000 | 2010 | 2010 ($M_x$=1) |
| Improved Pasture | | | | | |
| Ram | W to PW | 1.58 | 1.75 | 1.92 | 2.61 |
| | PW to Y | 1.67 | 1.85 | 2.03 | 2.42 |
| Ewe | W to PW | 1.34 | 1.50 | 1.65 | 2.02 |
| | PW to Y | 1.29 | 1.40 | 1.51 | 1.71 |
| Ryegrass/White Clover | | | | | |
| Ram | W to PW | 1.28 | 1.42 | 1.56 | 2.12 |
| | PW to Y | 1.35 | 1.50 | 1.64 | 1.96 |
| Ewe | W to PW | 1.09 | 1.21 | 1.34 | 1.63 |
| | PW to Y | 1.05 | 1.14 | 1.22 | 1.38 |
| Feedlot Ration | | | | | |
| Ram | W to PW | 1.06 | 1.18 | 1.29 | 1.76 |
| | PW to Y | 1.12 | 1.24 | 1.36 | 1.62 |
| Ewe | W to PW | 0.90 | 1.01 | 1.11 | 1.36 |
| | PW to Y | 0.87 | 0.94 | 1.02 | 1.15 |

The data presented in Table 6 for realised growth rates in the Suffolk LAMBPLAN data were obtained by setting the multiplier factor generally within the range 0.45-0.65. The results demonstrate that increases in growth rate in Suffolk's between 1990, 2000 and 2010 have also increased the requirements for both energy and protein. Results for Suffolk's support those for Poll Dorset's with percentage increases in requirements generally being higher for protein and for rams. Protein requirements in rams for the weaning to post weaning stage have increased 29.1% between 1990 and 2000 with a further 25.7% between 2000 and 2010. During the same period protein requirements of ewes increased 11.9% and 11.1%, respectively. The corresponding changes in energy requirements in rams were 11.5% between

1990 and 2000 and 7.9% between 2000 and 2010. In ewes these changes were 6.0% and 5.3%, respectively. Again the percentage increases in feed intake of the standard diet parallel the percentage increases in energy demand.

**Table 6:** Theoretical energy (MJ EE/day) and protein (g DCP/day) requirements to achieve realised rates of growth found in the LAMBPLAN data for the weaning to postweaning and postweaning to yearling periods of Suffolk's in 1990, 2000 and 2010.

| | | Year | | | |
|---|---|---|---|---|---|
| Sex | Stage | 1990 | 2000 | 2010 | 2010 ($M_x$=1) |
| Energy (MJ EE/day) | | | | | |
| Rams | W to PW | 10.34 | 11.53 | 12.44 | 18.78 |
| | PW to Y | 11.09 | 13.30 | 15.35 | 18.19 |
| Ewes | W to PW | 9.48 | 10.05 | 10.58 | 13.81 |
| | PW to Y | 9.02 | 10.03 | 11.02 | 12.03 |
| Protein (g DCP/day) | | | | | |
| Rams | W to PW | 28.24 | 36.46 | 45.83 | 69.00 |
| | PW to Y | 26.82 | 34.61 | 43.20 | 50.50 |
| Ewes | W to PW | 25.39 | 28.40 | 31.56 | 41.55 |
| | PW to Y | 21.29 | 24.30 | 27.36 | 30.08 |
| Standard Diet (kg DM/day) | | | | | |
| Rams | W to PW | 1.44 | 1.60 | 1.73 | 2.61 |
| | PW to Y | 1.54 | 1.85 | 2.14 | 2.53 |
| Ewes | W to PW | 1.32 | 1.40 | 1.47 | 1.92 |
| | PW to Y | 1.25 | 1.40 | 1.53 | 1.67 |

In contrast to the Poll Dorset results, increases in nutrient requirements between 1990 and 2000 and also between 2000 and 2010 for the postweaning to yearling stage were higher in most instances than those seen for the weaning to postweaning stage (Table 6). Energy requirements of rams increased 19.9% between 1990 and 2000 and a further increase of 15.4% was seen between 2000 and 2010. The corresponding increases in energy requirements in ewes were 11.2% and 9.9%, respectively. The increases in protein requirements for ewes were 14.1% between 1990 and 2000 and 12.6% between 2000 and 2010. The corresponding increases for rams were 29.0% and 24.8%, respectively, which were lower than the increases seen for the weaning to postweaning stage. When the base rate parameter was fully expressed for the 2010 Suffolk data nutrient requirements increased which supports the results seen in Poll Dorset's. To realise this level of performance for ram's energy and protein requirements would increase by 33-34% during the weaning to postweaning period and by 14-16% during the postweaning to yearling period. The corresponding increases for ewes would be 23-25% and 8-10%.

Table 7 presents the feed intakes required to satisfy the theoretical nutrient requirements of the realised growth rates in the Suffolk LAMBPLAN data shown in Table 6. These results support those shown in Table 5 for Poll Dorsets in that the percentage increases in feed intake irrespective of which diet is considered are similar to the percentage increases in energy demand thus suggesting these diets are not protein limiting but rather energy demand is driving feed intake.

**Table 7:** Daily intake (kg DM/day) of different diets to realise rates of growth found in the LAMBPLAN data for the weaning to postweaning and postweaning to yearling periods of Suffolk's in 1990, 2000 and 2010.

| | | Year | | | |
|---|---|---|---|---|---|
| Sex | Stage | 1990 | 2000 | 2010 | 2010 ($M_x$=1) |
| Improved Pasture | | | | | |
| Ram | W to PW | 1.54 | 1.72 | 1.86 | 2.80 |
| | PW to Y | 1.65 | 1.98 | 2.29 | 2.71 |
| Ewe | W to PW | 1.41 | 1.50 | 1.58 | 2.06 |
| | PW to Y | 1.35 | 1.50 | 1.64 | 1.79 |
| Ryegrass/White Clover | | | | | |
| Ram | W to PW | 1.25 | 1.39 | 1.50 | 2.27 |
| | PW to Y | 1.34 | 1.61 | 1.85 | 2.20 |
| Ewe | W to PW | 1.14 | 1.21 | 1.28 | 1.67 |
| | PW to Y | 1.09 | 1.21 | 1.33 | 1.45 |
| Feedlot Ration | | | | | |
| Ram | W to PW | 1.04 | 1.16 | 1.25 | 1.88 |
| | PW to Y | 1.11 | 1.33 | 1.54 | 1.82 |
| Ewe | W to PW | 0.95 | 1.01 | 1.06 | 1.39 |
| | PW to Y | 0.90 | 1.01 | 1.11 | 1.21 |

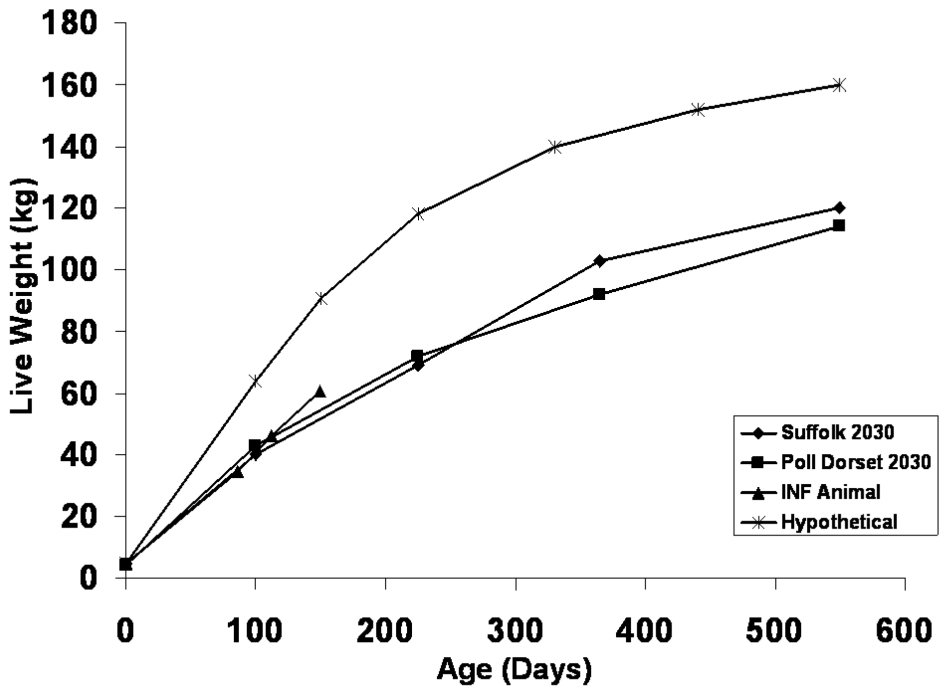


**Figure 7:** Projected growth patterns of Suffolk and Poll Dorset in 2030 in comparison to a hypothetical animal displaying average growth rates in excess of 400 grams per day postweaning and the animal with the highest average daily gain during the postweaning period of the Trangie and Cowra flocks from the INF.

The projected growth patterns of Suffolk and Poll Dorset animals in 2030 are demonstrated in Figure 7 in comparison to the animal with the highest postweaning growth rate in the Trangie and Cowra flocks in the INF. The animal from the INF expressed growth rates approximately equivalent to or better than those projected for the Suffolk and Poll Dorset breeds in 2030. Also presented in Figure 7 is the growth pattern of a hypothetical animal that had growth rates in excess of 500 g/day up to 150 days of age and greater than 400 g/day up to 225 days of age.

**Table 8:** Theoretical energy (MJ EE/day) and protein (g DCP/day) requirements to achieve projected rates of growth for the weaning to postweaning and postweaning to yearling stages in 2030 based on Poll Dorset and Suffolk trends extracted from LAMBPLAN data. These results are compared to a hypothetical animal which displays average growth rates in excess of 400 grams per day postweaning and the animal with the highest average daily gain during the postweaning period of the Trangie and Cowra flocks from the INF.

| | | Scenario | | | |
|---|---|---|---|---|---|
| Trait | Stage | INF | Poll Dorset | Suffolk | Hypothetical |
| ADG (g/day) | | | | | |
| | W to PW | 415.87 | 232.00 | 232.00 | 432.00 |
| | PW to Y | - | 142.86 | 242.86 | 209.52 |
| Energy (MJ EE/day) | | | | | |
| | W to PW | 17.37 | 15.30 | 14.50 | 25.82 |
| | PW to Y | - | 15.73 | 19.67 | 22.45 |
| Protein (g DCP/day) | | | | | |
| | W to PW | 102.59 | 58.42 | 60.45 | 99.43 |
| | PW to Y | - | 42.44 | 56.87 | 57.85 |
| Standard Diet (kg DM/day) | | | | | |
| | W to PW | 2.61 | 2.13 | 2.02 | 3.59 |
| | PW to Y | - | 2.19 | 2.74 | 3.12 |

The theoretical nutrient requirements to achieve the levels of production in Figure 7 are shown in Table 8. Energy requirements are projected to increase 15-19% in Poll Dorsets between 2010 and 2030 with protein requirements increasing 18-30%. The corresponding increases in energy and protein requirements for Suffolk's between 2010 and 2030 are 16-29% and 31-32%. These predictions support Tables 4 and 6 in that the percentage increases in feed intake of the standard diet parallel the percentage increases in energy demand. The nutrient requirements of the theoretical animal are between 64-78% higher than those of Suffolks and Poll Dorsets during the weaning to postweaning stage and 2-42% higher during the postweaning to yearling stage. The fastest growing animal in the Cowra and Trangie flocks required energy and protein supplies in excess of those predicted for the Suffolk and Poll Dorset breeds in 2030. Also of interest is the prediction that the fastest growing animal from the INF required higher dietary protein but lower dietary of energy than the hypothetical animal even though their average daily growth rates were not substantially different. These differences in requirement are explained by the differences in animal maturity when these growth rates were achieved. The hypothetical animal weighed 64 kg and was 40% mature at weaning (mature weight = 160 kg) while the fastest growing INF animal weighed 34.6 kg and was 27% mature at weaning (mature weight = 132 kg). These differences in maturity are associated with differences in growth priority and partitioning of nutrients. The hypothetical animal was in a growth phase where priorities are shifting to fat deposition and therefore more energy demanding while the fastest growing INF animal was still in the phase of growth where protein deposition has higher priority and thus more protein demanding.

Table 9 presents the feed intakes required to satisfy the theoretical nutrient requirements of projected growth patterns of Suffolk and Poll Dorset animals in 2030 in comparison to the animal with the highest postweaning growth rate in the Trangie and Cowra flocks in the INF. These results support those shown in Tables 5 and 6 for Poll Dorsets and Suffolks in that again the percentage increases in feed intake irrespective of which diet is considered are similar to the percentage increases in energy demand thus suggesting these diets would not be protein limiting and that energy demand drives feed intake. Also presented is the feed intake required for an animal to grow at rates in excess of 500 g/day up to 150 days of age and greater than 400 g/day up to 225 days of age. Once again the diets are not protein limiting and feed intake would be driven by energy demands. However, one point highlighted by the predicted feed intake of the hypothetical animal is that these intakes maybe beyond those considered possible for animals in current production systems particularly if pasture quality was not as high as those assumed in Table 1 (i.e. DM digestibility =50% and ME = 7.5 MJ/kg DM) which would restrict intake due to rumen fill constraints.

**Table 9:** Daily intake (kg/day) of different diets to achieve projected rates of growth for the weaning to postweaning and postweaning to yearling stages in 2030 based on Poll Dorset and Suffolk trends extracted from LAMBPLAN data. These results are compared to a hypothetical animal which displays average postweaning growth rates in excess of 400 grams per day and the animal found to have the highest average daily gain during the postweaning period of the Trangie and Cowra flocks from the INF.

| | | Scenario | | | |
|---|---|---|---|---|---|
| Diet | Stage | INF | Poll Dorset | Suffolk | Hypothetical |
| Improved Pasture | | | | | |
| | W to PW | 2.76 | 2.28 | 2.16 | 3.85 |
| | PW to Y | - | 2.35 | 2.93 | 3.35 |
| Ryegrass/White Clover | | | | | |
| | W to PW | 2.33 | 1.85 | 1.75 | 3.12 |
| | PW to Y | - | 1.90 | 2.38 | 2.71 |
| Feedlot Ration | | | | | |
| | W to PW | 1.91 | 1.53 | 1.45 | 2.59 |
| | PW to Y | - | 1.58 | 1.97 | 2.25 |

## 4.3 Comparison with studies of lambs finished in feedlots or on predominantly grain based diets.

Discussions with Alex Ball concerning the findings above highlighted the need to obtain data from animals with known breeding values finished in feedlots or on grain based diets (on the assumption that nutrient limitation would be reduced). A number of industry people were approached who were likely to have access to such data. These included San Jolly of Productive Nutrition and Tom Bull of LambPro. These industry people did not have access to appropriate data. Dr Andrew Thompson of DAFWA / Murdoch University and Nick Linden of DPIVic were subsequently approached. Direct access to data was unable to be obtained but these people were able to confirm that:

a) When fed grain, lambs with higher ASBV's for growth generally grew faster than contemporaries with low ASBVs for growth,

b) There was considerable variation in performance within and between studies and

c) The growth rates of lambs on grain based diets were generally in the range of 200-250g/d.

(Dr Andrew Thompson – pers comm., October 2012, Nick Linden pers. comm. November 2012.)

By contrast, a recent study (Haynes et al, 2012) used terminal cross lambs that were the progeny of Border Leicester cross Merino ewes mated to White Suffolk or Poll Dorset sires. These lambs were 5 months of age, weighed 40.1 (± 3.8 s.e.) kg and grew at 292 (± 5.7 s.e.) g/day for a period of 49 days when consuming 1.8 * maintenance of a pelleted diet (12 MJ ME/kg DM and 191 g CP/kg DM). The *ad-libitum* intake of this diet was not recorded, but it is anticipated it would of been approximately 10-20% above that of the 1.8 * maintenance diet offered.

These results indicate there is not yet sufficient data to comprehensively determine the extent to which lambs of high growth ASBVs meet their potential on high grain diets. They do however suggest that increasing intake of a high quality diet in a controlled environment can lead to growth rates closer to those anticipated but the variation in performance in the studies of Andrew Thompson (pers. Comm.) and Nick Linden (pers. Comm.) suggest that factors other than availability and quality of feed affect intake and growth of lambs. In particular, lambs are more difficult to introduce to high grain/energy diets than cattle and seemed to respond by increasing variability in feed intake.

The post weaning gains of 2$^{nd}$ cross lambs recorded in the Sheep CRC INF flock are comparable to those recorded in industry flocks. For example, during the course of the Sheep Genomics program worked was conducted with John Keilor (a lamb producer in South West Victoria) to evaluate the effects of gene markers for muscling on lamb carcass composition. The lambs used in that study were managed under industry best practice conditions and gained on average 135 (±30 SD) g/day (n=348) from scanning to slaughter (between 34 and 52 kg).

# 5 Discussion

Analysis of the LAMBPLAN data clearly demonstrates that in terminal breeds of sheep and Merinos selection between 1990 and 2010 has increased live weight at a given age (stage) which has in turn generally increased growth rates between stages (e.g. weaning to postweaning). However these increases in growth rate have varied in magnitude between breeds. Comparison of ram growth rates in the weaning to postweaning period between 1990 and 2010 (Table 2) demonstrates increases of 0.45 g/day have been achieved in the Border Leicester breed over 20 years while a decrease of 0.55 g/day have been seen in the postweaning to yearling period. The corresponding changes in growth rate for the Merino, Poll Dorset, Texel, Suffolk and White Suffolk breeds during the weaning to postweaning period are 0.75, 2.65, -0.5, 3.6 and 2.05 g/day respectively. Those changes for the postweaning to yearling period are 1.65, 1.55, 2.4, 4.1 and 3.35 g/day, respectively. When accumulated over 20 years these changes in growth rate have resulted in the Suffolk breed gaining an extra 26.28 kg during the weaning to postweaning period in 2010 compared to 1990. Corresponding gains in the Merino and Poll Dorset breeds are 5.475 and 19.345 kg, respectively. Although generally of smaller magnitude the changes in ewe growth rates over the same 20 year period follow these trends.

The consequence of these changes in growth rate particularly for breeds with larger changes in magnitude (e.g. Suffolks and Poll Dorsets) has been increased nutrient requirements during the different phases of growth in both sexes. In certain breeds (Poll Dorset) the increases in nutrient requirements have been more pronounced during the weaning to postweaning period reflecting the higher increase in growth rate during that period compared to the postweaning to yearling period. In other breeds (Suffolk) increases in nutrient requirements as a consequences of larger increases in growth have occurred during the postweaning to yearling period.

Although increases in growth rate were found in the LAMBPLAN data between 1990 and 2010 the growth rates being expressed in 2010 are disappointing. This is particularly the case for growth rates displayed during the postweaning to yearling stage. As shown in Tables 2 and 3, the growth rates displayed by Merinos of both sexes are below 100 g/day which is far below expectation. This finding maybe somewhat an artefact of the structure of the Australian sheep industry in that traditionally meat production has been considered a secondary output (although this may of changed to some extent in more recent times) of a fine wool orientated Merino dominated sheep industry. This finding may also be a consequence of the production structure of the industry where lambs are pushed to reach market targets in a time frame conducive to the remainder of the production system (i.e. a 25kg carcass at 5-6 months of age) and any animals retained beyond that time frame as replacements are not supplied with adequate nutrients to reach their potential and consequently not challenged to perform.

It is particularly instructive to compare actual growth rates with those expected based on intrinsic growth curve parameters for different breeds of sheep in the Sheep CRC INF. Figures 5 and 6 show realised post-weaning growth rates were significantly lower than expected. This could be because no attempt was made to maximise growth rates post-weaning. However, the average growth rates of Sheep CRC INF lambs is more than reported by industry in the LAMBPLAN database over the same period of time.

Based on anecdotal evidence from producers it was anticipated that post-weaning lamb growth rates would be significantly higher than those reported above. Some of the high growth rates reported by producers, and seen for short periods of time in the sheep CRC INF data are likely due to variation in weighing, and too short a period between weights to reliably estimate growth rate. It has been reported elsewhere (Archer et al. 1997) that for the error structure in estimation of weight gain in cattle on a feedlot / high energy diet to stabilise requires that weights be taken over 70 days. Regression techniques can be used to estimate weight gain (and sometimes reduce the time required to accurately estimate weight gain), and when used on Sheep CRC INF nucleus data here, they show that some of the high rates of gain observed are generated by “normal“ (i.e. due to usual errors in weighing) deviations in weights and comparatively short times between weighing. Nonetheless, the low average growth rates recorded in LAMBPLAN flocks and the Sheep CRC INF are of concern, particularly when comparing industry with research data over the past few decades. In general growth rates in research data are often higher, even when lambs are not eating ad-libitum (e.g. Haynes et al. 2012), suggesting that the production system under which industry lambs (reported in LAMBPLAN data) were grown out were sub-optimal. In simulating the nutrient requirements of lambs at the weights and growth rates observed, the rate parameter (*B*) had to be restricted using the multiplier factor ($M_x$) to achieve observed growth rates. This suggests that nutrient supply is potentially limiting in industry and the Sheep CRC INF flock. When expressed relative to the diets presented in Table 1 the predicted feed intakes are in agreement with those estimated by the updated Australian feeding standards for ruminant animals (CSIRO 2007) which indicates the animals are performing as would be projected given the surrounding production environment. In order to satisfy the full genetic potential of these animals changes in management practices may be required to achieve and sustain adequate levels of nutrient supply from industry feeding systems i.e. improved pastures and feedlot rations.

Previous studies of the factors contributing to differences achieved by selection lines for weight after weaning, indicated that differences in feed intake were not only associated with differences in growth rate, but were probably the major factor contributing to the difference in growth rate arising from selection for weight at a fixed age. Oddy (1993) reported that in Merino lambs selected for high vs low weaning weight for at least 20 generations (and which differed in weight at weaning and as hoggets and adults by more than 40%) the most likely basis for the difference (as a consequence of selection for growth) was feed intake. Evidence for this was, when Weight Minus (W-) lambs (i.e. those selected for low weight gain) were infused with milk at the same rate as that ingested by Weight Plus (W+) lambs (i.e. those selected for high weight gain) the growth rate and body composition changes in both W+ and W- lambs were similar. There were many other changes in potential mechanisms between the lambs (differences in digestibility of feed, differences in rate of protein deposition and energy expenditure, differences in sensitivity to insulin and IGF-1), but the consequences of these changes were dwarfed by that due to differences in feed intake. No comparable studies were conducted with the weaning / yearling Weight Selection lines of cattle, but using weigh / suckle / weigh techniques, it was observed that the difference in milk intake associated with the different selection lines, was principally (~80%) due to the calf (Herd 1990). Calves from weight+ lines suckled approximately the same amount of milk on weight– cows as on weight+ cows (and vice versa). These, and data from other species, suggest that feed intake is the major physiological factor upon which selection for weight (i.e. selection for growth rate) operates.

Of course selection takes place in contemporary groups, and is realised in progeny with the same amount and quantity of feed available to them and their dams. However, that doesn’t mean that the amount and quality of feed meet the potential requirements for growth of selected progeny, just that they outperform their unselected (or less fit) contemporaries in the same environment i.e. selected progeny provide evidence for a differential effect on growth (and consequently body composition) performance due to improved access to unlimited amounts of feed of the same quality because they can eat more. It is not clear that they would have an even more superior growth if the quality of feed on offer permitted maximal expression of their potential. Hegarty et al (1999) reported that growth of lambs above 35kg was primarily driven by energy intake, provided that sufficient protein was available to meet requirements to maximise microbial protein production. Moreover, in lambs undergoing compensatory growth in which it might be expected that protein requirements would be greater (to meet the needs of enhanced muscle growth) there was no response in growth of body and muscle to additional protein available to the small intestine at high energy intakes. In addition, Hegarty et al (2006) compared the responses of lambs differing in genetic potential for muscle growth experiencing pasture conditions that generated different growth rates and found that the rate of muscle growth was greater in high muscle EBV lambs irrespective of feed supply.

Comparison of energy and protein requirements for actual performance (Poll Dorsett and Suffolk) and a hypothetical animal growing at 400g/d post weaning (Table 5) indicate that it is total intake rather than content of digestible crude protein (for example) that is limiting performance. Together with the observations from published studies above, they suggest, it is feed intake that is limiting growth.

It is not clear if by simply increasing nutrient density that selected animals would outperform non-selected animals (as a metaphor/proxy for High cf Low growth lines). There is limited evidence in sheep that this might be the case, but substantial evidence in pigs that superior genetics do require additional nutrients to achieve potential rates of deposition of protein (e.g. Campbell et al. 1990). The same conclusions can be drawn from pig growth models (e.g. Emmans and Kyriazakis 1997), which incorporate data from many experiments.

The evidence in this report (Figures 4, 5 & 6, and Table 5) suggest that in addition to genetic improvement of livestock, there are still substantial gains in efficiency of production in individual enterprises that could be made if attention was focussed on developing systems for providing high quality feed to lambs between weaning and slaughter. In practical terms this may need to be for periods of 8-12 weeks. This may lend itself to production of specialty crops or pastures to match the production cycle on farm, or to the development of specialised finishing systems. It is unlikely these will be solely based on feeding grain based diets. Experience with feedlotting lambs shows that lambs are more difficult to manage onto high grain diets due to social and nutritional issues which affect adaptation to the diet, and are more prone to variation in intake and growth than cattle. Unpublished reports suggest that lamb growth is not necessarily increased by very high nutrient diets (Matthew McDonagh – pers. Comm.). It seems that maximising growth of lambs in practical production systems will require attention to both quality and quantity of feed availability, and minimising social stressors that adversely affect feed intake.

**Future possibilities.**

A characteristic of the Australian lamb industry over the past century has been its role as a secondary income source, initially to the wool and grains industry. Although lamb production has become a major component of sheep production systems in its own right over the past 25 years, it retains a number of legacies that negatively affect its ability to achieve its full biological potential. One of the issues currently being addressed by Sheep Genetics is the dependence on predominantly Merino genetics for the ewe base. However, providing a technical solution, in terms of a better prime lamb dam, cannot offset the structural weakness derived from seasonality of feed supply. This study highlights that despite genetic gains, lamb growth is considerably less than potential, and suggests that the major reason for this is lack of feed of sufficient quality and/or quantity postweaning.

If methods to overcome seasonal limitations to feed supply were devised, it is possible that lamb producers could focus on increasing productivity to a much larger extent than at present. Under these circumstances, it could be argued that the value to be obtained from increased genetic gain could be better realised.

# 6 Conclusions

Selection (of sires) has certainly increased growth rate and decreased fat and increased lean content of the body of lambs over the past 20-25 years.

The extent to which this has been capitalised on is variable. Analysis indicates that it is normal for growth to be less than expected based on genetic potential (modelled using anticipated changes in mature size). This exaggerates the differences in fat and lean deposition in the body of the lambs due to selective breeding. From a production efficiency perspective having growth rate (and consequent effects on body composition) less than maximum is not desirable.

The evidence suggests that lambs are most often nutrient deprived after weaning (i.e. growth rate is less than before weaning). Growth after weaning is less than anticipated based on models of nutrient requirements adjusted for anticipated increases in mature size. Modelling suggests composition of specific nutrients in the feed are alone unlikely to be responsible for the growth rate being less than expected, unless they have direct effects on feed intake. It seems that failure to achieve lamb growth potential is due to failure of the lambs to eat sufficient feed to maximise growth. The results strongly suggest that lamb performance could be improved by increasing the quality (essentially energy density, with sufficient protein to ensure rumen function is not impaired) of feed available to lambs after weaning and before slaughter. It is recognised that other factors (e.g. social, diet induced subclinical acidosis) also affect intake by lambs, and attention to these is warranted.

The limited data available from lambs with known ASBVs finished on pelletted and high grain diets suggested that even when presented with unlimited amounts of high energy density feed, lambs do not always respond as anticipated.

This might have happened for 2 reasons:

1. ASBVs overestimate the anticipated phenotypic differences in growth rate, and hence mature size leading to expectations of higher performance than may be achievable.

2. Management of the lambs and their feed supply in these studies was not as appropriate as it should have been. This in turn restricted growth potential of the lambs, so that overall performance was much less than potential even though the relativity in performance of lambs with different ASBVs was on average as expected.

It should be possible to determine which of the above possibilities are correct, if comprehensive records of lamb pedigree and subsequent growth and realised carcass characteristics were available from commercial feedlots. Unfortunately such information was unable to be found. It may be simpler in the first instance to conduct a series of designed studies under as near to commercial conditions as possible to obtain such data.

# 7 Recommendations

The data available to this study clearly indicates that lambs are often unable to meet anticipated growth rates based on genetic potential during the postweaning period. The data also indicates that genetic selection has increased lamb growth rates, and changed body composition (more lean, less fat) in terminal breeds especially those improved genotypes used for meat production. Accordingly, there is increasing potential for lamb growth to be constrained by nutrient availability. The issue is how best to overcome limitations in nutrient supply.

Lambs seem less well suited to feedlotting than cattle. Traditionally feedlotting of lambs has been on an opportunistic basis, and the development of systems for year round feedlotting has rarely been successful due to the seasonal nature of lamb production. It is more likely that practical solutions will come through the following:

1. Developing pastures that allow lambs to maximise nutrient intake for 8-12 weeks postweaning.

2. Managing these pastures to maximise growth and minimise detrimental impact of GINs, and nutrient density, e.g. rotational grazing, perhaps by incorporating other species and/or stock classes.

3. It is strongly suggested that a research project be conducted to establish:

    a. Maximum growth rate of lambs on pastures managed to provide different levels of nutrient supply,

    b. This be extended to include the use of supplement to maximise nutrient intake in order to demonstrate if pasture management practices can be used to maximise nutrient intake by lambs. If this is achievable this information along with recommendations on how to manage pastures to achieve maximum lamb growth rates needs to be provided to industry as a matter of urgency.

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