

British Journal of Educational Research
2(1): 59-76, 2012

SCIENCEDOMAIN *international*
www.sciencedomain.org



Teaching Animal Science and Genetics to Australian University Undergraduates to Enhance Inquiry-Based Student Learning and Research with Sheep: Growth and Conformation Traits in Crossbred Prime Lambs

A. E. O. Malau-Aduli^{1*}, E. Nightingale¹, P. McEvoy¹, J. U. Eve¹,
A. J. John¹, A. A. Hobbins¹, A. A. S. Alamoudi¹, K. R. Petrie¹, P. Damen¹,
M. E. French¹, A. M. Cragie¹, S. K. Bales¹, A. Kashani¹, B. W. B. Holman¹,
J. Vargas-Bravo¹, S. M. Jones², B.S. Malau-Aduli³ and P. A. Lane¹

¹Animal Production and Genetics, School of Agricultural Science, Tasmanian Institute of Agricultural Research, University of Tasmania, Private Bag 54 Hobart, TAS 7001, Australia.

²School of Zoology, University of Tasmania, Private Bag 5 Hobart, TAS 7001, Australia.

³Medical Education Unit, School of Medicine, University of Tasmania, TAS 7001, Australia.

Research Article

Received 5th September 2011
Accepted 7th December 2011
Online Ready 8th December 2011

ABSTRACT

The primary objective of this Australian Wool Education Trust funded teaching initiative on inquiry-based learning and research-led teaching approach was to enhance students' critical thinking and target their learning needs through active participation in hands-on experience with experimental sheep. The secondary objective was to study the effects of sire breed and sex on growth and body conformation traits in crossbred prime lambs at the University of Tasmania Farm, Cambridge. Body weight, average daily gain, body condition score, body length, withers height and chest girth in sixty first cross Merino lambs sired by White Suffolk and Poll Dorset rams were measured fortnightly over a ten-week period. Generalised linear model procedure in SAS was used for statistical analysis and included the fixed effects of sire breed, sex, fortnight and their second order interactions. Duncan's Multiple Range Test, correlations between growth and conformation traits and Bonferroni probabilities were estimated and used for comparisons.

A fortnightly increase in lamb body weight, average daily gain and body condition score was evident. Wethers were heavier and had higher average daily gains than ewes. White Suffolk

*Corresponding author: Email: Aduli.MalauAduli@utas.edu.au

sired progeny had higher average daily gains than those sired by Dorset rams, but body weight did not differ between sire breeds. However, a highly significant interaction ($P < 0.0001$) between sire breed and sex on body weight was evident as White Suffolk sired wethers were the heaviest prime lambs. It was concluded that the real world, hands-on research experience with experimental sheep, field trips, data collection, statistical analyses, data interpretation and seminar presentation of results facilitated a deeper student understanding of the scientific concepts of sire genetics and nutrition interactions in sheep growth.

Keywords: Research-based teaching; Inquiry-based learning; crossbred lambs; growth; body measurements; White Suffolk; Dorset; Merino; sheep genetics; SETL.

1. INTRODUCTION

Research-based teaching is a practice of scientific inquiry in which academics share their disciplinary research with students, teach them research methods and integrate field research into class-oriented teaching in order to enhance and enrich students' learning experience. One of the major dilemmas undergraduate students face in animal science is understanding the complex scientific concepts of genetics by nutrition interaction relationships in pasture-based systems obtainable in the sheep, dairy and beef cattle industries. This difficulty was clearly reflected in the 2006 Animal Production Systems Unit's student evaluation of teaching and learning (SETL) at the University of Tasmania's School of Agricultural Science where students expressed a lack of understanding of the concepts taught. In order to address this problem, we implemented an innovative, inquiry-based learning and research-led teaching approach that stimulated active student participation not only in the class theoretical framework, but also in hands-on field trials with experimental sheep, livestock industry visits and laboratory experimentation. The primary objective was to enhance students' critical thinking and target their learning needs through active participation in hands-on growth experimental research with sheep.

The real farm value of Australian lamb production at the farm gate has increased by about \$71 million/year to around \$1.75 billion for the period 1992–2009, while wool decreased by an average of \$138 million each year from \$4.7 billion in 1992 to under \$1.8 billion in 2009 (ABARE, 2010). Current Australian sheep industry data indicate that the value of sheep meat has increased from \$0.5 to \$2.2 billion while wool production has decreased from over \$6 billion to ~\$2.5 billion (Rowe, 2010). Australian sheep production systems use a variety of breeds to take advantage of economically important traits such as daily growth rate, body weight and condition score, muscle development and wool fibre diameter. Different genotypes can be selected for these individual traits using Australian Sheep Breeding Values (ASBV) (Hegarty et al., 2006a, 2006b). With the declining prices of wool and the increased price premium for prime lamb, the production of meat has taken precedence over wool and this explains why the production of high quality meat from crossbred sheep is the aim of many prime lamb producers (Rowe, 2010). Therefore, selecting the optimal sire breed for these important traits to maximize economic returns would be an informed choice many producers make.

Efficient conversion of feeds into fast growth and muscle can keep sheep production costs at a minimum for maximum output (Fahmy et al., 1992). Merino sheep are specifically kept for their excellent wool production ability, but they have a comparatively slower growth rate (Ponnampalam et al., 2007) and a lower feed efficiency (Wise et al., 2003) than meat sheep and dual-purpose breeds such as White Suffolk and Poll Dorset selected for both their wool characteristics as well as meat production (Cake et al., 2007). By crossing these meat rams with Merino maternal breeds, the resulting progeny takes advantage of the genetic variation, breed complementarity and heterosis between the breeds to produce a much more versatile and economically viable product (Afolayan et al., 2008). That is, the wool and reproductive traits from the maternal Merino and the muscle and fat development from the sire breed are exploited in enhancing a product that the farmer can sell for both wool and meat, thus adding value to their enterprise. Therefore, sheep crossbreeding provides opportunities to introduce complementary traits for prolificacy, lamb growth and the exploitation of heterosis for reproduction, survival and 'fitness' traits (Annett et al., 2010).

The growth of lambs is influenced by a number of factors such as nutrition, health, genetics sex, litter size, season of lambing, age of dam and year of lamb birth (Kuchtik and Dobes, 2006). To enable producers make informed decisions concerning breed, nutrition and management practices, there is a need for greater exploration of these factors including how they interact and influence growth performance in sheep. One way to achieve rapid growth or increase meat output and heavy market weight is by using terminal sire breeds (Mousa et al., 1999). Consequently, this study compares the growth performance and body conformation of Merino crossbred progeny sired by White Suffolk and Poll Dorset rams which are primarily used as terminal sire breeds for prime lamb production in Australia due to their early maturation and rapid growth (Hinton, 2006). The second objective of this study was to evaluate the effects of sire breed and sex on growth and body conformation traits in crossbred prime lambs and quantify their relationships.

2. MATERIALS AND METHODS

2.1 Experimental Site and Animal Management

The crossbred prime lamb growth experiment was carried out over a ten week period from February to May (autumn) of 2011 by students of Animal Production Systems Unit at the University of Tasmania (UTAS) School of Agricultural Science Farm in Cambridge, Hobart, Tasmania, Australia. The sixty experimental sheep were randomly selected from a composite population of over 1000 first cross Merino progeny sired by Poll Dorset and White Suffolk rams under the same management. The lambs were properly identified with their National Livestock Identification electronic ear tags that could be scanned automatically by the walk-over weighing scale, weaned at six weeks of age and raised on ryegrass, phalaris and fescue pastures and also rape forage. They had unlimited access to water and uncrushed barley daily. Lambs were randomly selected and allocated into three student groups for fortnightly weighing and body measurements.

2.2 Body Weights and Measurements

At the same time each fortnight, the student groups recorded live weights and body conformation measurements for each lamb for a period of 10 weeks. Each group comprised of four to five individuals who also undertook a range of body conformation measurements including body condition score, body length, height at withers and chest girth. Body condition

was subjectively scored on a scale of 0 (emaciated) to 5 (obese) by feeling the layer of fat on the back muscle (*Longissimus dorsi*) using the thumb and fingers on the ribs as described by the Western Australian Department of Agriculture (2010). Body length and chest girth were ascertained using a measuring tape. Body length was measured as the distance from the centre of the base of the neck to the top of the tail. Chest girth was measured using a measuring tape to determine the circumference of the chest posterior to the forelegs. The height at withers was measured from the ground to the top of the hip bone using a non-flexible ruler. Live weights were obtained from an automatic electronic walk-over weighing scale that saved the data in readily downloadable excel-spreadsheet format.

2.3 Statistical Analyses

Students were taken through a step-by-step, hands-on computer laboratory session on the use of SAS (Statistical Analysis System) software procedures of data analyses. In analysing the quantitative data comprising sheep body weight, average daily gain, body condition score, withers height, chest girth and body length, the Statistical Analysis System (SAS, 2009) software was used in a generalized linear model procedure (PROC GLM). Sire breed, sex, fortnight, student group and their second order interactions were included in the initial model as fixed effects. Non-significant effects and interactions were subsequently removed from the final model and separation of significant means ($P < 0.05$) was conducted using Duncan's multiple-range test. Correlations between growth and body conformation traits were computed using Pearson's coefficients and significance established using Bonferroni probabilities in PROC CORR procedures (SAS, 2009).

2.4 Laboratory Practical

In order to further understand the links between nutrition, breed variation and genetics of fat metabolism in marbling, students extracted meat intramuscular fat and quantified the melting points in the laboratory to fully appreciate the economic significance of Australian marbled meat exports to Japan and why it attracts a high premium.

2.5 Sensory Evaluation of Meat Eating Quality

Students also participated in a sensory evaluation of meat quality practical in which meat samples from both grass-fed and grain-fed sources were evaluated in a barbeque where the students tasted and scored samples for flavour, juiciness, tenderness, aroma and other quality traits.

2.6 Livestock Industry Excursion

Students were taken on a two-day excursion to Tasmanian livestock industries to ensure that there was a practical, face-to-face interaction with practicing livestock farmers, meat processors and other stakeholders.

2.7 Seminar Presentations

Students individually made a 20-minute seminar presentation designed to enhance their scientific communication skills and had an opportunity to grade and comment on each other's performance according to standard seminar assessment criteria.

2.8 Student Evaluation of Teaching and Learning (SETL) Survey

Student survey of their learning experiences was conducted through SETL. The quantitative data comprised of responses from a total of 104 out of 125 students (83% response rate) to 10 standard UTAS SETL questions that offer academic staff customized evaluations of their teaching and of units/courses. The results provided in the summary (Tables 7 and 8) are the mean student responses to each question where: 1 = “Strongly Disagree”, 2 = “Disagree”, 3 = “Neutral”, 4 = “Agree” and 5 = “Strongly Agree”. More information about student evaluations at UTAS can be found at <http://www.studentcentre.utas.edu.au/setl/index.html>.

3. RESULTS AND DISCUSSION

3.1 Results

Generally, body weight and body condition score increased from the first to the fifth fortnightly intervals. Body weight increased incrementally from an average, initial body weight of 36 kg to 43 kg in the final fortnight, representing a 7 kg or 16% increase (Table 1). As expected, body condition score followed the same incremental pattern. Moreover, an incremental increase in average daily gain was evident, with the exception of the final fortnight. An increase in average daily gain of 198 g/d or 3.8 times was evident from the second to the fourth fortnights (Table 1).

Table 1. Fortnightly variation in body weight and conformation in crossbred sheep

Fortnight	Unadjusted mean±standard deviation					
	BWT (kg)	ADG (g/d)	BCS	BL(cm)	WH (cm)	CG (cm)
1	35.9 ± 4.5	-	2.5 ± 0.7	68.4 ± 6.4	54.7 ± 4.3	79.5 ± 10.8
2	36.7 ± 4.2	51.0 ± 136.2	2.8 ± 0.6	66.7 ± 4.4	55.5 ± 4.4	78.7 ± 7.8
3	39.1 ± 4.4	173.0 ± 96.7	3.0 ± 0.5	68.3 ± 5.5	58.1 ± 4.8	81.1 ± 8.7
4	42.1 ± 4.9	248.6 ± 179.9	3.34 ± 0.46	69.3 ± 5.9	59.7 ± 4.3	83.7 ± 8.3
5	43.1 ± 4.5	201.4 ± 71.4	3.36 ± 0.47	69.5 ± 5.6	60.1 ± 4.4	87.6 ± 8.8

BWT=Bodyweight, ADG=Average daily gain, BCS=Body condition score, BL=Body length, WH=Withers height, CG=Chest girth

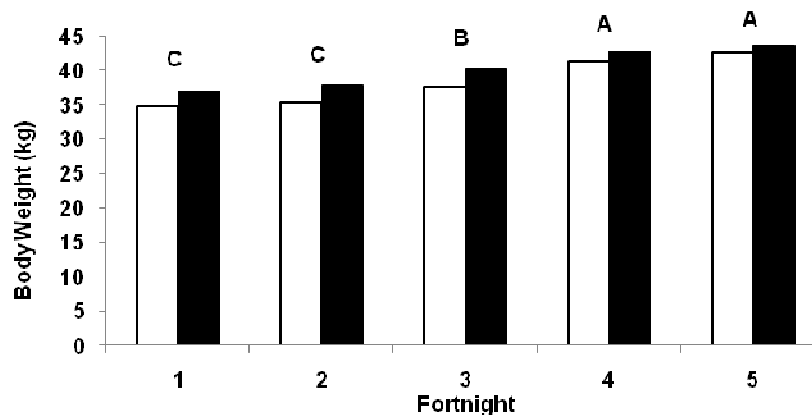


Fig. 1. Fortnightly variations in body weight of lambs which shows a steady increase of overall body weight

The body weights of the ewes (\square) were always lower than those of wethers (\blacksquare). The combined sexes for each fortnightly period was significantly different ($P < 0.05$). The different letters above the bars indicate significant differences between the fortnights but not the sexes. Significant value set at $P < 0.05$.

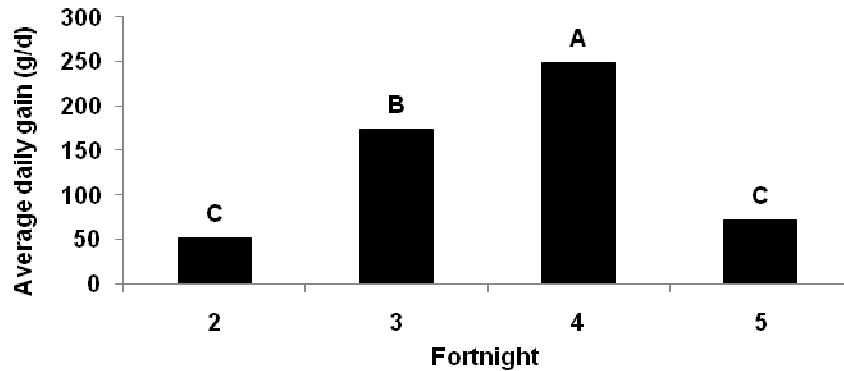


Fig. 2. The average daily gain (ADG) of the lambs over the 10-week trial period.

There was a significant difference between the ADG for each fortnight except fortnights 2 and 5. The different letters above the bars indicate significant differences between the fortnights ($P < 0.05$).

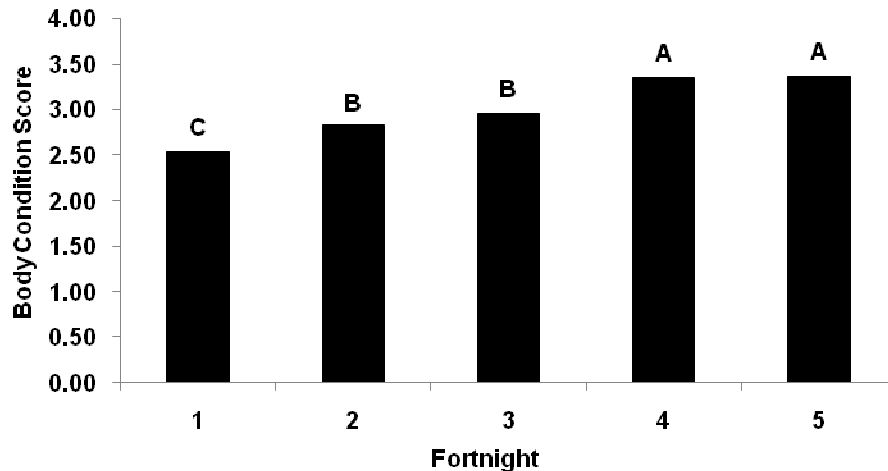


Fig. 3. The mean body condition scores (BCS) of all lambs for each fortnight period.

There was a significant increase in BCS in fortnights 4 and 5 compared to fortnights 3 and 4, which was significantly greater than fortnight 1. The different letters above the bars indicate significant differences between the fortnights ($P < 0.05$).

As depicted in Table 2, wethers were heavier and grew faster than ewes on average, by about 2kg and 8g/d respectively. In contrast, the differences in body measurements between wethers and ewes were not significant (Table 2).

Table 2. Body weight and body conformation (Least squares Means \pm Standard Error) in ewes and wethers

Sex	BWT (kg)	ADG (g/d)	BCS	BL(cm)	WH (cm)	CG (cm)
Ewes	38.4 \pm 5.0 ^D	135.5 \pm 94.4 ^D	2.97 \pm 0.6	68.0 \pm 5.7	56.8 \pm 4.4	81.86 \pm 8.75
Wethers	40.1 \pm 5.4 ^A	143.5 \pm 98.6 ^A	3.00 \pm 0.7	68.7 \pm 5.6	57.9 \pm 5.4	81.94 \pm 10.21

BWT=Bodyweight, ADG=Average daily gain, BCS=Body condition score, BL=Body length, WH=Withers height, CG=Chest girth. Column means bearing different superscripts significantly differ ($P<0.05$).

Table 3 shows that there was a 0.6kg difference in body weight and 13g/d in average daily gain between the sire breeds. These differences however, were not statistically significant ($P>0.05$). In contrast, there was moderate evidence of a difference in body length and weak evidence of a difference in body condition scale between sire breeds (Table 3).

Table 3. Sire breed variation in body weight and body conformation (Least squares Means \pm Standard Error) in crossbred sheep

Sire Breed	BWT (kg)	ADG (g/d)	BCS	BL(cm)	WH (cm)	CG (cm)
Dorset	38.9 \pm 4.7	133.5 \pm 196.2	2.9 \pm 0.6 ^D	69.4 \pm 5.0 ^A	57.7 \pm 5.1	81.8 \pm 10.2
WS	39.5 \pm 5.8	146.4 \pm 143.7	3.1 \pm 0.7 ^A	67.3 \pm 6.0 ^D	57.2 \pm 4.7	82.1 \pm 8.7

WS=White Suffolk, BWT=Bodyweight, ADG=Average daily gain, BCS=Body condition score, BL=Body length, WH=Withers height, CG=Chest girth. Column means bearing different superscripts significantly differ ($P<0.05$).

As portrayed in Table 4, fortnightly intervals exerted a highly significant effect ($P<0.0001$) on body weight, average daily gain, body condition score and withers height. Furthermore, sire breed significantly ($P<0.05$) influenced body condition score and body length, whereas sex influenced body weight only. Observed interactions that were significant included the interaction between sex and sire breed for body weight and withers height (Table 4).

Table 4: Factors affecting body weight and conformation in crossbred sheep (P-values)

z	BWT	ADG	BCS	BL	WH	CG
Fortnight	0.0001 ^{***}	0.0001 ^{***}	0.0001 ^{***}	0.06	0.0001 ^{***}	0.01 ^{**}
Sex	0.0001 ^{***}	0.05 [*]	0.33	0.18	0.15	0.79
Sire breed	0.16	0.44	0.05 [*]	0.0014 ^{**}	0.23	0.98
Fortnight x Sex	0.82	0.71	0.55	0.89	0.51	0.07
Fortnight x Sirebreed	0.92	0.12	0.92	0.97	0.87	0.99
Sex x Sire breed	0.0001 ^{***}	0.60	0.86	0.31	0.01 ^{**}	0.95

^{*} $P<0.05$, ^{**} $P<0.01$, ^{***} $P<0.0001$, BWT=Bodyweight, ADG=Average daily gain, BCS=Body condition score, BL=Body length, WH=Withers height, CG=Chest girth

Given the highly significant sire breed by sex interaction ($P<0.0001$) influencing body weight and withers height, White Suffolk sired wethers were found to have the highest body weight and shortest withers height, representing 40.95kg and 56cm respectively (Table 5). Conversely, White Suffolk sired ewes had the lowest body weight and longest withers height, representing 36.85kg and 58.42cm, respectively.

Table 5. Sire breed and sex interaction effect on body weight (BWT) and withers height (WH) (Least squares Means \pm Standard Error)

Sire breed and sex	BWT (kg)	WH (cm)
Dorset Ewes	39.76 \pm 4.51	57.60 \pm 4.50
Dorset Wethers	39.95 \pm 4.85	57.82 \pm 5.78
White Suffolk Ewes	36.85 \pm 5.13 ^b	58.42 \pm 4.21 ^b
White Suffolk Wethers	40.95 \pm 5.83 ^a	56.00 \pm 4.95 ^a

Within each sire breed, gender column means bearing different superscripts significantly differ ($P < 0.01$)

As expected, body weight was positively and highly significantly correlated with body conformation measurements (Table 6). Furthermore, body condition score was positively and highly significantly correlated with body length, withers height and chest girth. A highly significant, positive correlation was evident between chest girth and withers height, with 60% of variation explained. In contrast, among body measurements, body length was negatively correlated to wither height and chest girth, however, no significant difference was found (Table 6).

Table 6. Correlations between body weight and conformation traits in crossbred sheep

	BWT	ADG	BCS	BL	WH	CG
BWT	1.00	0.32***	0.55***	0.48***	0.37***	0.36***
ADG	0.32***	1.00	0.17*	0.05	0.07	0.05
BCS	0.55***	0.17*	1.00	0.33***	0.22***	0.45***
BL	0.48***	0.05	0.33***	1.00	-0.11	-0.07
WH	0.37***	0.07	0.22***	-0.11	1.00	0.60***
CG	0.36***	0.05	0.45***	-0.07	0.60***	1.00

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.0001$, BWT=Bodyweight, ADG=Average daily gain, BCS=Body condition score, BL=Body length, WH=Withers height, CG=Chest girth

Quantitative analyses of teaching evaluation SETL scores on Table 7 indicate that there was an improvement in overall mean scores from 4.19 in 2006 to 4.55 in 2010 and when these means were compared to the average scores within the UTAS Faculty of Science, Engineering and Technology (Figure 4), a clear demonstration of achievement over and above expectations was evident.

Overall means of Unit evaluation depicted on Table 8 show that there was a progressive improvement from 3.90 in 2006 to 3.93 in 2008 and 4.40 in 2010 while this performance exceeded the average Faculty threshold in 2008 and 2010 (Figure 5).

3.1 Discussion

As expected, a fortnightly increase in body weight, average daily gain and body condition score was evident with the greatest increase in body weight observed between the third and fourth fortnights, followed by fortnights two and three, suggesting that with time, body weight exhibited a linear increment in sheep managed under optimal nutritional conditions. However, there was a notable decrease in average daily gain during the last fortnight of the study.

**Table 7: Mean scores of student evaluation of teaching and learning (SETL) for Animal Production Systems Unit from 1 ('Strongly Disagree') to a max of 5 ('Strongly Agree')
SETL Standard Teaching Evaluation Questions**

Year	Enrolled Students	Respondents	<i>The lecturer was well organised</i>	<i>The lecturer made the subject matter interesting</i>	<i>The lecturer gave helpful feedback on my progress</i>	<i>The lecturer treated students with respect</i>	<i>The lecturer knew the subject matter well</i>	<i>The lecturer communicated enthusiasm for the subject area</i>	<i>The lecturer assisted me in gaining a good understanding of the subject matter</i>	<i>The lecturer was good at explaining the subject matter</i>	<i>I had reasonable opportunity for interaction with the lecturer</i>	<i>The lecturer motivated me to learn</i>	Mean of Means
			Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
2011	12	12	3.81	4.08	4.00	4.66	4.00	4.08	4.00	3.91	4.33	4.00	4.09
2010	33	28	4.57	4.57	4.46	4.60	4.71	4.64	4.40	4.57	4.53	4.40	4.55
2008	25	20	3.90	3.71	4.14	4.20	4.19	4.38	3.60	4.14	4.42	3.70	4.04
2006	36	24	3.80	4.20	3.70	4.60	4.50	4.40	4.20	4.10	4.40	4.00	4.19
2004a	9	9	4.10	4.30	3.90	4.90	4.80	4.70	4.30	4.40	4.80	4.10	4.43
2004b	8	5	4.20	3.80	4.00	4.80	4.60	4.60	3.80	4.40	4.40	3.80	4.24
2004c	14	6	4.20	4.30	3.80	4.70	4.80	4.70	4.70	4.70	4.50	4.20	4.46
Total	125	104	24.8	24.9	24.0	27.8	27.6	27.4	25.0	26.3	27.1	24.2	25.9
Mean	20.8	20.8	4.1	4.1	4.0	4.6	4.6	4.6	4.2	4.4	4.5	4.0	4.32

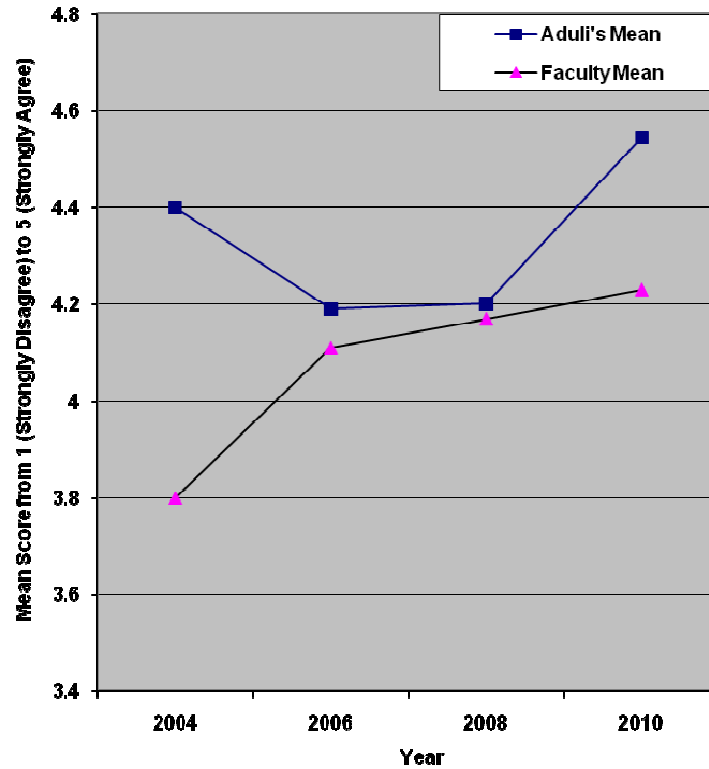


Fig. 4. Comparative teaching SETL evaluation between Animal Production Systems and Faculty means from 2004 to 2010 involving 125 students with a 83% response rate

This decrease was very likely attributable to adverse cold weather conditions experienced during that fortnight when the temperatures dropped below ten degrees centigrade with continuous rainfall. Previous studies have highlighted the negative impact of cold stress on growth, particularly due to increased metabolism and reduced grazing time (Bird et al., 1984) and additional energy requirements needed during times of thermal stress (Ames and Brink 1977).

(i) Effect of sex: The finding that wethers were heavier and had higher average daily gains than ewes is consistent with Dimoski et al. (1999) and Thatcher et al. (1991) who also found that among a range of breeds, wethers had better average daily gain due to more rapid postweaning growth than ewes. Moreover, Ahmad and Davies (1986), Jones et al. (1984) and Notter et al. (1991) found that castration reduced growth differences between the sexes, concluding that these differences were larger between rams and ewes. It has also been demonstrated that males have a steeper growth curve than females (Lewis et al., 2002). Additionally, the heavier weights of the males in the estimated growth curve are reflected in this trial where the wethers were heavier than the females. This supports other studies that showed that wethers reach a higher carcass size and muscle specification at an earlier age than ewes (Ponnampalam et al., 2007). These differences between the sexes in body weight gains are typical of other studies where sex effects were observed independent of the genotype (Ponnampalam et al., 2007).

**Table 8. Mean scores of Unit SETL evaluation for Animal Production Systems Unit from a minimum of 1 ('Strongly Disagree') to a maximum of 5 ('Strongly Agree')
SETL: Standard Unit Evaluation Questions**

Year	Enrolled Students	Respondents	<i>The unit addressed the learning outcomes stated in the Unit Outline</i>	<i>The criteria for each assessment component were clearly identified</i>	<i>The workload in this unit was appropriate</i>	<i>There was reasonable opportunity for interaction with teaching staff</i>	<i>I was given useful feedback on my assessment work</i>	<i>Submitted work was returned to me in a reasonable time frame</i>	<i>The unit stimulated my interest in the subject area</i>	<i>I gained a good understanding of the subject matter</i>	<i>I enhanced my skills in this unit</i>	<i>The unit was well taught</i>	Mean of Means
2011	12	12	4.09	4.16	4.25	4.33	4.00	3.75	3.75	3.72	4.00	4.00	4.01
2010	33	28	4.23	4.30	4.42	4.42	4.38	4.32	4.32	4.48	4.40	4.48	4.40
2008	25	20	4.00	3.84	4.10	4.25	4.00	4.30	3.80	3.85	3.45	3.75	3.93
2006	36	24	4.00	3.70	4.20	4.40	3.30	2.90	4.00	4.20	4.10	4.10	3.90
2004	9	9	4.00	3.30	3.60	3.70	3.50	3.80	4.00	4.00	3.90	3.90	3.80
2004	8	5	3.60	3.40	4.40	3.00	3.20	4.20	3.20	3.60	3.60	3.40	3.60
2004	14	6	4.20	4.20	4.50	4.00	4.30	4.70	4.70	4.60	4.70	4.50	4.44
Total	125	104	28.12	26.9	29.5	28.1	26.7	28.0	27.8	28.5	28.2	28.1	27.97
Mean	20.8	20.8	4.02	3.84	4.21	4.01	3.81	4.00	3.97	4.06	4.02	4.02	4.00

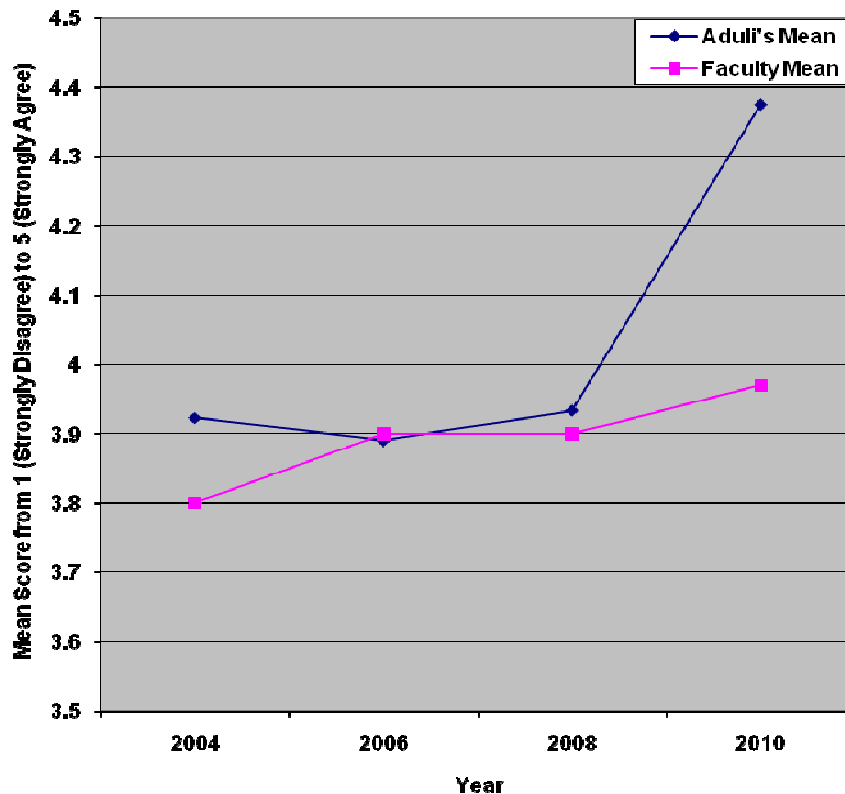


Fig. 5. Comparative Unit SETL evaluation between Animal Production Systems and Faculty means from 2004 to 2010 involving 125 students with a 74% response rate

Ellis et al. (1997) found that wethers were heavier with larger tibia/fibula and femur bones and greater longissimus muscle widths than the ewes in Suffolk, Charollais and Texel sired meat sheep. They also observed that the ewes on the other hand, had a higher fat content than the wethers showing distinct sex differences that could explain the gender variation in body weight but not body condition score in our study.

(ii) Effect of sire genetics: White Suffolk sired progeny were found to have higher average daily gain than those sired by Dorset rams, which agrees with findings of Malau-Aduli and Holman (2010), Hammell and Laforest (1999), Peeters et al. (1995), Malau-Aduli et al. (2009a, 2009b, 2009c, 2009d, 2009e) and Wolf et al. (1980). Unexpectedly, there was no significant difference in body weight between the sire breeds ($P > 0.05$). This finding is inconsistent with Malau-Aduli et al. (2009a), who found that White Suffolk sired progeny had significantly heavier weaning weights than lambs sired by Dorset rams. Similarly, in the study of Wolf et al. (1980), Suffolk cross lambs were found to be heaviest at all ages when compared to other terminal sire breeds including the Dorset Down. It is likely that this apparent contradiction is due to confounding effects associated with the significant interaction ($P > 0.0001$) between sire breed and sex on body weight, in which it was found that White Suffolk sired wethers were the heaviest. It has been established in previous studies that estimated growth rates of lambs exhibit a gradual increase in live weight during the first 50 days followed by a rapid increase in the following 75-100 days, before it starts slowing down again (Lewis et al., 2002; Malau-Aduli et al., 2007). This may explain the

reduction in average daily gain in the final two-week period of the trial where the lambs were approximately 120 days old and there may have been this slow down in the growth rate possibly exacerbated by cold weather spell.

The feed efficiency of sheep production needs to be considered when selecting sire and maternal breeds for meat and wool production. Dorset is a breed that is more cost effective than the Leicester breed (not studied here), which means that the muscle development is quicker over time than in other breeds for the same amount of feed (Hopkins et al., 2007). Whilst nutrition is important for growth and development, the sire genetics influence on the carcass composition can be higher than nutrition alone (Hegarty et al., 2006b; Hopkins et al., 2007, Bignell et al., 2010). Slower growth in some breeds such as the Merino could potentially lead to less carcass fat depth measurements with more lean muscle mass (Hodge and Star 1984). The analysis of the average daily gain between the Sire bred lambs was non significant due to the high within group variation but looking at the means the White Suffolk does show a trend of a higher ADG, but not a heavier bodyweight. This shows the variability between the breeds in the way that weight is gained. Therefore, the benefits to the meat industry could be improved for particular markets. Selecting the optimal breed for this may be important and a look at first-cross sheep to improve growth vigour may be more beneficial.

It has been demonstrated that even within breeds, there are particular ASBV's that can be selected for particular traits such as fat depth and eye muscle depth (Hopkins et al., 2007). The Dorset is a breed that is selected for high growth rate and muscle depth. Comparatively, the White Suffolk, which also has high growth rate and muscle depth, is more renowned for its heavier frame with an acceptable level of fat deposition, and also as a general 'good doer' by sheep farmers such that farms in areas with particularly variable environments may utilise this breed. Therefore, care and consideration must be given to the selection of traits in sires used for breeding to meet particular market specifications dictated by the important elements in those markets (i.e. fat content, muscle depth, carcass weight) (Rowe, 2010).

(iii) Phenotypic relationships: Correlations among and between body weight and conformation traits were highly positive and significant, consistent with the findings of Borg et al. (2009), Cam et al. (2010), Malau-Aduli and Deng Akuoch (2010) and Sowande and Sobola (2008). This suggests that producers may be able to utilise body weight as a predictor of body conformation measurements and vice versa.

(iv) Student evaluation of teaching and learning (SETL): Scientific inquiry includes: identifying and posing questions, designing and conducting investigations, analyzing data and evidence, using models and explanations, and communicating findings (Keys and Bryan 2001). Unlike the classical teacher-focused approach that emphasizes transmission of research knowledge to a student audience (Healy 2000; 2003), the student-focused approach emphasises students constructing their own knowledge through active, inquiry-based participation.

Inquiry-based experiences have been demonstrated to provide valuable opportunities for students to improve their understanding of both science content and scientific practices because inquiry-based learning is essentially a question-driven, open-ended process, and students must have personal experience with scientific inquiry to understand this fundamental aspect of science (Edelson et al., 1999). It has also been suggested by Healy (2005a) that research-based learning structured around inquiry is one of the most effective ways for students to benefit from the research that occurs in departments. This is primarily

because undergraduate students are likely to gain most benefit from research in terms of depth of learning and understanding when they are involved actively, particularly through various forms of inquiry-based learning (Healy, 2005a). This approach has been demonstrated to enhance student learning, including the development of graduate attributes, and potentially leads to increased student enrolments and completions in graduate research programmes (Blackmore and Cousin, 2003). In this study, the primary objective of inquiry-based learning and research-led teaching approach to enhance students' critical thinking and target their learning needs through active participation in hands-on growth experimental research with sheep was achieved. The curiosity-stimulated, research-led teaching approach actively engaged the undergraduate students in Animal Production Systems Unit to reflectively ask questions, think innovatively about what they needed to do to get answers and motivated them to search and retrieve relevant information from published literature. This approach in combination with the livestock industry visits, seminar presentations, field trips and laboratory experiments was very effective in giving them a rich learning experience as indicated by empirical and quantitative evidence from the SETL scores. This finding is strongly supported by literature that "learning by doing" is an effective way for students to benefit from staff research (Gibbs, 1998; McLachlan, 2006). Further supporting evidence comes from the work of Blackmore and Cousin (2003) demonstrating that students involved in research-based inquiries acquire a more sophisticated level of intellectual development. This is because active learning is more likely to encourage students to adopt a deep approach to learning, than is the teacher-focused transmission model which may encourage a surface approach (Biggs, 2003; Brew and Boud, 1995; Prosser and Trigwell, 1999).

This research-led teaching approach and experimental exercise with sheep has undoubtedly made a significant contribution to the student learning experience in animal science and genetics through the development of students' critical thinking skills, statistical analytical skills and scholarly values going by the following student comments on the best aspects of teaching and support they received: *"The field practicals were very enjoyable, made me understand the subject very well. Assignment support was very helpful in that it gave me a diverse understanding of how to tackle animal science written report", "Field trips were an excellent component of this Unit. They were an opportunity to meet & hear from producers and very useful in gaining a practical knowledge of animal production industries", "BBQ and field trips to the Uni Farm – best aspects for me", "Felt that the seminars were a great way to learn", "Aduli is very diligent about giving people the best chance to learn and show their knowledge", "Very good at explaining topics, knew material very well and made subject matter interesting", "Encyclopaedic knowledge & an ability to explain clearly and precisely. Good interaction with students", "Plenty of diagrams & photos to develop good mental picture of concepts", "Good mid-semester test, helpful for learning", "Lectures and field experiments were really inspiring, lab helped understand material", "Excursions made it interesting".*

(v) Limitations: There were however, notable limitations to this study that need to be taken into account when interpreting our findings. Firstly, student error during the first few weeks of learning and acquiring skills and methodologies in body conformation measurements are likely to have influenced results, especially given that the same individual was not responsible for undertaking the same measurements each fortnight. Secondly, the relatively small sample size may not have provided a true representation of the population. Finally, information with respect to other key factors known to influence growth, for example age and parity of dam, type of birth (single, twin or multiple), was not available to statistically account for any likely variance they might have contributed to the observed results.

4. CONCLUSION

The significant interaction between sire genetics and sex in influencing average daily gains implies that prime lamb producers can make informed choices in their selection of crossbreds by preferentially utilizing White Suffolk wethers for a faster attainment of slaughter weight. This study further highlights the fact that sire breed and sex can affect lamb growth and that these factors require careful consideration in practical prime lamb management. As a consequence further expanded studies are required to conclusively ascertain how growth can best be maximised. It was also concluded that the real world, hands-on experience with sheep, field trips, data collection, statistical analyses, interpretation and seminar presentation of results facilitated a deeper student understanding of the scientific concepts of sire genetics and nutrition interactions in sheep growth.

ACKNOWLEDGEMENTS

This research was funded by the Australian Wool Education Trust (AWET) as part of a Teaching Development Grant Initiative. We are grateful to AWET. Thanks to Chris Gunn for looking after the crossbreeding aspects of the experimental design and daily management of the sheep as well the Tasmanian livestock industry members that helped with our student excursions to their properties. The senior author is also grateful to all his present and past undergraduate students for their voluntary participation in the standard University of Tasmania Student Evaluation of Teaching and Learning Survey at the end of the teaching semester.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- ABARE. (2010). Australian Commodities. Vol. 17, No. 2 June Quarter 2010. Appendix Table 16 and 19 ABARE Project 1163, Canberra.
- Afolayan, R.A., Fogarty, N.M., Gilmour, A.R., Ingham, V.M., Gaunt, G.M., Cummins, L.J. (2008). Reproductive performance, and genetic parameters in first cross ewes from different maternal genotypes. *J. Anim. Sci.*, 86, 804-814.
- Ahmad, N.A., Davies, H.L. (1986). Effect of sex and dietary energy concentration on feed conversion ratio, growth and carcass characteristics in Merino x Border Leicester lambs. *Proceedings of the Australian Society of Animal Production.*, 16, 119–122.
- Ames, D.R., Brink, D.R. (1977). Effect of temperature on lamb performance and protein efficiency ratio. *J. Anim. Sci.*, 44, 136-144.
- Annett, R.W., Carson, A.F., Dawson, L.E.R., Irwin, D., Kilpatrick, D.J. (2010). Effects of breed and age on the performance of crossbred hill ewes from Scottish Blackface dams. *Animal.*, 10, 356-366.
- Biggs, J. (2003). *Teaching for quality learning at University: What the student does.* 2nd edn. Buckingham: SRHE and Open University Press.
- Bignell, C.W., Malau-Aduli, A.E.O., Nichols, P.D., McCulloch, R., Kijas, J.W. (2010). East Friesian sheep carry a myostatin allele known to cause muscle hypertrophy in other breeds. *Animal Genetics*, 41, 445-446.

- Bird, P.R., Lynch, J.J., Obst, J.M. (1984). Effect of shelter on plant and animal production. *Animal Production in Australia.*, 15, 270–273.
- Blackmore, P., Cousin, G. (2003). Linking teaching and research through research-based learning. *Educational Developments.*, 4, 24–27.
- Borg, R.C., Notter, D.R., Kott, R.W. (2009). Phenotypic and genetic associations between lamb growth traits and adult ewe body weights in western range sheep. *J. Anim. Sci.*, 87, 3506-3514.
- Brew, A., Boud, D. (1995). Teaching and research: Establishing the vital link with learning. *Higher Education.*, 29, 261-173.
- Cake, M.A., Boyce, M.D., Gardner, G.E., Hopkins, D.L., Pethick, D.W. (2007). Genotype and gender effects on sheep limb bone growth and maturation: selection for loin depth causes bone hypotrophy. *Australian J. Expt. Agric.*, 47, 1128-1136.
- Cam, M.A., Olfaz, M., Soydan, E. (2010). Body measurements reflect body weights and carcass yields in Karayaka sheep. *Asian J. Anim. Vet. Advances.*, 5, 120-127.
- Department of Primary Industries, Parks, Water, and Environment (2009). Sheep body condition scoring. Available at [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LBUN-7XU78N/\\$FILE/SHEEPbodyscore.mlc.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LBUN-7XU78N/$FILE/SHEEPbodyscore.mlc.pdf) [Verified 16 May 2011]
- Dimoski, P., Tosh, J.J., Clay, J.C., Irvin, K.M. (1999). Influence of management system on litter size, lamb growth, and carcass characteristics in sheep. *J. Anim. Sci.*, 77, 1037-1043.
- Edelson, D.C., Gordin, D.N., Pea, R.D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *J. Learning Sci.*, 8, 391-450.
- Ellis, M., Webster, G.M., Merrell, B.G., Brown, I. (1997). The influence of terminal sire breed on carcass composition and eating quality of crossbred lambs. *Animal Sci.*, 64, 77-86.
- Fahmy, M.H., Boucher, J.M., Poste, L.M., Gregoire, R., Butler, G., Comeau, J.E. (1992). Feed efficiency, carcass characteristics, and sensory quality of lambs, with or without prolific ancestry, fed diets with different protein supplements. *J. Anim. Sci.*, 70, 1365-1374.
- Gibbs, G. (1998). *Learning by doing: A guide to teaching and learning methods*. London: Further Education Unit. www.glos.ac.uk/gdn/gibbs/index.htm (Accessed 13 August 2010).
- Hammell K.L., Laforest, J.P. (2000). Evaluation of the growth performance and carcass characteristics of lambs produced in Quebec. *Canadian J. Anim. Sci.*, 80, 25–33.
- Healey, M. (2000). Developing the scholarship of teaching in higher education: A discipline based approach. *Higher Educ. Res. Dev.*, 19, 169-189.
- Healey, M. (2003). The scholarship of teaching: issues around an evolving concept. *J. Excellence in College Teaching.*, 14, 5-26.
- Healy, M. (2005a). Linking research and teaching to benefit student learning. *J. Geography in Higher Education.*, 29, 183–201.
- Healy, M. (2005b). Linking research and teaching: exploring disciplinary spaces and the role of inquiry-based learning. In Barnett, R (ed). *Reshaping the University: New Relationships between Research, Scholarship and Teaching*. McGraw Hill / Open University Press, 67-78.
- Hegarty, R.S., Shands, C., Marchant, R., Hopkins, D.L., Ball, A.J., Harden, S. (2006a). Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 1: Growth and carcass characteristics. *Australian J. Agric. Res.*, 57, 593-603.
- Hegarty, R.S., Hopkins, D.L., Farrell, T.C., Banks, R., Harden, S. (2006b). Effects of available nutrition and sire breeding values for growth and muscling on the

- development of crossbred lambs. 2: Composition and commercial yield. *Australian J. Agric. Res.*, 57, 617-626.
- Hinton, D.G. (2006) 'Running a Small Flock of Sheep (2nd edn)'. (Landlinks Press: Victoria, AUS)
- Hodge, R.W., Star, M. (1984). Comparison of the fat status of lambs during continuous growth and following nutritional restriction and subsequent re-alimentation. *Australian J. Expt. Agric.*, 24, 150-155.
- Hopkins, D.L., Stanley, D.F., Martin, L.C., Ponnampalam, E.N., van de Ven, R. (2007). Sire and growth path effects on sheep meat production 1. Growth and carcass characteristics. *Australian J. Expt. Agric.*, 47, 1208-1218.
- Jones, S.D., Burgess, T.D., Dupchak, K., Pollock, E. (1984). The growth performance and carcass composition of ram and ewe lambs fed on pasture or in confinement and slaughtered at similar fatness. *Canadian J. Anim. Sci.*, 64, 631-640.
- Keys, C.W., Bryan, L.A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *J. Research in Science Teaching.*, 38, 631-645.
- Kuchtik, I., Dobes, I. (2006). Effect of some factors on growth of lambs from crossing between the Improved Wallachian and East Friesian. *Czech J. Anim. Sci.*, 51, 54-60.
- Lewis, R.M., Emmans, G.C., Dingwall, W.S., Simm, G. (2002). A description of the growth of sheep and its genetic analysis. *Animal Sci.*, 74, 51-62.
- Malau-Aduli, A.E.O., Holman, B. (2010). Genetics-nutrition interactions influencing wool spinning fineness in Australian crossbred sheep. *J. Anim. Sci.*, 88 (E-Suppl 2), 469.
- Malau-Aduli, A.E.O., Deng Akuoch, D.J. (2010). Wool comfort factor variation in Australian crossbred sheep. *J. Anim. Sci.*, 88 (E-Suppl 2), 860.
- Malau-Aduli, A.E.O., Ranson, C.F., Bignell, C.W. (2009a). Wool quality and growth traits of Tasmanian pasture-fed crossbred lambs and relationships with plasma metabolites. *J. Anim. Sci.*, 87 (E-Suppl 2), 499.
- Malau-Aduli, A.E.O., Walker, R.E., Bignell, C.W. (2009b). Prediction of wool fibre diameter from protein and metabolisable energy digestibility coefficients in crossbred sheep. *J. Anim. Sci.*, 87 (E-Suppl 2), 498.
- Malau-Aduli, A.E.O., Walker, R.E., Bignell, C.W. (2009c). Variation in sire genetics is an irrelevant determinant of digestibility in supplemented crossbred sheep. In: Y. Chilliard, F. Glasser, Y. Faulconnier, F. Bocquier, I. Veissier, M. Doreau (Editors), Wageningen Academic Publishers, The Netherlands. Proceedings of the XIth International Symposium on Ruminant Physiology, 6-9 September 2009, Clermont-Ferrand, France, 11, 278-279.
- Malau-Aduli, A.E.O., Walker, R.E., Ranson, C.F., Sykes, J.M., Bignell, C.W. (2009d). Nutrition-genetics interaction in nutrient utilization of canola and lupins by Australian sheep: Prediction of wool fibre diameter. In: D. Sauvant (Editor) Proceedings of the 7th International Workshop on Modelling Nutrition, Digestion and Utilization in Farm Animals, 10-12 September 2009, AgroParisTech, Paris, France., 7, 50.
- Malau-Aduli, A.E.O., Sykes, J.M., Bignell, C.W. (2009e). Influence of lupins and canola supplements on plasma amino acids, wool fibre diameter and liveweight in genetically divergent first cross Merino lambs. Proceedings of the World Congress on Oils and Fats & 28th International Society for Fats Research Congress, 27-30 September 2009, Convention & Exhibition Centre, Sydney, Australia., 28, 63.
- Malau-Aduli, A.E.O., Bond, G.H., Dunbabin, M. (2007). Influence of body weight and body condition score at breeding on conception and prolificacy of Merino and Composite Coopworth, East Friesian, Romney and Texel sheep in Tasmania, Australia. *J. Anim. Sci.*, 85 (Suppl 1), 663.
- McLachlan, J.C. (2006). The relationship between assessment and learning. *Medical Education.*, 40, 716-717.

- Mousa, E., Van Vleck, L.D., Leymaster, K.A. (1999). Genetic parameters for growth traits for a composite terminal sire breed of sheep. *J. Anim. Sci.*, 77, 1659–1665.
- Notter, D.R., Kelly, R.F., McClaugherty, F.S. (1991). Effects of ewe breed and management system on efficiency of lamb production: II. Lamb growth, survival and carcass characteristics. *J. Anim. Sci.*, 69, 22–33.
- Peeters, R., Kox, G., Van Isterdael, J. (1995). Environmental and genetic influences on growth performance of lambs in different fattening systems. *Small Rum. Res.*, 18, 57–67.
- Ponnampalam, E.N., Hopkins, D.L., Butler, K.L., Dunshea, F.R., Warner, R.D. (2007). Genotype and age effects on sheep meat production 2. Carcass quality traits. *Australian J. Expt. Agric.*, 47, 1147-1154.
- Prosser, M., Trigwell, K. (1999). *Understanding learning and teaching: The experience of higher education*. Buckingham: SRHE and Open University Press.
- Rowe, J.B. (2010). The Australian sheep industry - undergoing transformation. *Animal Prod. Sci.*, 50, 991-997.
- SAS. (2009). *Statistical Analysis System, Version 9.2*, SAS Institute, Cary, North Carolina.
- Sowande, O.S., Sobola, O.S. (2008). Body measurements of West African Dwarf sheep as parameters for estimation of live weight. *Trop. Anim. Health Prod.*, 40, 433-439.
- Thatcher, L.P., Maden, J.J.L., Plant, C.L. (1991). Influence of sex and year on carcass characteristics important in the marketing of second cross lambs. *Australian J. Expt. Agric.*, 30, 171-177.
- Western Australian Department of Agriculture and Food (2010). *Condition Scoring of Sheep*. [Online](Available online with updates at http://www.agric.wa.gov.au/PC_91885.html?s=417419591) (verified 27 May 2011).
- Wise, S.C., White, C.L., Masters, D.G., Milton, J.T.B., Davidson, R.H. (2003). The growth performance and carcass attributes of Merino and Poll Dorset x Merino lambs fed rumen-protected methionine (Smartamine (TM)-M). *Australian J. Agric. Res.*, 54, 507-513.
- Wolf, B.T., Smith, C., Sales, D.I. (1980). Growth and carcass composition in the crossbred progeny of six terminal sire breeds of sheep. *Animal Prod.*, 31, 307-313.