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Managing pre-slaughter stress to optimise glycogen

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EXECUTIVE SUMMARY

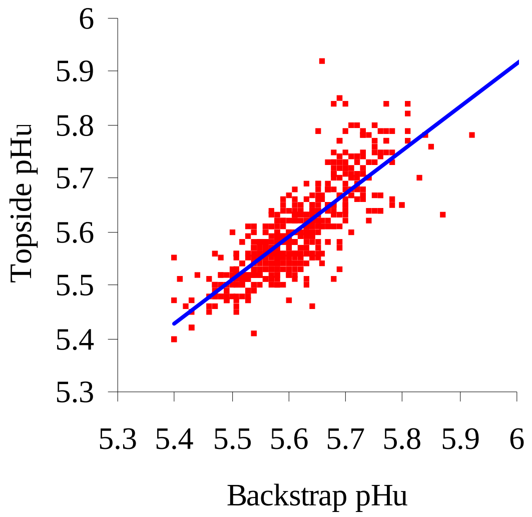
Overview

- This study consisted of two experiments. Experiment 1 investigated the potential for muscle glycogen loss due to stress and feed withdrawal during the transport and lairage periods undertaken with commercial slaughter. Experiment 2 tested the impact on muscle glycogen of feeding two levels of metabolisable energy and shearing prior to consignment for slaughter.

- In both experiments glycogen and ultimate pH (pHu) were measured in the topside and eye round muscles. Topside was chosen rather than backstrap due to practical difficulties encountered with sampling the backstrap in a commercial environment. The topside is more accessible than backstrap in both the live animal and carcass.

- Previous research has shown a strong correlation (figure 0.01) between backstrap and topside as these two muscles have a similar range of fibre types. By extrapolation affects seen in topside glycogen levels can be expected in backstrap glycogen levels as well. Eye round was measured as it has a different range of fibre types to both backstrap and topside that make it more susceptible to the affects of stress. It was included specifically to be an indicator of stress.

Figure 0.1 The correlation between backstrap and topside pHu



Experiment 1 Transport and Lairage

Background

- The aim of this experiment was to determine the affect of commercial transport and lairage on muscle glycogen and ultimate pH (pHu) for lamb over a range of transport and lairage periods.

- Measurements were taken from 1682 animals in 10 commercial consignments of lamb delivered to 5 different abattoirs.

- Three lairage periods; killed on arrival, killed on day 1 and killed on day 2 of lairage were included in the study. The affects of saleyards and extended lairage in abattoir holding pens were also examined but in one consignment only.

General Findings

- For topside 17% of carcasses had a pHu greater than 5.7 which can be taken as an estimate of the incidence of high pHu in backstrap under commercial conditions.

- For eye round 84% of carcasses had a pHu greater than 5.7, which confirms the greater susceptibility of this muscle has to stress compared to topside and backstrap.

- Muscle glycogen was strongly correlated with pHu. The mean pHu of all consignments and lairage periods for topside was 5.61 and for eye round was 5.97. The mean glycogen concentration of all consignments and lairage periods for topside was 1.13 g/100g and for eye round was 0.7 g/100g.

- Relationships were found between muscle glycogen, pHu and management factors and these relationships were complex.

- Lairage time, age type (sucker or carry over), time from paddock to slaughter, mustering time and carcass weight all had an affect on pHu. Of these factors age type (sucker or carry over) had the greatest impact on pHu. Transport and lairage times had relatively small affects but interacted with age type.

- Lairage time, age type (sucker or carry over), time from paddock to slaughter, mustering time, transport distance, and carcass weight all had an affect on muscle glycogen at slaughter. Of these factors mustering time had the greatest impact on muscle glycogen. Locating lambs close to yards on farm would be an advantage for preventing dark cutting.

- Feed type (pasture/grain) affected muscle glycogen measured on farm. There was evidence that this affect was at least part of the difference between sucker and carry over lambs. The results showed that research to improve sucker nutrition prior to consignment is warranted.

- Lairage time had a major impact on carcass weight and fat score. Significant adjusted hot carcass weight (0.95 x cold carcass weight) and fat score reductions occurred in the first but not the second day of lairage. Tissue hydration changes were thought to be involved as the changes were too great to be due to tissue breakdown alone. Further research into tissue hydration at slaughter may be warranted.

- High pHu was associated with lower carcass weight. Mean adjusted hot carcass weight was 1.0 kg lower for high pHu (both muscles above 5.7) carcasses than low pHu carcasses (both muscles below 5.7) in both sucker and carry over lambs.

- The optimal lairage times were different for ultimate pH, carcass weight and fat score. Optimal lairage time might therefore depend on the relative economic values of each parameter and the age type of the lambs (sucker or carry over).

Affects specific to Sucker Lambs

- Transport had no affect on glycogen in the topside but decreased it by 15% in the more stress sensitive eye round. Therefore transport caused some stress but the affect on muscle glycogen was relatively small.

- Sucker lambs had a higher mean pHu than carry over lambs. This was due to sucker lambs starting with lower muscle glycogen on farm as well as being more susceptible to stress. Suckers were weaned on the same day as consignment to slaughter and it was speculated that this may have predisposed sucker lambs to stress during transport and lairage

- 24 hour lairage was optimal for sucker lambs. The incidence of high pHu in topside on arrival was 29.4%, 19% on day 1 and 45.2% on day 2. Topside mean ultimate pH on day 1 was 0.5 units lower compared to the means on arrival and day 2.

- Saleyards caused a similar response to transport in the one consignment of sucker lambs for which this was measured. Eye round pHu was increased but topside pHu, topside glycogen and eye round glycogen were the same in comparison to lambs sent direct to abattoirs. (None of the carry over consignments went through saleyards to allow a similar comparison.)

- Sucker lambs were smaller than carry over lambs with a mean adjusted hot carcass weight of 18.1 kg and a fat score of 2.7. Sucker lambs lost 0.62 kg of carcass weight (3.4%) and 0.4 of a fat score in the first day of lairage.

Affects specific to Carry Over Lambs

- Carry over lambs coped well with stress and feed withdrawal in lairage. pHu of topside progressively declined from 5.57 on arrival to 5.56 on day 2. Muscle glycogen progressively increased by a small amount and this accounted for pHu going down over the same period.

- The resilience of carry over lambs to lairage stress was further reinforced with the one consignment that had extended lairage of 4 days. This involved hay feeding in abattoir yards and resulted in lower topside pHu compared to lambs killed on arrival. (None of the sucker consignments had extended lairage of 4 days to allow a similar comparison.)

- Grain based finishing rations resulted in higher muscle glycogen on farm than pasture. The pastures were of sufficient quality to provide muscle glycogen levels that would avoid dark cutting. However, this difference in relation to grain feeding suggests that low quality pasture would increase the risk of dark cutting (see experiment 2).

- Carry-over lambs were heavier and leaner than suckers with a mean cold carcass weight of 19.7 kg and a fat score of 2.45. They lost 1.73 kg of carcass weight (8.4%) and 0.3 of a fat score in the first day of lairage.

Experiment 2 Feeding and shearing prior to consignment for slaughter

Background

- The aim of this experiment was to measure the change in muscle glycogen over a 4 week period when shorn and unshorn sheep were offered a high energy diet compared to a low energy diet.

- 84 merino wether hoggets were used for this experiment under paddock conditions at Yalanbee Research Station, Bakers Hill.

General Findings

- A cereal based hay ration offered before the experiment resulted in body weight loss and basal muscle glycogen low enough to cause dark cutting.

- Changing the diet from cereal hay to a grain-based pellet diet caused a rapid increase in muscle glycogen.

- This nutritional affect occurred in both muscle types.

- The higher the ME intake the greater the increase in muscle glycogen.

- Feeding for the specific purpose of increasing muscle glycogen need only be for 7-14 days duration. After 7 days muscle glycogen declined at both levels of feeding but stabilised at new basal levels 14 days after the change from hay to the pelleted ration.

- The acute (immediate) effect of shearing was to reduce muscle glycogen by a small amount in the stress sensitive eye round muscle but not the topside. This was consistent with the affect of transport (experiment 1) and shows that topside was more resilient to stress than eye round.

- Shearing changed the lower critical temperature of sheep such that ambient temperatures during the experiment were sufficiently low to cause cold stress. This was determined by predictions using the Grazfeed^{TM} simulation model. It was predicted that shearing had a greater affect on ME requirements of sheep than did rain during the period of the experiment.

- Cold stress in combination with shearing caused reductions in muscle glycogen for eye round and topside in sheep fed restricted ME. This affect lasted until 4 weeks after shearing.

- Cold stress had no affect on muscle glycogen in well-fed sheep.

- Shearing stimulated appetite such that shorn sheep ate 7% more feed than the unshorn sheep fed to appetite, over the 4-week period of the experiment.

Finding on Stress Common to Both Experiments

- Transport (experiment 1), saleyards in suckers (experiment 1), and the acute affect of shearing (experiment 2), caused stress as demonstrated by a reduction in glycogen or an increase in pHu in the stress sensitive eye round. However in each case the degree of stress did not reduce glycogen or increase pHu in topside hence would not have caused dark cutting in higher value cuts such as backstrap.

- Further investigation is required to confirm this conclusion that stress associated with transport, saleyards and shearing had no detrimental impact on eating quality of higher value cuts. There may be affects of stress on eating quality other than those related to the level of muscle glycogen. Also there is a need to clarify the economic significance of low glycogen in low value cuts.

INDUSTRY COMMUNICATION

Several opportunities were taken to communicate some preliminary findings of this project to industry. Considerable interest was generated by these activities and field days in particular were very well attended.

Event	Date	Location	Presentation Type
[Ω]P M L A Accreditation Day	Feb 2000	Mingenew	Oral
[Ω]P M L A Accreditation Day	Feb 2000	Wyalcatchem	Oral
[Ω]P M L A Accreditation Day	March 2000	Corrigin	Oral
[Ψ]SSBA Annual Meeting	July 2000	South Perth	Oral
[Ω]P M L A Accreditation Day	Oct 2000	Gnowangerup	Oral
[Ω]P M L A Accreditation Day	Nov 2000	Northampton	Oral
[Ω]P M L A Accreditation Day	Nov 2000	Merredin	Oral
Recent Advances in Nutrition Conference	July 2001	Armidale	Poster
[θ]MLA Meat Profit Day	July 2000	Carnarvon	Poster
[Φ]L P D O meeting	Nov 2000	Cottesloe	Oral
Ag Victoria journal club meeting	Nov 2000	Werribee	Oral
[θ]MLA Meat Profit Day	Feb 2001	Adelaide	Poster
[θ]MLA On farm tips and tools Marketing: SMEQ01	Feb 2001	Sydney	Written article
[π]AGWA bulletin: The Good Food Guide for Sheep	June 2001	South Perth	Written article

[Ω]Prime merino lamb alliance, [Φ]Lamb product development officer, [Ψ]South Suffolk Breeders Association, [θ]Meat and Livestock Australia, [π]Agriculture Western Australia

GENERAL INTRODUCTION

Glycogen stored in muscle is converted to lactic acid post mortem by anaerobic glycolysis and is the major determinant of the acidity or pH of meat. Muscle pH declines after slaughter from about 7 in the live animal until glycolysis ceases, due to product inhibition of glycolytic enzymes, at which point the ultimate pH (pHu) is reached. Ultimate pHu affects several meat characteristics including colour, tenderness, flavour, and keeping qualities, all of which impact on consumer acceptance of red meat.

High pHu meat is darker than normal, tougher in the range of 5.7-6.2, has a stronger sheep flavour, has poorer keeping qualities, and takes longer to cook. Normal meat has a pHu of about 5.5 and meat with a pHu above 5.7 is known as dark cutting or dark firm and dry (DFD).

Glycogen is a polymer of glucose and is stored as an energy source for use within the muscle itself. The level of glycogen in muscle is a balance between factors that increase muscle glycogen such as a high plane of nutrition and factors that decrease muscle glycogen such as stress and intense exercise. A high plane of nutrition increases muscle glycogen by providing glucose substrate and by stimulating the release of insulin. Insulin has several activities including the activation of GLUT 4 transporters on muscle cell membranes enabling absorption of glucose from the blood, and activation of the enzyme glycogen synthase that catalyses glycogen synthesis.

Stress decreases muscle glycogen by the release of adrenaline, which causes activation of the enzyme glycogen phosphorylase and glycogen breakdown within muscle cells. Exercise causes muscle glycogen breakdown if intense or prolonged through release of adrenaline and by the contractile mechanism of muscle. Cold stress also activates the release of adrenaline to cause muscle glycogen breakdown.

Both muscle glycogen and pHu were measured in this study despite the fact that they are intrinsically linked. This was done to overcome the insensitivities of each measurement at the different ends of the normal range for muscle glycogen. Muscle glycogen is related to meat pHu in a negative exponential way (Warriss, 1990). At low muscle glycogen levels a small increase in muscle glycogen will result in a relatively large decrease in pHu. However at higher levels of muscle glycogen, levels greater than 1g/100g, changes in muscle glycogen cause relatively little change in pHu. Hence a change in muscle glycogen may not cause a detectable change in pHu when the glycogen level is greater than 1g/100g (figure 0.1). Similiarly at levels of muscle glycogen less than 1g/100g, a change in pHu may not be detected as a change in muscle glycogen. In the commercial situation the levels of muscle glycogen of sheep can be expected to vary along the normal range hence the need to do both measurements to gain a full understanding.

Two different muscles were examined in this study the topside (*m. semimembranosus)* and the eye round (*m. semitendinosus)*. The topside was used to represent the commercially important back strap whilst the eye round was used particularly to detect any affects of stress on muscle glycogen.

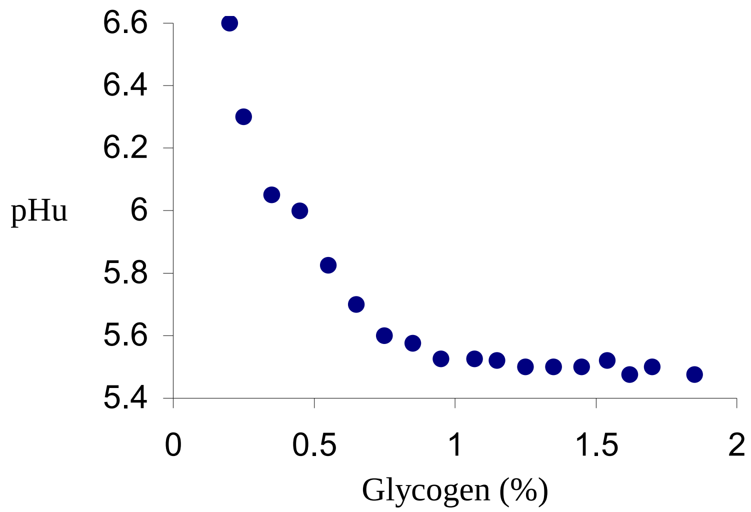
Muscle fibre types are broadly classified into the categories type I, IIA, and IIB according to their biochemical characteristics. Topside is of a similar type to the back strap (*m. longisimuss dorsi*) and is classified as a fast red or oxidative muscle type with a ratio of type I:IIA:IIB muscle fibres in sheep of 50:40:10 (Suzuki 1971; Aalhus and Price 1991). In previous studies we have found a positive linear relationship between back strap pHu and topside pHu (r^2= 0.67, $p<0.05$). The advantage that topside has over the back strap from a research point of view is that it can be sampled in both the live animal and carcass after slaughter by causing minimal intervention. Lamb differs from beef in that the carcass is split at the boning out stage making back strap measurements of commercial consignments logistically more difficult for lamb.

The eye round lies adjacent and lateral to the topside and is easily accessible in both live animal and carcass as well. In contrast to topside, eye round is classified as a fast white muscle tissue or oxido-glycolytic, and has fibre ratios of 34:56:10 in sheep (Suzuki, 1971); (Aalhus and Price, 1991).

The two muscle types respond differently to hormonal control. In ruminants the GLUT 4 content is higher in glycolytic and oxido-glycolytic muscles than oxidative muscles hence the glycolytic and oxido-glycolytic muscles are the major site of insulin mediated glucose utilisation and the oxidative muscles are the major site of non insulin mediated glucose utilisation (Weekes et al., 2000).

With lower proportions of Type I fibres, eye round is characterised by low levels of glycogen, low rates of glycogen resynthesis and a high susceptibility to stress induced glycogen depletion. As such it is a more sensitive indicator of stress than fast red muscles such as the topside.

Figure 0.02 The relationship between pHu and the concentration of glycogen in muscle (backstrap) post-slaughter
(adapted from Warriss, 1990)).



MAIN REPORT EXPERIMENT 1

The affects of transport and lairage on muscle glycogen and ultimate pH in lamb

Hypotheses

- Commercial transport and lairage deplete muscle glycogen due to stress and feed withdrawal prior to slaughter.

- Muscle glycogen at slaughter is related to the time in transit and lairage. Long transit and or lairage are expected to cause low muscle glycogen and high ultimate pH (pHu).

Aim

- To measure glycogen in topside and eye round at different points of the commercial lamb delivery process: on farm, after transport and at different times in lairage.

- To measure pHu in topside and eye round from lambs killed after different transport and lairage periods.

Methods

Ten commercial consignments of lamb from nine different farms were sampled for muscle glycogen and pHu. Four were sucker lambs weaned at the time of slaughter and six were carry-over lambs weaned several months before slaughter.

The first muscle samplings were taken on farm using live animals representative of consigned sheep, done on the day of embarkation from the farm in most cases. The muscle biopsy technique using local anaesthetic enabled collection from live animals. Twenty lambs were sampled this way for each consignment and all samples collected were analysed for glycogen and lactate. Farm biopsy results were obtained from a further 3 properties using carry over lambs.

For each consignment 50 lambs were killed on arrival, 50 at 24 hours, and 50 at 48 hours after arrival in lairage with samples being collected from each carcass. In one consignment, consignment E, these three lairage periods could not be used because of marketing decisions made by the abattoir. Instead 50 were killed on arrival and the balance of the consignment was put into a holding yard, fed hay and killed 4 days after arrival. The results from this consignment were included in the analysis of transport affects and extended lairage as a special case.

Muscle samples were collected in abattoir chiller rooms within 60 minutes of slaughter from both topside and eye round muscles and placed in liquid nitrogen immediately. Ultimate pH was measured at 48 hours post slaughter with an Orion model 250A pH metre (Orion Research Incorporated, USA) with a glass body, spear tipped, Ross type probe (Cat. No. 8163B Orion Research Incorporated, USA) using temperature compensation. Both muscles on every carcass of each consignment were measured. For all 10 consignments glycogen and lactate analyses were done on half the samples collected, being from 25 carcasses for each consignment and lairage time. Glycogen concentration in muscle was measured using the enzymatic method of (Chan and Exton, 1976), modified by removing the filter paper step. Glycogen concentration represented the sum pf glycogen plus free glucose and does not account for glucose-6-phosphate or glucose-1-phosphate. Lactate concentration was determined by the method of (Noll, 1985).

Information about the husbandry system used to raise the lambs, preparation methods prior to slaughter and trucking details was collected from participating farmers via a standard questionnaire at the time of trucking. Eight consignments were raised on pasture and two were finished in feedlots. Data from 3 consignments from other studies was included to allow comparison of on farm muscle glycogen for lambs finished on different feed types, specifically grain versus pasture.

For the pasture-reared consignments an assessment was made of the food on offer available in paddocks grazed by the lambs. Pasture samples were collected at the time of sale for nutritional analyses including digestible energy and crude protein. For the feedlot consignments details of the feeding regime were collected as well as a feed samples for analyses, the same as for the pasture consignments.

Carcass weight and fat score details were recorded at the time of muscle sample collection from information printed on individual carcass tags. Carcass weight recorded on the tag was measured as a hot weight when the carcass was at the end of the slaughter chain. It was then converted to a cold weight equivalent (adjusted hot weight) by multiplying each hot weight by the constant 0.95. Fat score measurement techniques varied between abattoirs. At Shark Lake abattoir fat thickness was measured with a ruler at the GR site. In other abattoirs inspectors used a manual palpation technique at the GR site. This was standard practice at these abattoirs and was regulated by a quality assurance protocol with daily auditing. The fat measurement data from Shark Lake abattoir was converted to a fat score to conform to data from other abattoirs.

Results

Description of the consignments

Table 1.01 Sheep age

Consignment	Slaughter Age (days)	Weaning Age (days)	Weaning to slaughter (days)	Age class
A	142	140	2	Sucker
B	119	117	2	Sucker
C	205	197	8	Sucker
D	123	121	2	Sucker
E	NA*	NA*	NA*	Carry over
F	333	126	207	Carry over
G	333	126	207	Carry over
H	336	138	218	Carry over
I	316	101	215	Carry over
J	393	108	285	Carry over
K$^{\Phi}$				Carry over
L$^{\Phi}$				Carry over
M$^{\Phi}$				Carry over

Values are means

NA* accurate age data was not available for sheep in this consignment They had been purchased at saleyards and kept for approximately 6 weeks before sale for slaughter.

$^{\Phi}$ Consignments K, L, and M are from another study and were included for the purpose of comparing on farm glycogen levels only (Figure 1.18). Abattoir data was not available for these consignments.

Table 1.02 Genotype history

Consignment	Sire breed	Dam breed	Breed type
A	Poll Dorset, Border Leicester, Texel	Merino	1st cross
B	White Suffolk	Merino	1st cross
C	Poll Dorset	Merino	1st cross
D	Suffolk	Merino	1st cross
E	Poll Dorset, White Suffolk	Merino	1st cross
F	Merino	Merino	Purebred
G	Merino	Merino	Purebred
H	Texel, Suffolk	Merino/Border Leicester	2nd cross
I	White Suffolk	Merino	1st cross
J	Merino	Merino	Purebred
K^{Φ}	Merino	Merino	Purebred
L^{Φ}	Merino	Merino	Purebred
M^{Φ}	Merino	Merino	Purebred

There was 6 pure merinos, 6 first cross and 1 second cross consignments. In 3 of the first cross consignments 2 or more breeds were used as sires. Suckers made up 4 consignments and carry over lambs 9 consignments.

Table 1.03 Transport times and distance.

Consignment	Mustering (hours)	Curfew (hours)	$^{\Psi}$Travel (hours)	$^{\Phi}$Truck (hours)	*Total (hours)	Distance (kilometres)
A	0.5	6.5	5	17	24	320
B	1	18	1.5	1.5	20.5	165
C	1	7.5	6	15	23.5	420
D	1.25	24	1.5	1.5	26.75	160
E	0.5	4.5	7	19	25	600
F	1.25	14	2	2	17.25	100
G	1.25	22	8	17	40.25	630
H	0.25	16	9	9	25.25	532
I	0.1	14	0.5	0.5	14.6	6
J	1	13	7	7	21	230
Mean	0.81	13.95	4.75	8.95	23.81	316.3

Values are means

$^{\Phi}$Travel time is the period when the truck was moving.

$^{\Phi}$Time on the truck included moving time and stationary time.

*Total paddock to abattoir time is the sum of mustering time, farm curfew time and time on truck. Total time off feed was the paddock to abattoir time plus the lairage time that varied according to the lairage treatment. This is presented in table 1.04.

Apart from consignment G that took nearly 2 days, most consignments took about 1 day to be mustered from the paddock and delivered to an abattoir. Farm curfew time was negatively correlated with trucking time and time from paddock to abattoir, that is farm curfew time decreased as travel time increased.

Equation 1.01 correlation between farm curfew time and trucking time

$y = 17.006-0.66x-0.22x^2$,

$r^2 = 0.446$, $p<0.01$,

y = trucking time, x = farm curfew time.

Table 1.04 Time from paddock to slaughter (hours)

Consignment	Lairage category		
	Arrival	Day 1	Day 2
A	24	48	72
B	20.5	44.5	68.5
C	23.5	47.5	71.5
D	26.75	50.75	74.75
E	25	49	73
F	17.25	41.25	65.25
G	40.25	64.25	88.25
H	25.25	49.25	73.25
I	14.6	38.6	62.6
J	21	45	69

Values are means

Table 1.05 Age at weaning and slaughter (days)

	Age group		[y]Significance
	Sucker	Carry over	
Weaning age	144±1.2[a]	119±0.5[b]	**
Slaughter age	147±1. [a]	346±1.2[b]	**
Weaning to slaughter	3±0.1[a]	227±1.1[b]	**

Values are means ±standard errors.[y] ** p <0.01 values with different superscripts within rows are different.

Table 1.06 Farm and abattoir locations

Consignment	Farm Location	Abattoir Location
A	Carnamah	Lynley Valley
B	Boyup Brook	Bunbury
C	Mt. Barker	Lynley Valley
D	Boyup Brook	Bunbury
E	Lort River	Bunbury
F	Esperance	Esperance
G	Esperance	Katanning
H	Esperance	Katanning
I	Wooroloo	Lynley Valley
J	Beacon	Lynley Valley
K	Quairading	Lynley Valley
L	Pingelly	Narrogin
M	Pingelly	Narrogin

There were five different abattoirs used. Consignments F and G were from the same farm hence of the same genotype and grown under the same management system. The kills for these two consignments were coordinated to be on the same times and days such that the major difference between these two apart from the abattoir was transport time and distance.

Table 1.07 Pasture quantity and quality for the consignments finished on pasture

Consignment	Growth stage	Food on Offer (kg/ha)	Crude protein (%)	DE (MJ/kg)	Ψ Predicted growth rate (grams/head/day)
A	mature	4600	9.49	9.57	179
B	mature	4200	9.20	8.83	62
C	mature	NA*	NA*	NA*	NA
D	mature	1500	16.2	7.1	-18
E	vegetative	900	15.32	9.54	204
E^{Φ}	vegetative	500	9.6	8	61
E^{Φ}	pasture hay	Ad lib	19.0	10.1	115
F	vegetative	1500	18.1	11.1	134
G	vegetative	1805	14.6	9.50	94
H	vegetative	900	15.5	11.30	20

NA* samples were not available at the time of sampling

$^{\Phi}$ For consignment E, abattoir management intervened after the first group was killed on arrival, as the lambs were heavier than the buyer had expected. As markets for heavy lambs were limited, the remainder of the consignment was held in an abattoir holding yard and slaughtered on day 4 after arrival. The holding yard was vegetated with green Kikuyu grass and the lambs were also fed ad lib pasture hay from a large round bale.

Table 1.08 Feed quantity and quality for the consignments finished on concentrated diets

Consignment	Ingredient	Quantity (kg/hd/day)	Crude protein %	DE (MJ/kg)	Ψ Predicted Growth rate (grams/head/day)
I	ΦPellet, Oats, hay	Ad lib	16 NA*	9.5 NA*	50
J	ΩPellet, Hay	Ad lib	12.5 9.2	10.10 4.5	10
K	Oats, lupins, hay	Ad lib	18.05	11.2	120
L	Oats, lupins	Ad lib	18	11	100
M	Oats, lupins	Ad lib	18	11	100

Φ Q lamb ™ pellet, Ω WAMMCO Prime Merino Lamb Alliance finishing pellet Ψ Growth rates were predicted from feed availability using the Grazfeed simulation model

Table 1.09 Slaughter dates

Consignment	Lairage category			
	Arrival	Day 1	Day 2	Day 4
A	11-Oct-99	12-Oct-99	13-Oct-99	
B	17-Nov-99	18-Nov-99	19-Nov-99	
C	7-Dec-99	8-Dec-99	9-Dec-99	
D	15-Dec-99	16-Dec-99	17-Dec-99	
E	20-Mar-00			24-Mar$^{\Phi}$
F	11-Apr-00	12-Apr-00	13-Apr-00	
G	11-Apr-00	12-Apr-00	13-Apr-00	
H	6-Jun-00	7-Jun-00	8-Jun-00	
I	19-Jun-00	20-Jun-00	21-Jun-00	
J	26-Jun-00	27-Jun-00	28-Jun-00	

$^{\Phi}$ See table 1.07

Ultimate pH

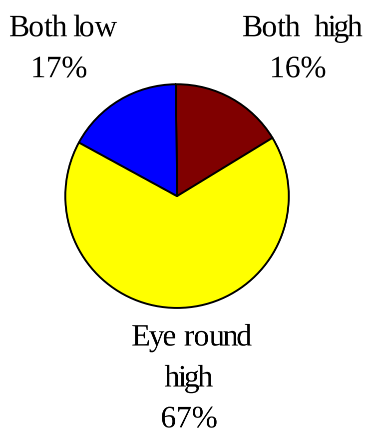
Ultimate pH data is presented in both continuous and categorical formats. In the continuous format means were compared whereas in the categorical format values were classified as being above or below the value of 5.7 (5.71 or greater) and then frequencies of carcasses within each category were compared. Both methods were used as categorical classification was thought to bear some practical relevance to industry. Grading systems in the beef industry for example discriminate between high and low pH and the rate of payment can depend on such classification

The system used to categorise carcasses according to pH is described in table 1.10. In this system the pHu from both muscles were considered together and this created 4 discrete categories. There were 3 carcasses where the topside pHu exceeded 5.7 and the eye round was less than 5.7. With such a low frequency this result might be expected to be a measuring error and from a theoretical viewpoint such an outcome is not expected. If this category is disregarded there are 3 pHu categories of which the high eye round category was the most common (figure 1.01). With such a low frequency disregarding this category will not alter the outcome of any analyses.

Table 1.10 Classification of carcasses according to pHu

	Muscle	
pHu category	Topside	Eye round
Both low	≤ 5.71	≤ 5.71
Eye round high	≤ 5.71	≥ 5.71
Topside high	≥ 5.71	≤ 5.71
Both high	≥ 5.71	≥ 5.71

Figure 1.01 The frequency of each pHu category for 10 consignments



N = 1392

Table 1.11 Ultimate pH of topside and eye round for each consignment

Consignment	Topside	Eye Round

A	5.68^{g}	6.03^{cd}
B	5.67^{f}	6.17^{e}
C	5.63^{e}	5.83^{ab}
D	5.76^{h}	6.1^{d}
E*	5.58^{bc}	5.87^{b}
F	5.57^{bc}	5.92^{b}
G	5.6^{d}	6.07^{d}
H	5.54^{ab}	5.98^{c}
I	5.52^{a}	5.78^{a}
J	5.58^{c}	5.88^{b}
Mean	5.61	5.97

Superscripts denote a significant difference between consignments ($p<0.05$) within each column.

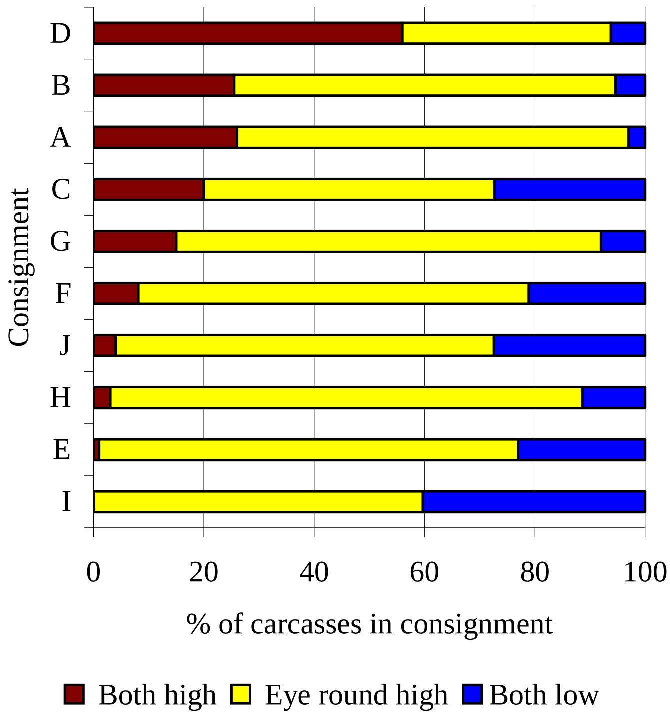
* Only one lairage period was included in this result (see methods).

Table 1.12 The affect of consignment on the frequency of each pHu category.

Consignment	pHu category		
	Both high (%)	Eye round high (%)	Both low (%)
A	25.5	71.1	3.4
B	25.5	69.1	5.4
C	20	52.7	27.3
D	56	37.9	6.2
E	1	76	23
F	8.2	70.7	21.1
G	14.3	76.9	8.2
H	3	85.6	11.4
I	0	59.7	40.3
J	4	68.5	27.4

Values are means.

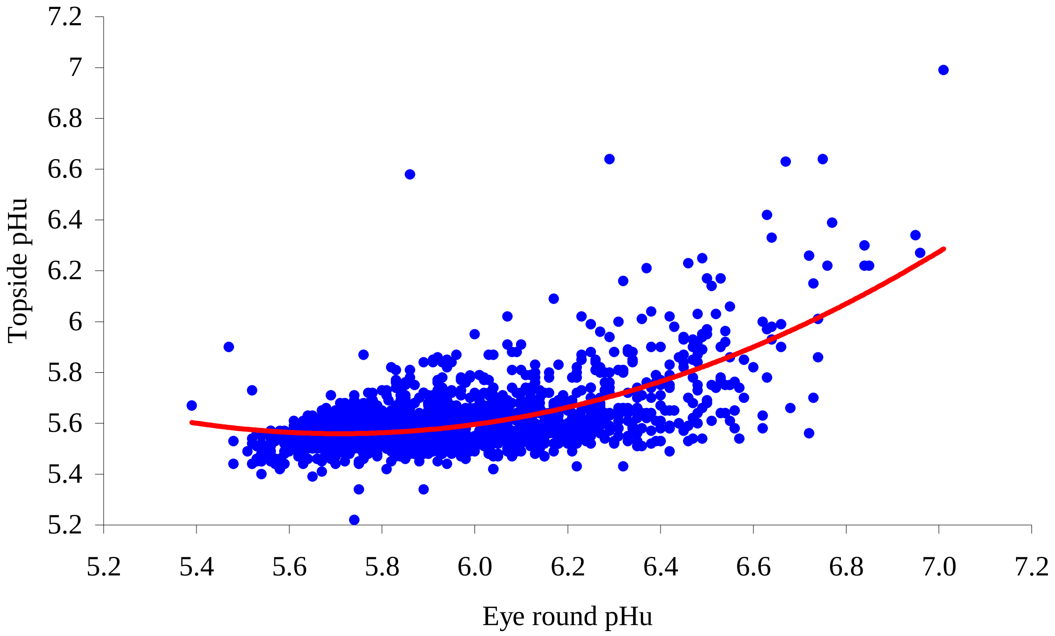
Figure 1.02 The affect of consignment on the frequency of each pHu category



Correlation between the pHu of eye round and the pHu of topside muscles

A curvilinear relationship existed between pHu of the eye round and pHu of the topside.

Figure 1.03 The correlation between eye round pHu and topside pHu



Equation 1.02 The correlation between the pHu of topside and pHu of eye round.

$y = 19.618 - 4.921x + 0.431x^{2.}$

y = topside pHu

x=eye round pHu

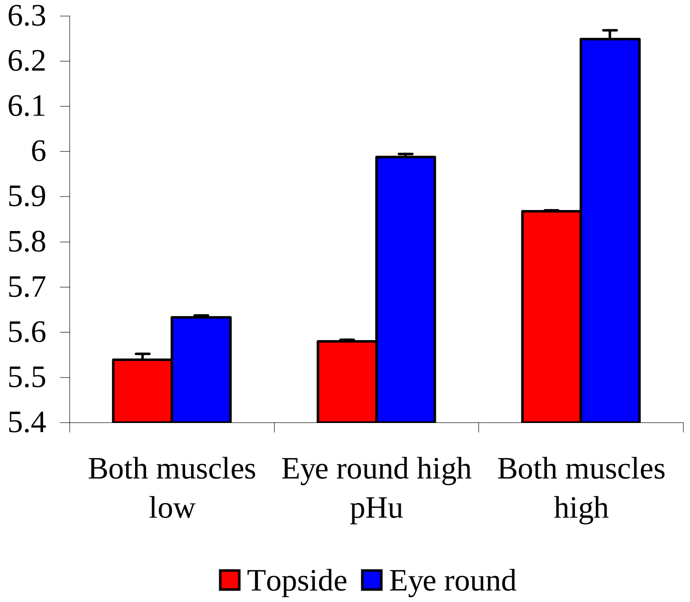
$r^2 = 0.39$ $p<0.01$

Table 1.13 Mean pHu of topside and eye round for each pHu category.

Muscle	pHu category			Significance of effect (P)[y]
	Both high	Eye round high	Both low	
Topside	5.87 ± 0.013^a	5.58 ± 0.003^b	5.54 ± 0.003^c	**
Eye round	6.25 ± 0.019^a	5.99 ± 0.007^b	5.63 ± 0.004^c	**

Values are means ± sem, [x] Superscripts denote a difference within a row [y] ** P<0.01

Figure 1.04 Mean pHu of topside and eye round for each pHu category



Comparison of pHu in sucker and carry over lambs

Sucker lambs had higher mean pHu for both topside and eye round muscles ($p<0.01$) and were more likely to be in the high pHu category compared to carry over lambs. Similiarly carry over lambs were more likely to be in the low pHu category than sucker lambs.

Table 1.14 Ultimate pH of topside and eye round for sucker and carry over lambs.

Muscle	Age group		Significance (P)[y]
	Carry over	Sucker	
Topside	5.57±0.003	5.69±0.007	**
Eye round	5.93±0.009	6.03±0.012	**

Values are means ± sem, those with different superscipts are different. [y] ** p<0.01

Table 1.15 Percentage of carcasses in each pHu category for carry over and sucker lambs.

pHu category	**Age group**		**Mean**
	Carry over	**Sucker**	
Both muscles low	21.9	10.6	17.1
Eye round only high	72.6	57.8	66.3
Both muscles high	5.4	31.2	16.4
Mean	57.4	42.6	

Values are means Age group was significant (p<0.01)

Figure 1.05 Mean ultimate pHu of topside for sucker and carry over lambs

Columns with different superscripts are different.

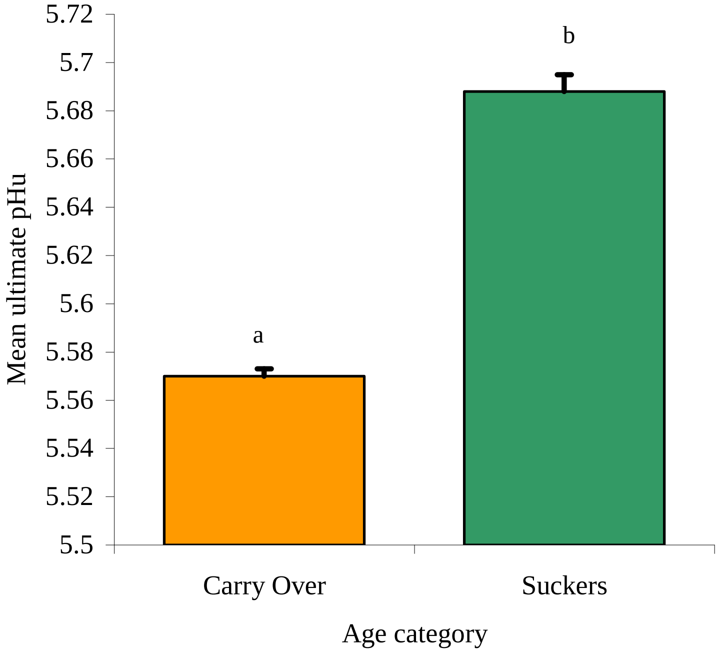


Figure 1.06 Mean ultimate pHu of eye round for sucker and carry over lambs

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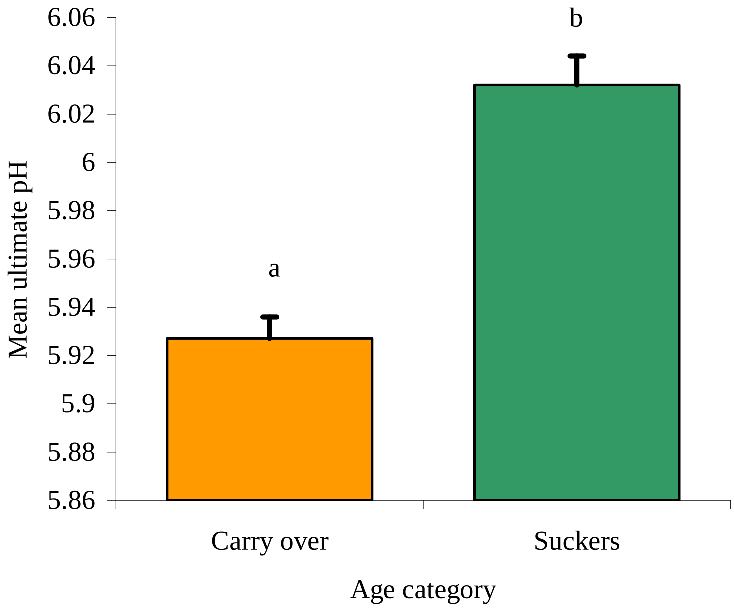
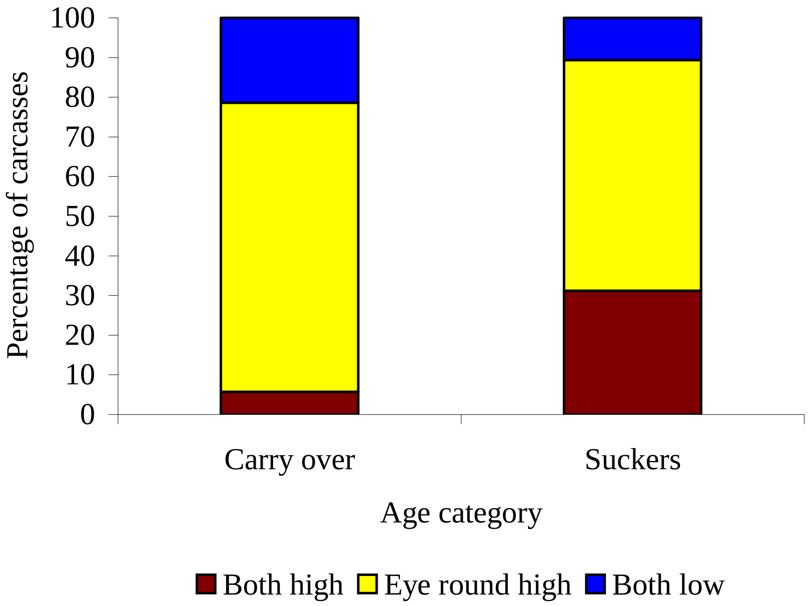


Columns with different superscripts are different

Figure 1.07 The effect of age category percentage of carcasses in each pHu category



The affect of lairage on topside ultimate pH

There was a significant affect of lairage on topside ultimate pH with an interaction between lairage time and age category such that the pHu change during lairage was different in sucker lambs compared to carry over lambs (table 1.16). For sucker lambs the day-1 lairage group had a significantly lower pHu than the day-2 and arrival lairage groups. For carry over lambs the 2-day lairage pHu was significantly lower than for arrival and day-1 lairage.

Lairage also reduced the standard error for pH data for the topside muscle in sucker lambs on day 2. As a result the magnitude of the changes in mean pH between day 1 and day 2 as well as arrival and day 2 underestimate the change in the percentage of carcasses above pH 5.7 (see table1.16 and figure 1.10).

Table 1.16 The affect of lairage on ultimate pH in the topside for sucker and carry over lambs.

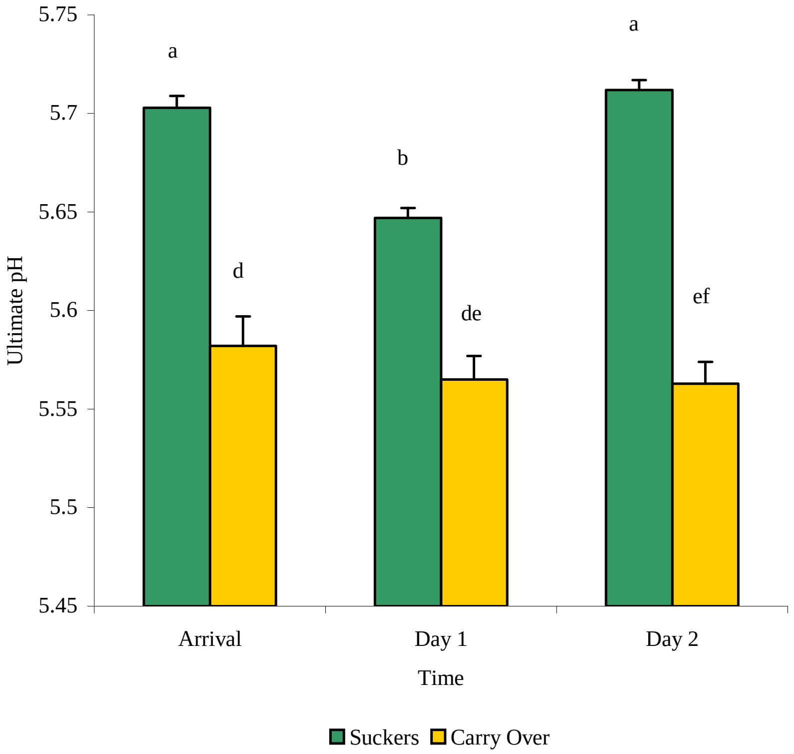
	Lairage category ^{x}			
Age Group	**Arrival**	**Day 1**	**Day 2**	**Significance of effect (P)^{y}**

Sucker	5.70±0.015[a]	5.65±0.012[b]	5.71±0.011[a]	**
Carry over	5.58±0.007[a]	5.57±0.005[ab]	5.56±0.005[bc]	**
Mean	5.63±0.007[a]	5.60±0.006[b]	5.63±0.007[c]	**

Values are mean ± standard error of the mean (sem).

[x] Values within rows with different superscripts are different. [y] ns - not significant, ** - P<0.01

Figure 1.08 Ultimate pH of topside for different lairage times and age groups.



Values are means±se, columns with different superscripts are different (p<0.05), ab superscripts compare sucker columns and def superscripts compare carry over columns.

The affect of lairage on eye round ultimate pH

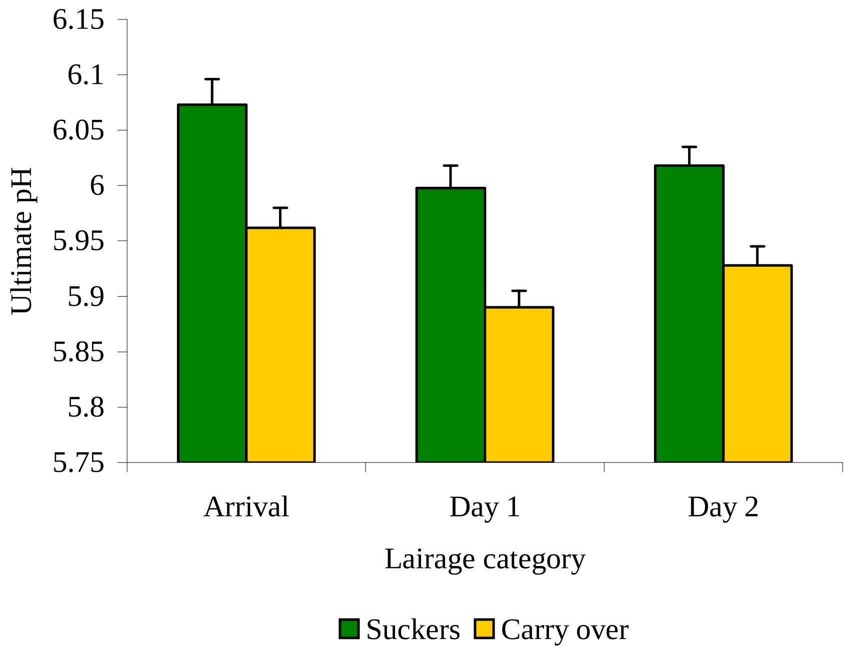
There was a significant although small affect of lairage on pHu of the eye round muscle. The interaction seen with the topside did not occur such that suckers responded to lairage the same way as carry over lambs for eye round pHu.

Table 1.17 The affect of lairage on ultimate pH in the eye round for sucker and carry over lambs.

	Lairage category [x]			
Age Group	Arrival	Day 1	Day 2	Significance of effect (P)[y]
Sucker	6.07 ±. 023[a]	6.0 ± .02[b]	6.02 ± .017[ab]	**
Carry over	5.96 ± .018[c]	5.89 ±0.015[d]	5.93 ± .017[cd]	**
Mean	6.0±0.014[a]	5.94±0.012[b]	5.97±0.012[c]	**

Values are mean ± standard error of the mean (sem) [x] Values within rows with different superscripts are different. [y] ns - not significant, ** - P<0.01

Figure 1.09 Ultimate pH of eye round for different lairage and age categories.



The affect of lairage on pHu category

Table 1.18 Percentage of sucker lamb carcasses in each pHu category for each lairage category

pHu category	Lairage category Arrival	Day 1	Day 2	Mean
Both low	11.4	16.4	4	10
Eye round high	59.2	63.6	50.7	57
Both high	29.4	19	45.2	31

Figure 1.10 Percentage of sucker carcasses in each pHu category for each lairage category

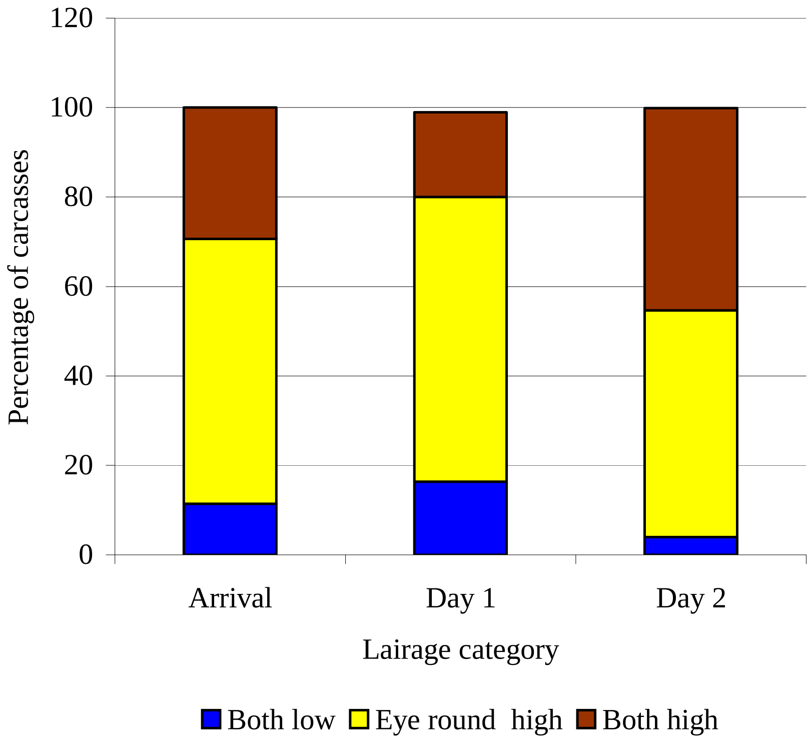
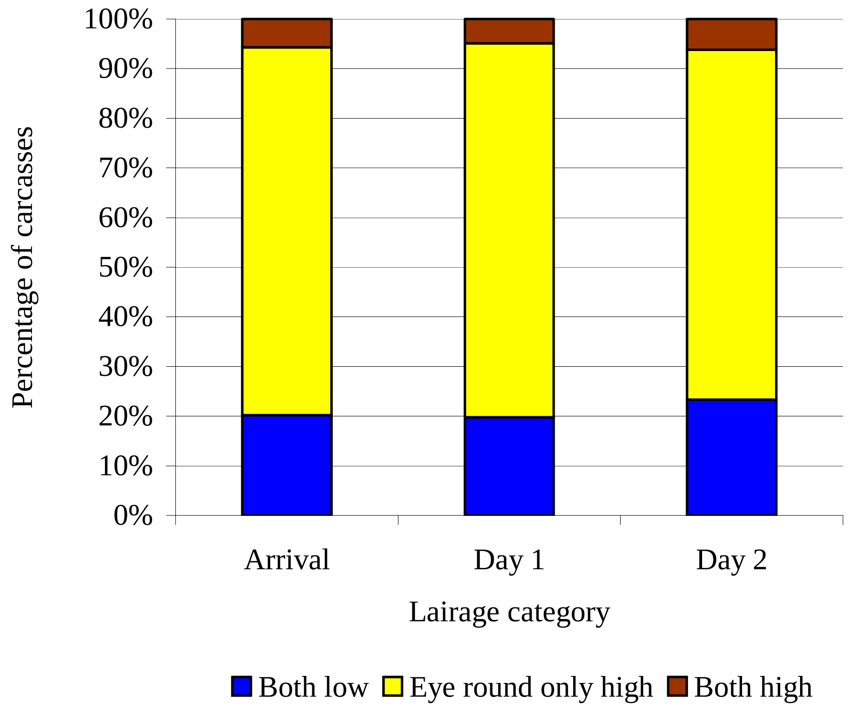


Table 1.19 Percentage of carry over lamb carcasses in each pHu category for each lairage category

	Lairage category	Mean

pHu category	Arrival	Day 1	Day 2	
Both low	20.2	19.4	23.2	21
Eye round high	74	74	70	73
Both high	5.7	4.8	6.2	5.5

Figure 1.11 Percentage of carry over lambs in each pHu category at each lairage category



The affect of sex on muscle ultimate pH

Sex had no affect on ultimate pH in either of the two muscles.

Table 1.20 Comparison between ewe and wether mean muscle ultimate pH in topside and eye round muscles

Muscle	Sex category		Significance[y]
	Ewe	Wether	
Topside	5.62±0.006	5.62±0.006	NS
Eye round	5.96±0.010	5.98±0.011	NS

Values are mean ± standard error of the mean (sem). [y] ns - not significant, ** - P<0.01

Glycogen

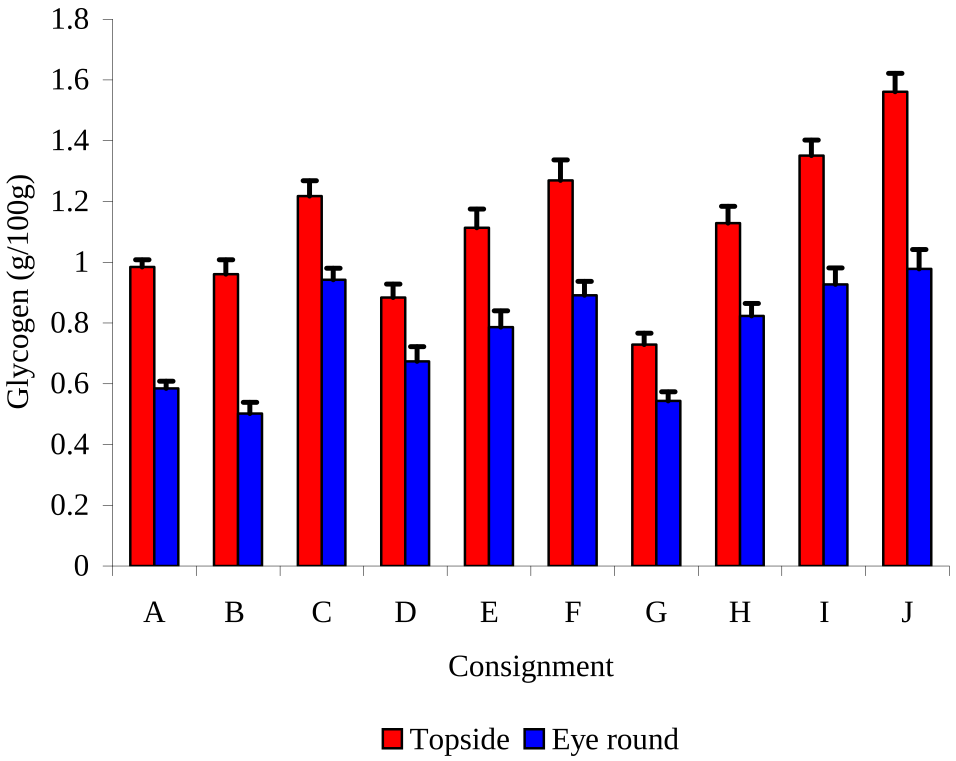
Variation in muscle glycogen between consignments

Mean muscle glycogen on farm (table 1.21 and fig. 1.12) varied between consignments ($p<0.01$) and was below 1g/100g on 4 properties. Notably there was a significant difference between consignments F and G. Sheep in these two consignments were from the same property, genotype and feed system but different paddocks.

Table 1.21 On farm muscle glycogen in topside and eye round for each consignment.

Consignment	Muscle	
	Topside	Eye round
A	0.99±0.023	0.59±0.024
B	0.96±0.047	0.50±0.037
C	1.22±0.05	0.94±0.037
D	0.88±0.044	0.67±0.048
E	1.11±0.061	0.79±0.053
F	1.27±0.068	0.89±0.046
G	0.73±0.037	0.54±0.030
H	1.13±0.055	0.82±0.041
I	1.35±0.052	0.93± 0.054
J	1.56±0.061	0.98±0.064
Mean	1.13±0.010	0.70±0.008

Figure 1.12 On farm muscle glycogen in topside and eye round for each consignment.



Affect of age type on muscle glycogen

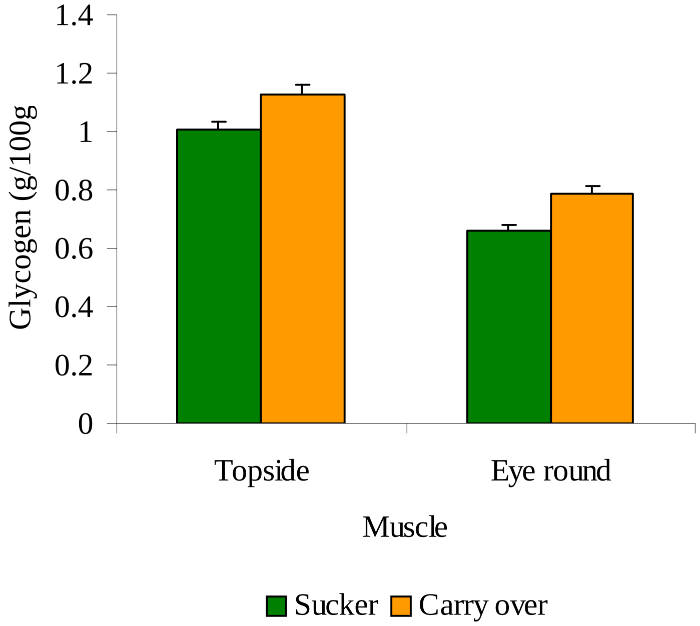
Carry over lambs had higher muscle glycogen than sucker lambs (table 1.22 and fig 1.13).

Table 1.22 Comparison between sucker and carry over lambs of mean muscle glycogen in topside and eye round on farm

Muscle	Age category		Significance (P)
	Sucker	Carry over	
Topside	1.01±0.022	1.13±0.032	**
Eye round	0.66±0.023	0.79±0.023	**

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.0

Figure 1.13 Comparison between sucker and carry over lambs of muscle glycogen in topside and eye round on farm



Transport and lairage affects on muscle glycogen

Transport decreased glycogen in the eye round but had no affect on glycogen in the topside (table 1.23).

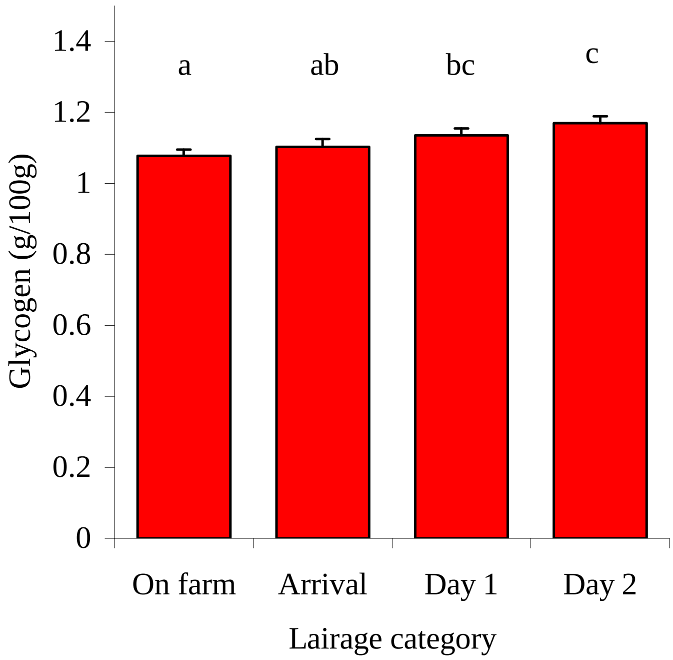
Table 1.23. Muscle glycogen on farm and at each lairage period in topside and eye round

(Consignment E not included, as data was not available for day 1 and day 2 lairage periods for this consignment)

Muscle	Sample Time				Significance
	On Farm	Arrival	Day 1	Day 2	(P)[y]
Topside	1.08±0.022	1.10±0.019	1.14±0.02	1.17±0.018	**
Eye round	0.73±0.018	0.65±0.017	0.67±0.015	0.69±0.016	**

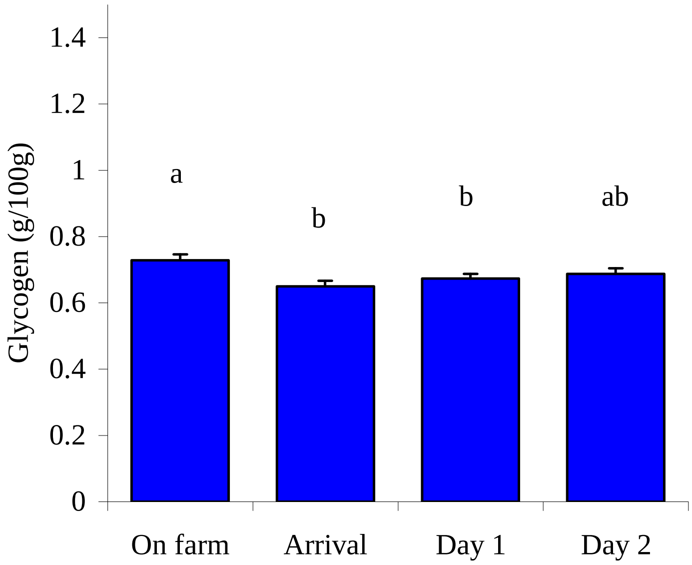
Values are mean ± standard error of the mean (sem) [y] ** - P<0.01

Figure 1.14 Glycogen in topside muscle on farm and at each lairage time



Different superscripts denote a significant difference p<0.05. Data includes sucker and carry over consignments

Figure 1.15 Glycogen in eye round muscle on farm and at each lairage time



Different superscripts denote a significant difference p<0.05. Data includes sucker and carry over consignments.

Figure 1.16 Comparison between suckers and carry over lambs for glycogen in topside muscle on farm and at each lairage time

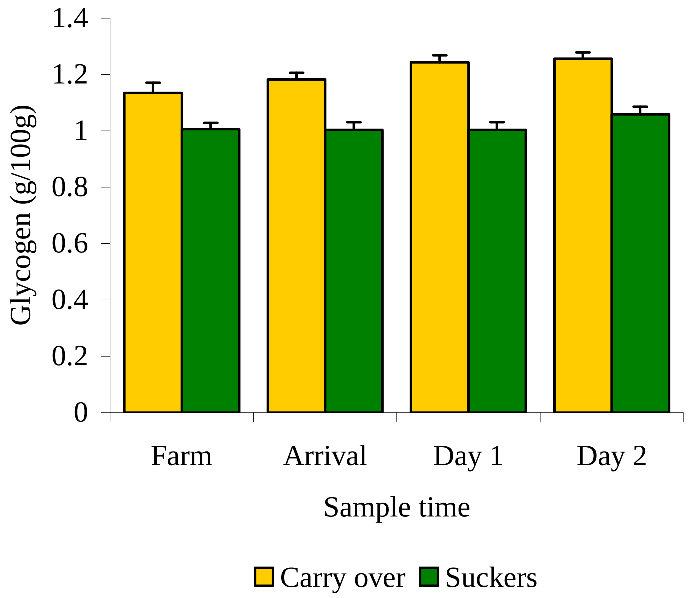
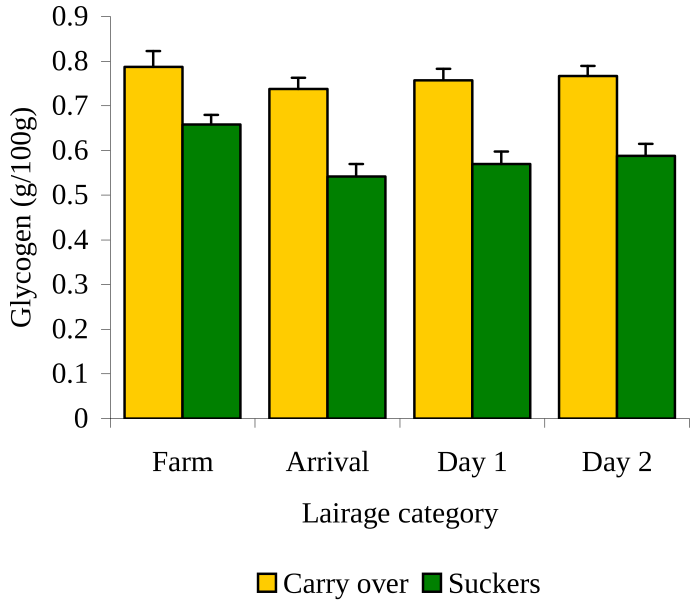


Figure 1.17 Comparison between sucker and carry over lambs for glycogen in eye round muscle on farm and at each lairage time



The affect of sex on muscle glycogen

There was a small affect of sex on muscle glycogen that was significant for the topside but not for the eye round. For topside wether lambs had slightly lower muscle glycogen than ewe lambs.

Table 1.24 Comparison between ewe and wether mean muscle glycogen in topside and eye round at slaughter

Muscle	Sex category		Significance (P)^{y}
	Ewe	Wether	
Topside	1.17±0.016	1.12±0.015	*
Eye round	0.68±0.13	0.67±0.013	NS

Values are mean ± standard error of the mean (sem) ^{y} ns - not significant, * - P<0.05

Feed type and muscle glycogen

Lambs in consignments fed grain prior to slaughter had higher muscle glycogen on farm than those fed pasture (table 1.25 and figure 1.18). Sucker lambs were finished on pasture only hence the grain fed consignments were all carry over lambs. This bias made it impossible to compare both age categories and both finishing feed systems simultaneously. However when analysed separately, grain fed carry over lambs had higher glycogen on farm than pasture fed carry over lambs for both muscles (p<0.01). In lambs on pasture there was no difference between suckers and carry over lambs for the topside but there was a trend for sucker lambs to have a lower glycogen in the eye round (p<0.10) than carry over lambs. This result suggests that the difference in topside glycogen seen between sucker and carry over lambs in table 1.22 and figure 1.13 may have been due to different feeding systems on farm.

Table 1.25 Glycogen on farm in grain fed consignments compared to pasture fed consignments.

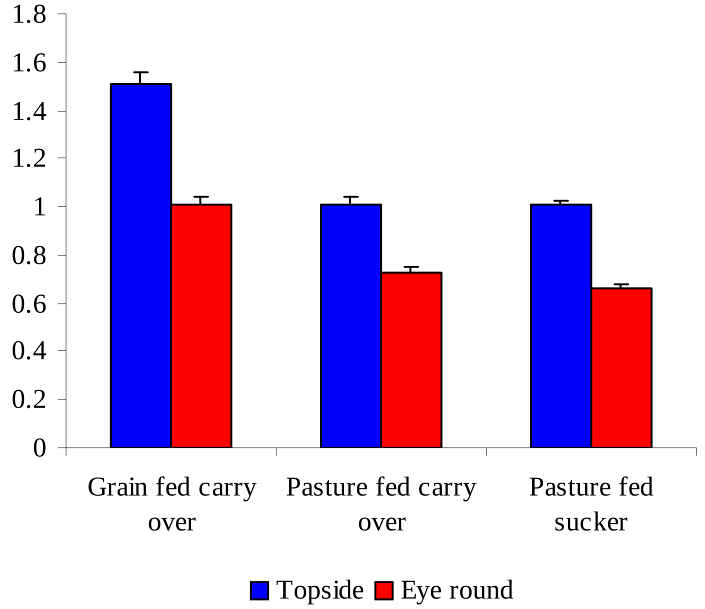
Muscle	Finishing feed/age type		
	$^{\Phi}$Grain fed carry over	$^{\Omega}$Pasture fed carry over	$^{\Psi}$Pasture fed sucker
Topside	1.51±0.041	1.01±0.034	1.01±0.22
Eye round	1.01±0.034	0.72±0.024	0.66±0.022

$^{\Phi}$Grain fed carry over consignments included I, J, K, L, and M

$^{\Omega}$Pasture fed carry over consignments included, E, F, G, H

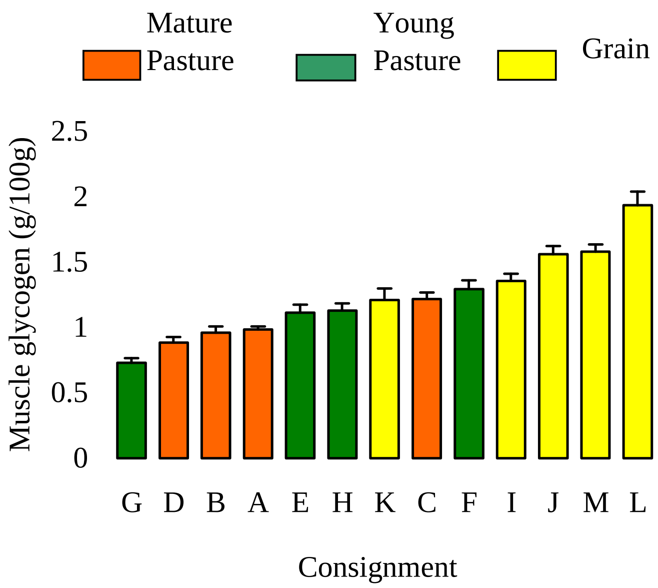
$^{\Psi}$Pasture fed sucker consignments included A, B, C, D,

Figure 1.18 Muscle glycogen on farm in grain fed consignments compared to pasture fed consignments.



Values are means±sem.

Figure 1.19 Glycogen in topside muscle with each consignment categorised according to feed type.

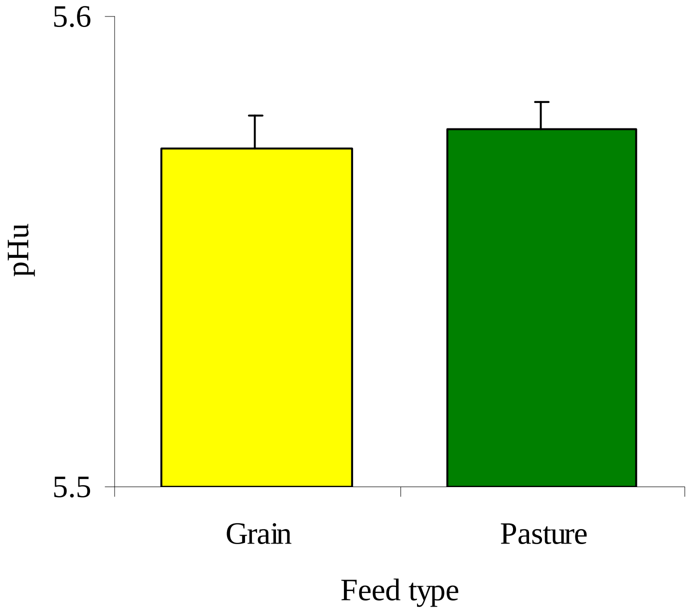


Values are mean ± standard error of the mean (sem)

Feed type and pHu

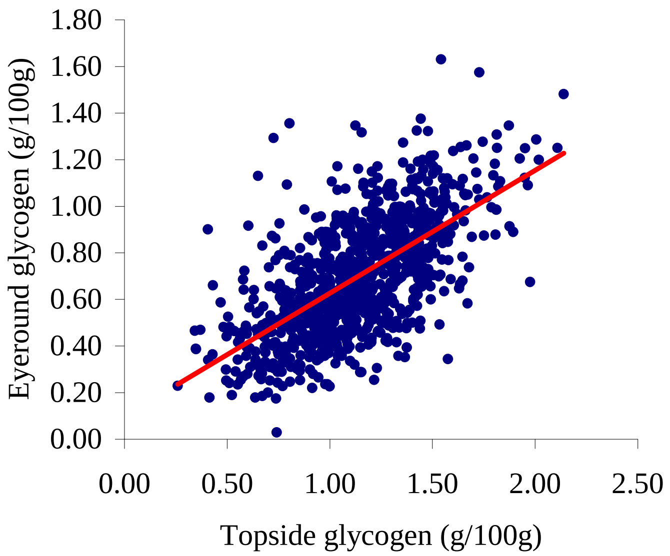
Despite the difference seen in glycogen (figure 1.18), there was no difference in pHu between grain and pasture fed carry over lambs. The pHu was low in both categories and glycogen would be more sensitive than pHu at this level.

Figure 1.20 Comparison of topside pHu between grain fed and pasture fed carry over lambs



Relationship between topside and eye round for glycogen

Figure 1.21 Correlation of glycogen in topside with glycogen in eye round



Equation 1.03 Correlation of glycogen in topside with glycogen in eye round

y = 0.5277x + 0.0992

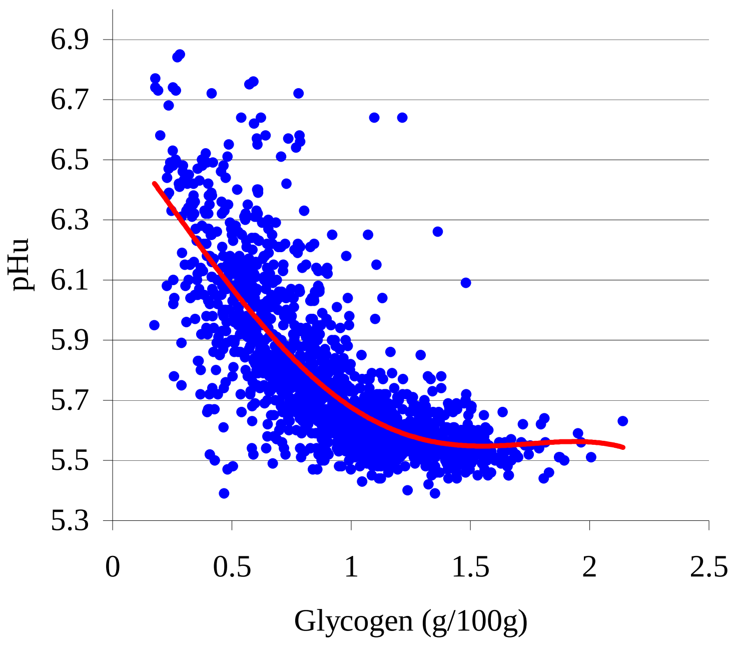
y= glycogen in eye round, x = glycogen in topside

$r^2 = 0.411$, $p<0.01$

Correlation between muscle glycogen and pHu

A polynomial relationship existed between muscle glycogen and ultimate pH.

Figure 1.22 Regression of pHu with muscle glycogen (topside and eye round included)



Equation 1.04 Correlation between glycogen and pHu

$y=6.601-0.966x-0.486x^2+.703x^3-0.1742x^4$

y= pHu, x= ,muscle glycogen

$r^2 = 0.59$ $p<0.01$

The effect of mustering on muscle glycogen

There was no relationship between glycogen on farm and mustering time. There was a significant but weak negative relationship between glycogen at slaughter and mustering time.

Equation 1.05 Correlation between glycogen and mustering time

$y=1.435-0.788x + 0.423x^2$

y= glycogen on farm, x= mustering time

$r^2 = 0.101$ $p<0.01$

Carcass weight

Carcass weight is expressed as an adjusted hot weight, which was hot weight multiplied by 0.95. Abattoirs reported this figure as an estimate of cold carcass weight. Consignments E and J were excluded from carcass weight analyses to avoid incomplete carcass weight data for these two consignments being confounding particularly for the affect of different lairage times.

Age group and carcass weight

Carry over lambs had a higher mean carcass weight than sucker lambs.

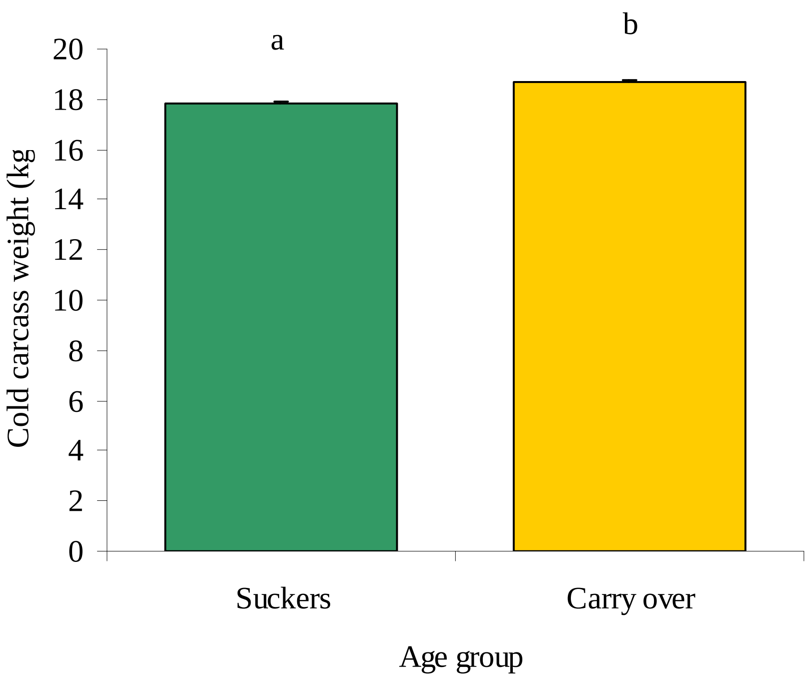
Table 1.26 The affect of age on carcass weight.

	Age group	Significance (P)

	Sucker	Carry over	
Adjusted hot carcass weight (kg)	17.86±0.076[a]	18.69±0.077[b]	**

Values are mean ± standard error of the mean (sem) y ns - not significant, ** - P<0.01

Figure 1.23 The affect of age on carcass weight.



Values are mean ± standard error of the mean (sem) Diifferent superscripts denote statistical difference p<0.01

The affect of lairage on carcass weight

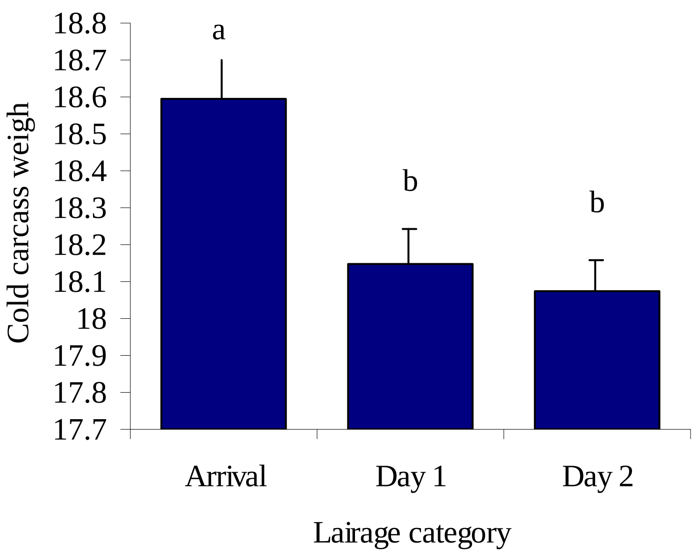
Carcass weight declined between arrival and day 1 but not between day 1 and day 2. The trend was the same for both sucker and carry over lambs but in absolute terms the loss between arrival and day 1 was greater for carry over lambs than sucker lambs (table 1.31).

Table 1.27 Carcass weight (kg) for sucker and carry over lambs at different lairage times.

Age group	Lairage category			Significance of effect (P)
	Arrival	Day 1	Day 2	
Sucker	18.27±0.156[a]	17.65±0.118[b]	17.66±0.11[b]	**
Carry over	18.95±0.138[a]	18.65±0.137[b]	18.49±0.125[b]	**
Mean	18.59±0.106[a]	18.15±0.094[b]	18.07±0.86[b]	**

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01

Figure 1.24 The affect of lairage on carcass weight (means of sucker and carry over consignments).

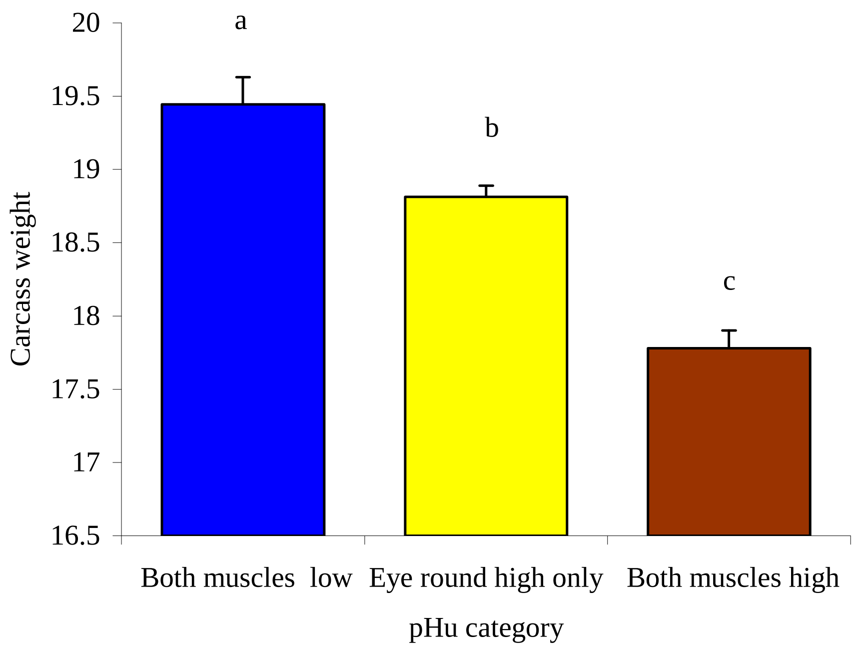


Values are mean ± standard error of the mean (sem). Different superscripts denote statistical difference - P<0.01

The association of pHu with carcass weight

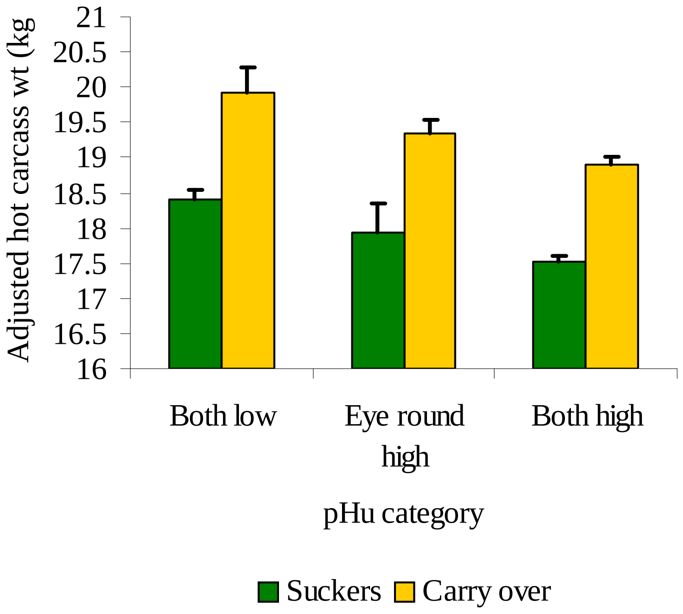
All 10 consignments were included for this analysis. High pHu category was associated with lower carcass weight and this affect was greatest when both muscles had a high pHu (figure 1.24). This affect was seen in both sucker and carry over lambs such that the lower carcass weights in the high pHu categories was not simply due to sucker lambs being over represented in this part of the data. This was expected because sucker lambs weighed less (table 1.30) and tended to have a higher pHu than carry over lambs (figure 1.07).

Figure 1.25 The association of pHu category with carcass weight



(different letters denote statistically significant differences p<0.01)

Figure 1.26 The affect of pHu category on carcass weight in sucker and carry over lambs



Values are mean ± standard error of the mean (sem)

The affect of muscle glycogen on carcass weight

Muscle glycogen had a small affect on carcass weight, however this was not significant when multivariate analyses were used.

Equation 1.06 Correlation between muscle glycogen and carcass weight

$Y = 1.836X + 16.8$

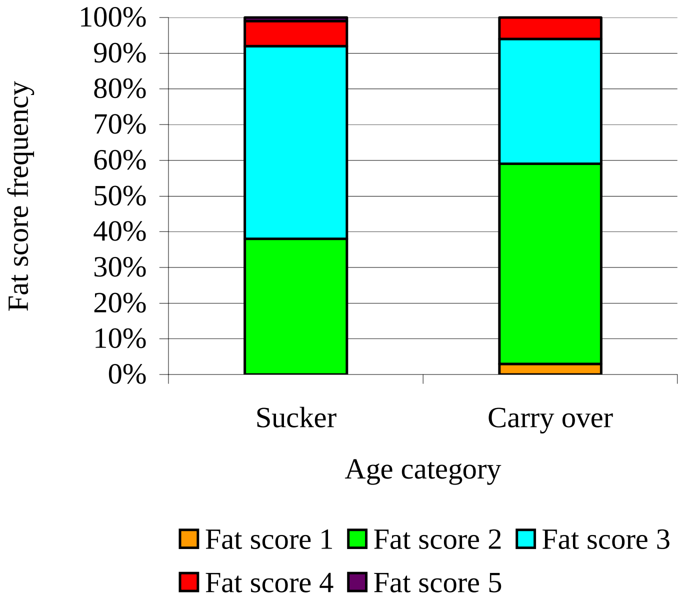
Y = carcass weight, X = topside muscle glycogen

$r^2 = 0.05$, $p < 0.01$

Fat Score

As with carcass weight fat score was affected by age and lairage. However it was not affected by pHu. In carry over lambs score 2 was the most frequent fat score whilst in sucker lambs score 3 was most frequent. Hence the mean fat score was lower in carry over lambs compared to sucker lambs. The ratio of score 2 to score 3 lambs increased between arrival and day 1 of lairage but did not change significantly between day 1 and day 2.

Figure 1.27 The relative frequencies of each fat score for sucker and carry over lambs



Values are means

Table 1.28 Comparison of mean fat score for sucker and carry over lambs

	Age category		[y]Significance
	Sucker	Carry over	(P)
Mean fat score	2.70±0.026[a]	2.45±0.024[b]	**

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01

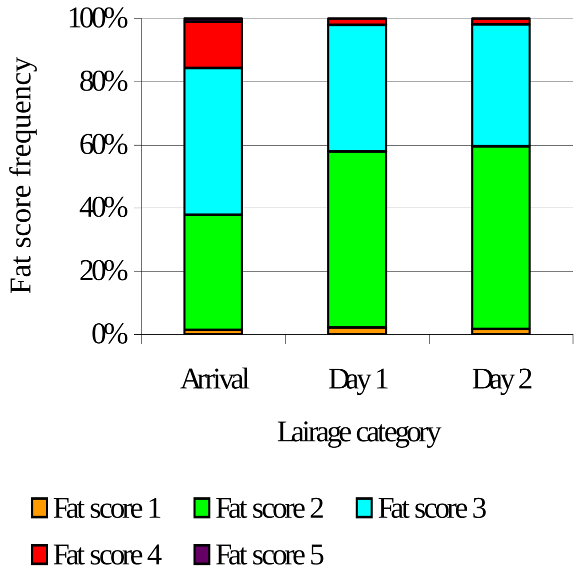
Table 1.29 Comparison of mean fat score for 3 lairage categories

	Lairage category			[y]Significance
	Arrival	Day 1	Day 2	(P)
Mean fat score	2.77±0.034[a]	2.42±0.029[b]	2.41±0.027 [b]	**

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01

Values with different superscripts are different.

Figure 1.28 The relative frequencies of each fat score for each lairage category



Values are means

The impact of saleyards (Consignment A only)

For consignment A part of the same production group used in the study was sent to Midland saleyard rather than direct to abattoir. This group was sent to sale on the same day as consignment A was sent to Lynley valley abattoir.

The saleyard group coincidentally was purchased by the abattoir and killed on the same day as the day 1 lairage group of consignment A. Lambs that went via the saleyard were sampled in the same way as those in consignment A. This allowed direct comparison of the two selling methods.

Sending the group to saleyards was part of a strategy to avoid the penalties associated with over fatness on direct consignment. The mean adjusted hot carcass weight was 1.75 kg higher in the saleyard group compared to consignment A day 1 kill which is consistent with them being heavier on farm as perceived by the farmer.

The affect of saleyards on pHu

Lambs that went to the saleyard had a higher pHu in the eye round but not the topside muscle.

Table 1.30 Comparison of direct consignment with saleyards for pHu in topside and eye round muscles

Muscle	Selling method		Significance[y]
	Direct	Saleyard	
Topside	5.67±0.011	5.70±0.009	NS
Eye round	6.08±0.032	6.26±0.034	**

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01

The affect of saleyards on muscle glycogen

There was no difference in muscle glycogen between saleyard and direct consignment for both topside and eye round. This may be a reflection of pHu being more sensitive to change at low glycogen levels as the pHu was higher in the saleyard group for the eye round compared to the direct consignment group.

Table 1.31 Comparison of direct consignment with saleyards for glycogen in topside and eye round muscles

Muscle	Selling method		Significance^y
	Direct	Saleyard	
Topside	1.14±0.034	1.20±0.043	NS
Eye round	0.57±0.180	0.50±0.174	NS

Values are mean ± standard error of the mean (sem) ^{y} ns - not significant, ** - P<0.01

Based on this result from just one consignment, the saleyards did impact negatively on pHu but only in the eye round and not the topside.

The impact of abattoir holding yards (Consignment E only)

As mentioned previously, the group of lambs killed on arrival in Consignment E were heavier than the buyer had expected. As the abattoir had a limited market for heavy carcasses they delayed the slaughter of the remainder of the consignment until day 4 after arrival. During this time the lambs were kept in a holding yard at the abattoir and fed hay and green kikuyu pasture. The carcasses from these lambs were sampled and compared with those killed on arrival.

Table 1.32 Comparison of pHu for lambs killed on arrival with those killed on day 4 in topside and eye round muscles

Muscle	Sample time		Significance^y
	Arrival	Day 4	
Topside	5.61±0.005	5.54±0.011	**
Eye round	5.89±0.031	5.85±0.028	NS

Values are mean ± standard error of the mean (sem) ^{y} ns - not significant, ** - P<0.01

Mean pHu of topside was lower in lambs killed on day 4 compared to those killed on arrival.

Table 1.33 Comparison of muscle glycogen for lambs on farm with those killed on arrival and those killed on day 4 in topside and eye round muscles

Muscle	Sample Time			Significance[y]
	On Farm	Arrival	Day 4	
Topside	1.11±0.061[a]	1.47±0.033[b]	1.21±0.035[a]	**
Eye round	0.78±0.053	0.91±0.039	0.82±0.04	NS

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01
Values with different superscripts in the same row are different.

Muscle glycogen decreased during the 4 days in holding yards and this was significant in the topside but not the eye round. Holding lambs in an abattoir yard whilst fed hay and green kikuyu resulted in a an acceptable result for pHu and glycogen.

Multivariate analysis

Two techniques were used to perform multivariate analysis. Logistic regression was used to analyse affects on the incidence of high pHu in the topside, as incidence was a discrete variable. Multiple regression was used to analyse multi variate affects on muscle glycogen as this was a continuous variables.

Incidence of high pHu in Topside

Factors found to be significant (p<0.01) were included in a model (equation 1.05).

Equation 1.07 Logistic regression model for the incidence of high pHu.

$$Y = 1.109X_1 - 0.115X_2 + 0.002X_3 + 0.073X_4 + 1.9171X_5 - 0.064\,X_6 - 3.1$$

Y = Topside pH category, when Y is close to 0 the pH will be less than 5.7, when Y is close to 1 pH will be less than 5.7.

X_1 = mustering time (hours), X_2 = Carcass wt (kg), X_3 = trucking distance (kilometres), X_4 = paddock to slaughter time (hours), X_5 = age category (sucker= 0 and carry over = 1), X_6 = lairage time (hours)

$r^2 = 0.192$, $p<0.01$

From the model (equation 1.06) it can be seen that incidence of high pHu increased with increasing mustering time, trucking distance, paddock to slaughter time, lairage time, and age category being suckers. Increasing carcass weight decreased the incidence of high pHu. Of the factors in the model age category had the largest coefficient and therefore the greatest affect on the incidence of high pHu

Topside glycogen

Factors found to be significant ($p<0.01$) were included in a model (equation 1.06).

Equation 1.08 Multiple regression model for topside glycogen

$$Y = 0.001 X_1 – 0.004X_2 – 0.00029X_3 – 0.069X_4 + 0.025X_5 + 0.01 X_6 – 3.1$$

Y = topside glycogen (g/100g) at slaughter

X_1 = lairage time (hours), X_2 = paddock to abattoir time (hours), X_3 = trucking distance (kilometres), X_4 = mustering time (hours), X_5 = trucking time (hours), X_6 = weaning to slaughter period (days).

From the model (equation 1.07) it can be seen that topside glycogen increased with increasing lairage time, trucking time, and weaning to slaughter time. Weaning to slaughter time is a reflection of age category (sucker/carry over) so this result is similar to that seen for age category in equation 1.05. Increasing paddock to abattoir time, trucking distance and mustering time decreased muscle glycogen. Of the factors in the model mustering time had the largest coefficient and therefore the greatest affect on the level of muscle glycogen. Feed type could not be included in this model as it was a discrete variable and not suitable for use in multiple regression. Carcass weight did not have a significant affect on muscle glycogen in this analysis.

Discussion

Management History

The number of sheep measured in this study was large compared to other similar studies and the range of production systems covered by the 10 consignments was a good reflection of the commercial situation. Nevertheless care needs to be taken in extrapolating the results outside of the context of this study, as they may not all be externally valid. Selection of consignments was influenced by availability of sheep and the willingness of individual producers to participate. Also the number of sheep measured was small in relation to the total size of the lamb industry.

A seasonal abnormality was rainfall in the summer period resulting in green pasture for autumn carry over lambs that would not be seen in the typical year. This made pasture conditions for consignments E, F, and G, much better in quantity and quality than in a typical year.

Genotype

Second cross lambs are relatively uncommon in Western Australia and only one consignment in the study was second cross. The consignments in the spring to early summer were suckers and those in the late summer, autumn and winter periods were carryovers as generally happens in the market place. Merinos were represented in carry over lambs only and sucker lambs were predominantly first cross lambs. In three of the crossbred flocks more than one breed was used as a sire.

Mustering time

Mustering times varied from being very short where yards were in the paddock that sheep were depastured to situations where yards were more remote. However the maximum mustering distance was relatively short at 1.5 kilometres so longer mustering distances certainly occur in practice.

Conceivably muscle activity during mustering could cause glycogen depletion. While there was no correlation between mustering time and glycogen on farm there was a weak relationship between mustering time and muscle glycogen at abattoirs. (equation1.05). Mustering time was also significant ($p<0.01$) in the multivariate analyses (equation 1.07) Harman and Pethick (1994) found that exercise had a profound affect on muscle glycogen but only when it was intense. At moderate exercise muscle glycogen did not change. Liver glycogen was mobilised at all levels of exercise and may be rapid at early stages of walking. Glucose made available from the liver is used by muscle as a fuel to make up for any deficit incurred during exercise. Fatty acids are the preferred energy source in low intensity exercise. Hence mustering may have caused glycogen depletion from the liver but not the muscle and this perhaps was important for sustaining muscle glycogen during feed deprivation in lairage. Liver glycogen was not measured in this study so any affects of mustering on liver glycogen cannot be ascertained.

Besides high energy diets a benefit of feed lotting is that sheep can be loaded from the feedlot directly on to trucks with minimal mustering time. This benefit is present with short term as well as long term feed lotting as feeding for 7-14 days is likely to replace glycogen lost during mustering (see experiment 2)..

Transport

The longest distance lambs were transported in this study was 630 kilometres. It is unlikely that travel distances would be longer than this for lambs raised and slaughtered in the southwest land division of Western Australia. Lambs from pastoral districts such as Carnarvon may have to travel further. Transport of live lambs into South Australia and New South Wales from the Esperance and eastern wheat belt districts fluctuates but can be significant in some years. Distances travelled to these markets would be much greater than those examined in this study.

Farmers appeared to choose abattoirs on economic returns rather than closeness to their farm as shown by consignments C, G, and H. For each of these consignments an abattoir was within 2 hours travelling time from the property yet the farmers chose more distant facilities to kill their lambs. Abattoirs often market their own product or have an alliance with a meat wholesaler. Hence the buyer of the lambs often determined the location of slaughter.

Time spent on trucks was greater than the travel time when arrival at abattoirs was later than closing time. Abattoirs generally have a time in the day after which sheep are not received until the next day. This occurred for consignments A, C, E and G where only about half of the travel time was spent moving. For the remainder of the time the trucks remained loaded but stationary whilst waiting for lairages to open.

The stationary periods occurred towards the ends of the journey either at or close to the abattoir. Transport time could have been shorter for these consignments if arrival was coordinated with lairage opening times or if lairages times were open during the night. The former would involve loading and driving at night, which would be more difficult for the transport operator, and the latter would likely increase labour costs for abattoirs.

The correlation between trucking time and farm curfew time (equation 1.01) suggests farmers took the length of journey into account when deciding on farm curfew time except in the case of consignment G. Truck drivers prefer sheep to be "empty" before loading to avoid faecal soiling during transport so curfew is mandatory. Farmers obviously observed this requirement but clearly reduced curfew times for long journeys. This tendency resulted in paddock to abattoir times being less variable than the transport times. Average paddock to abattoir time was 23.81 hours. Very short paddock to abattoir times were not represented in this study and could be investigated further. In practice they may be more difficult to implement.

Lairage time

Time spent in lairage had a large influence on the total time lambs were off feed prior to slaughter. With the industry lairage standard of 24 hours, time spent in lairage represented about 50% of the total time off feed on average (table 1.04). Lairage was the longest single period in the delivery process from paddock to slaughter. Managing lairage time can therefore have a large impact on total time spent off feed if this was seen to be important.

In practice lairage periods vary. The abattoir production manager and the AQIS veterinarian determine lairage time for individual consignments. Consignment E demonstrated that marketing requirements can influence the order that different lines are killed hence lairage times. In this case the abattoir manager determined that lambs in this consignment could not be sold until later in the week hence slaughter was delayed to facilitate this. During the course of this study it was noted that if sheep arrived wet they were required to dry before they could be processed and if they arrived excessively dusty they were shower washed at one abattoir only.

Decisions about the time that lambs spend in lairage may be influenced by length of journey but this cannot be ascertained from the data. Whilst the time spent on transport could be estimated from the origin of a consignment, it would be more difficult to know the curfew time on farm without specific instructions from the farm.

Management differences between the two age groups

Age

Carry over lambs were 199 days older than weaners on average (table 1.03). Other factors besides age that were different between the two age groups were the weaning to slaughter time interval, weaning age, and nutrition. Suckers were slaughtered 3 days from weaning on average compared to 227 days for carry over lambs (table 1.05).

Weaning

For suckers the immediate post-weaning period coincided with trucking and lairage and may have added stress at this time. In carry over lambs weaning stress could not have had an influence during the pre slaughter period due to the large time period between weaning and slaughter. A delayed weaning can have a negative impact on lamb live weight as well as ewe live weight and fleece weight. Weaning at 12-14 weeks is recommended to optimise ewe and lamb production (Kelly pers. comm.). Inherently the sucker production system may therefore be less efficient than the carry over system as suckers lambs were kept with the ewe for 25 days longer than carry over lambs.

Nutrition

Nutrition varied for both age groups but on average was better as predicted by Grazfeed in the carry over group than the sucker group (table 1.07,1.08). Carry over pastures were influenced by the unusually wet summer as already mentioned. Suckers are traditionally finished on pasture as this is a relatively simple and cheap production system. Depending on the season and farm location, annual pastures senesce from September onwards. Suckers marketed in the October, November, and December period therefore finished on mature dry pastures of declining nutritional value. Contribution to sucker nutrition from the ewe milk would be low at this age of the lamb.

Hence suckers at this time of year were on a falling plane of nutrition at the time of sale for slaughter. None of the sucker groups were fed grain and grain feeding is generally not a part of the sucker production system.

Ultimate pH

Incidence of high pHu

Frequency of high pHu was 17% of carcasses above 5.7 for both muscle types (figure 1.01). This is higher than the mean of 10% seen in an audit done at the Spearwood Boning Room of crossbred sucker lambs in 1999. Part of this difference may be due to the different lairage treatments imposed but could also be due to other factors such as season and genotype. Several studies have shown a seasonal incidence in dark cutting in beef. Cummins et al. (2000) demonstrated that muscle glycogen in yearling steers grazing permanent ryegrass/sub clover pastures was highest during the spring. The dry spring and wet summer would have changed the seasonal influences to some extent in our study. With regard to genotype Gardner et al. (1999) demonstrated an increase in susceptibility to stress in merino sheep compared to first cross and second cross lambs that had an impact on muscle glycogen. As the merino consignments in this study generally had less than 10% of carcasses with a high pHu, genotype could not be the reason for increased incidence of high pHu in this study despite the Spearwood boning room audit consisting entirely of crossbred lambs.

Consignment had a large impact on pHu suggesting farm of origin was important (table 1.11, table 1.12 and figure1.02). Consignment D had the highest incidence with 55.2% of carcasses having a high pHu in both muscles while consignment I had the lowest incidence with 0% of carcasses having a high pHu in both muscles. However farm of origin was not the only difference between consignments with many factors differing including nutrition, abattoir, age and time of year.

Consignments F and G were from the same farm of origin yet had a significantly different pHu in topside and eye round. They had similar genotype, mustering and feeding histories. This suggests that any affect of farm of origin may not be repeatable such that the farm supplying consignment D for example may not be more likely to have a high pHu compared to consignments from other farms in the future.

Affect of age and lairage time on pHu

Age group had a significant affect on pHu with sucker lamb carcasses having a higher mean pHu than carry over lamb carcasses (table 1.14, figures 1.05, 1.06 and 1.07). Lairage time interacted with age group for topside pHu such that sucker lambs were more sensitive to lairage time than carry over lambs for this muscle (equation 1.06). As discussed factors other than age differed between the age groups and may have been responsible for the differences seen in pHu between the two age groups. Sucker lamb quality may respond to changes in nutrition and flock management unless the difference was due inherently to age alone, which is unlikely. Devine et al. (1993) found the opposite result that high pHu was more prevalent in 14-month lambs than 7-month-old lambs. However in their study the older lambs were subjected to lower nutrition as well as extra stresses including shearing and washing prior to slaughter.

Our results are in agreement with anecdotal perceptions from industry that dark cutting is a greater problem in suckers than older lambs and with experience in the beef industry that vealer calves are more susceptible to dark cutting than older animals (Tudor pers comm.).

In the comparison between lairage times for topside in suckers, the difference between the means (table 1.14) was less than the difference between the frequencies (table 1.15) for different lairage periods. Therefore the magnitude of the affect of lairage on sucker topside pHu appeared greater when analysed as a categorical variable. Extended lairage increased the mean but reduced the standard error for the topside pHu in suckers. When conditions influence standard error as well as the mean a different result will occur depending on wether a mean or a proportion is used for setting targets. This may be an important consideration for setting goals in commercial situations.

In the eye round a simliar trend for pHu was seen in the two age groups with different lairage times. This trend resembled that seen in the topside for sucker lambs although the difference between day 1 and day 2 was not significant in the eye round comparison. Killing on arrival resulted in high pHu relative to other lairage periods in both age groups and both muscles. Longer lairage had no affect on eye round pHu in both age groups but decreased topside pHu in carry over lambs.

Other studies have shown that very short lairage periods may allow insufficient time to recover from stress of transport. Warriss et al. (1992) showed that 2-3 hours was necessary after transport to reduce plasma cortisol levels significantly in pigs.

Significance of pHu changes

Changes in pHu suggest that lairage time could affect the eating quality. However sucker lamb meat has the reputation of being very acceptable to consumers, which is contrary to these pHu findings seen in isolation. Perhaps other characteristics related to age diminish the impact of high pHu on eating quality of sucker lamb in comparison to carry over lamb. Devine et al. (1993) compared tenderness of 7-month-old entire male Romney lambs with 14-month-old lambs of the same genotype and found no difference for lambs with the same pHu. They concluded that connective tissue age affects were minimal in the loin. However the *m.longisimuss dorsi* (back strap) is a low connective tissue muscle and the same relationships may not hold for high connective tissue muscles.

Notwithstanding concerns about external validity of these results to the whole lamb industry, attention to lairage time was more important for sucker lambs than carry over lambs for a consistent pHu to be achieved in both muscles. On the basis of achieving the lowest pHu possible, sucker lambs were best slaughtered after 24 hours lairage compared to slaughter on arrival or after 48 hours in lairage. Carry over lambs could have been slaughtered at any time during the lairage period although slaughter on arrival was the least preferable time.

Relative importance of eye round pHu

In an industry context pHu is most relevant for high value cuts with low connective tissue such as the back strap. In this study pHu of eye round was used as a research tool to measure the affect of stress. If pHu of low value cuts (exemplified by eye round) was also of concern to industry, then the task of reducing the incidence of high pHu would be much larger, as 83.4% of carcasses had a pHu above 5.7 in eye round.

The significance to eating quality of high pHu in eye round when pHu topside was below 5.7 is not entirely clear. The scenario may be that lambs in this category had adequate glycogen prior to mustering but then were stressed during the pre-slaughter process. Warner et al. (2000) found that lambs undergoing antemortem stress exhibited an increase in muscle drip loss and in cooking loss in the *m. longisimuss thoracis et lumborum,* and attributed this to protein denaturation due to an increase in pH decline post slaughter. However in their study mean pHu was generally above 5.8 so glycogen levels would have been marginal. It might be speculated that stress could cause such changes in eating quality of the high value cuts without causing a high pHu in these muscles. Measuring pHu in glycolytic type muscles would be an indirect method of measuring stress prior to slaughter and the value of doing this in the commercial situation remains an open question.

Pearsson's correlation coefficient (r^2) for the relationship between pHu topside and pHu eye round was 0.39 (equation 1.02). A pHu measurement predicted for one muscle from the pHu in the other muscle would be imprecise if used on an individual carcass basis although a mean value would identify high pHu lines. This may be of value for providing feedback to farmers about management but not for classifying and marketing individual carcasses.

Muscle Glycogen

Affect of transport on muscle glycogen

Transport reduced glycogen in the eye round but not the topside (table 1.23). Eye round muscle has a higher percentage of type IIb fibres that are more sensitive to adrenaline than type I or type IIa. In two carry over consignments (consignments E and G) topside glycogen was higher on arrival than on farm suggesting some repletion may have occurred.

In both of these consignments transport distance was relatively long, perhaps sufficient to allow repletion after the sheep had assimilated to truck surroundings. Parrott et al. (1998) showed that loading was the most stressful part of transport and that sheep settle down during a journey. Baldock and Sibly (1990) demonstrated that sheep in a moving trailer had a higher heart rate than those in a stationary trailer. Changing lairage arrangements such that night arrivals can be unloaded on arrival may therefore be of no advantage for conserving muscle glycogen. However, from a welfare point of view this may still be a worthwhile consideration.

On farm glycogen was measured in yards prior to embarkation and after mustering. The period between the on farm and arrival measurements included loading, transport itself and unloading at lairage. Loading, unloading and maintaining balance during the journey would have involved muscle activity. However the loss in the eye round rather than topside suggests the response was more a reaction to stress than muscle activity. Loading and unloading generally involved dogs on trucks and in lairages. As previously mentioned weaning was coincidental with trucking for suckers and may have exacerbated the stress reaction.

Muscle glycogen being resilient to transport stress with current transport systems is consistent with the findings of Lambert et al. (2000) who concluded that increased emphasis on improved animal handling during yarding and trucking of cattle is unlikely to markedly lower the incidence of high-pH beef. However, in our study selective depletion of eye round glycogen during transport may have contributed to the larger proportion of carcasses in the middle pHu category, that is low topside pHu and high eye round pHu, for sucker lambs. In susceptible groups such as suckers transport stress may still be an important issue although is likely to affect cuts that predominantly consist of type IIB fibres.

Affect of lairage on muscle glycogen

Lairage had little affect on muscle glycogen in both muscles although there was a trend for muscle glycogen to increase during lairage particularly in the topside. When analysed according to age group this trend was seen in carry over lambs and not suckers (figure 1.16). Carry over lambs also had a higher starting muscle glycogen on farm. Pethick and Warner (2000) found no change in eye round and the topside glycogen for domestic trade cattle in the 320-400 kg weight range, killed under commercial conditions, after 1 hour, 1 day and 2 days in lairage.

Food was withdrawn during the lairage period, as is the normal commercial practice. Food retained in the rumen can be expected to last for at least a day although this depends on nutrient type Rook and Thomas (1983). As the mean paddock to lairage period was 24 hours, rumen food reserves would have been low on arrival and continuing to diminish during lairage. Substrate for glycogenesis from food in the rumen would therefore have been diminishing during the lairage period. Other sources of substrate may have been liver glycogen, and recycling of lactate formed in muscles during transport. Gluconeogenesis from non-dietary sources such as amino acids from protein catabolism and glycerol from triglyceride breakdown may have also supplied gluconeogenic substrate.

During feed deprivation both hormonal and allosteric affects inhibit the enzymes of glycogenolysis causing a “glycogen sparing” affect (Murray et al., 1996). Fatty acids are used preferentially as an energy source providing oxygen is available (Harman and Pethick, 1994). This along with availability of substrate from a variety of intrinsic sources may have allowed glycogenesis to maintain muscle glycogen during the lairage period.

The higher pHu on arrival relative to day 1 could have been due to the trend for muscle glycogen to increase during lairage. However other mechanisms such as inhibition of post mortem glycolysis may also be relevant. Using a mathematical model Vetharaniam and Daly (2000) demonstrated that high concentrations of lactate ions due to stress prior to slaughter could inhibit post mortem glycolysis and increase pHu. Hydrogen ions diffuse from muscle much more quickly than do lactate ions. In consignment E both pHu and glycogen decreased together in the topside between arrival and slaughter 4 days later whereas pHu would be expected to increase when muscle glycogen decreased. Also pHu increased in topside of suckers between day 1 and day 2 with no change in muscle glycogen between these two days. Conceivably lactate may have accumulated in muscle during the unloading process and still have been present in muscle when lambs were killed on arrival. By day 1 the lactate will have moved out of the muscle to the liver for resynthesis to glucose. If this was the reason for the relatively high pHu in lambs killed on arrival then killing a few hours after arrival should be sufficient to allow the lactate ions to be removed from muscle tissue.

Affect of age on muscle glycogen

Glycogen was lower on farm in suckers compared to carry over lambs. (figure 1.13). Whilst glycogen loss occurred during transport in both age groups, the amount of glycogen loss was greater in the eye round for the sucker consignments (figure 1.17), suggesting a greater stress response in suckers. This might be due to weaning coinciding with transport and stresses being greater as a result. In lairage glycogen did not change for suckers but tended to increase for carry over lambs as lairage time increased (figure 1.16). Perhaps glycogen repletion in lairage depended on body reserves of gluconeogenic precursors prior to the start of lairage in other organs such as the liver.

The greater propensity for suckers to have a high carcass pHu appears therefore to be due both to a lower starting muscle glycogen on farm for both muscles and an increased susceptibility to stress during transport at least for the eye round.

Affect of diet on muscle glycogen

Carry over lambs finished on grain had higher muscle glycogen on farm in both muscle types (figure 1.18) than carry over lambs finished on pasture. This was despite the Grazfeed predictions that the pastures were of sufficient quality and quantity to sustain live weight gain (table 1.07). Grain finishing would therefore appear to be an advantage for muscle glycogen and this would certainly seem to be the case if pasture was dry and of low nutritional quality. However as the glycogen was relatively high in both pasture and grain fed carry over lambs, the glycogen difference was not translated into a difference in pHu at slaughter. So from an economic point of view the value of feeding grain may depend on other factors that are likely to affect the risk of high pHu.

As none of the sucker consignments were fed grain the same comparison could not be made for them. However there was no difference between the topside glycogen in sucker lambs finished on pasture and carry over lambs finished on pasture. The pastures available to the sucker consignments tended to be lower in quality but higher in quantity than those available to carry over lambs (table 1.07). It could be extrapolated that a difference was seen between suckers and carry over lambs for on farm glycogen because some of the carry over lambs were fed grain diets that were more favourable for muscle glycogen relative to pasture diets. (Jurie et al., 1995) found in bovine eye round that differentiation towards the glycolytic fibre type, during early development, seems to be reversed to the oxidative type I fibre soon after puberty. So while nutrition seemed to be important developmental reasons may have also been the cause of the difference between suckers and carry over lambs for muscle glycogen.

Topside glycogen was correlated with eye round glycogen

Topside glycogen was correlated with eye round glycogen (figure 1.20) but the relationship was linear rather than curvilinear as found with pHu (figure 1.03). Warriss et al. (1989) demonstrated that pHu and glycogen are correlated in a curvilinear way (figure 0.01). So it is logical that the relationship between the two muscles to be curvilinear for pHu when the relationship between glycogen for the two muscles was linear. The two muscles were simply on a different part of the glycogen to pHu curve at any one-time. Therefore the rates at which pHu in each muscle appeared to have changed in response to stress or nutrition was different except at the lower and higher ranges. As glycogen in eye round was always lower than glycogen in topside, pHu in eye round can be expected to change at a greater rate than pHu in topside for a given change in glycogen.

The mean muscle glycogen in topside was 1.13 g/100g and was 1.6 times greater than the glycogen concentration in eye round that was 0.70 g/100g. This difference is a reflection of the different fibre types in the two muscles (Briand et al., 1981).

Carcass weight and fat score

Affect of age on carcass weight

Carcass weight was 1.81 kg higher and fat score was 0.25 lower in carry over lambs compared to sucker lambs. These differences were relatively small considering the age difference between suckers and carry over lambs. Genotype may have had an influence, as all three of the merino consignments were carry-over lambs and merino lambs are later maturing than crossbreds. Nevertheless it suggests a different growth path for the two age groups, with carry over lambs perhaps losing condition and live weight during the summer period, then regaining live weight and condition score prior to sale.

Affect of lairage on carcass weight and fat score

Lairage had a major affect on carcass weight and fat score that was evident mostly in the first day of lairage (table 1.31, and figure 1.23). Warriss et al. (1987) and Thompson et al. (1987) demonstrated similar findings that carcass loss was greatest in the first 24 hours after feed withdrawal. In our study the lairage period was preceded by a curfew and transport period so the length of feed withdrawal was approximately 24 hours longer than the lairage period although this varied between consignments. Warriss et al. (1987) reported a mean loss of 0.09% of carcass weight per hour compared to 0.146% by Thompson et al. (1987) and 0.0997% mean adjusted hot carcass weight loss per hour in our study during the first day of lairage.

Assuming the lambs had a maintenance energy requirement of 7 MJ/day and fat has an energy value of 37 MJ/Kg, the amount of fat required to meet the entire maintenance requirement would have been 190 grams per day. This is in the order of 1% of carcass weight compared to the mean carcass weight loss of 2.39 % observed on the first day. Warriss et al. (1987) made a similar conclusion and attributed carcass weight loss during feed withdrawal largely to dehydration as water consumption is reduced after feed deprivation. This being the case the reduction in carcass weight may not be alleviated by giving sheep better access to water in lairage despite the likely association with dehydration.

Glycogen can have an affect on tissue density, as it is associated with water in the ratio of 4 grams of water to 1 gram of glycogen. As there was no difference between arrival and day 1for muscle glycogen this could not have been the cause of the affect of lairage on carcass weight.

Tissue hydration may still have been responsible for part of the change in carcass weight and fat score. Fat score is a thickness assessment hence could reflect tissue hydration as well as fat content. Water was available in lairage yards continuously from the time of arrival. However it is very unlikely that lambs would have prior experience with the bowl drinkers used in lairage yards and may have had to learn how to drink from them before using them. A behavioural reason associated with learning to use the drinkers in lairage could explain the carcass weight and fat score changes being greater on the first day compared to the second day but there was no measurement of water intake to confirm this.

Affect of transport on carcass weight and fat score

There was a tendency for carcass weight to be lower for the consignments that travelled the longer distances. Thompson et al. (1987) found that transport had no affect on carcass weight other than due to the time spent off feed. Hence the difference seen in this study may have been due to the long transport consignments being off feed for 9 hours longer than the short transport consignments.

Implications of carcass weight loss

Reducing carcass weight may reduce the value of the carcass particularly if the carcass is moved to a lower weight range that attracts a lower price per kilogram. The same applies for fat score although the medium range of score 2-3 generally achieves the premium price for fat score. Lairage time could therefore change carcass value regardless of muscle glycogen and dark cutting status. Current abattoir management practices favour a 24-hour lairage period for hygiene and welfare requirements but logistical reasons can also be important. By then most of the carcass weight and fat score changes can be expected to have occurred. It would have been impossible to optimise carcass weight and pHu in sucker consignments by lairage time alone. In carry over lambs that were less susceptible to stress than sucker lambs, the lairage time was important mainly for carcass weight.

Association of pHu with carcass weight

Whilst carcasses categorised in the high pHu category had low carcass weights it is not clear which of these two variables is dependant on the other. As carcass weight was an adjusted hot weight the differences cannot have been caused by different rates of drip loss in the chiller associated with pHu (Hwang and Thompson, 2000). Chilling may have increased the differences even further if pHu had an impact on drip loss. If so using a constant to convert hot weight to estimated cold weight (adjusted hot weight) as done currently may not always provide a precise estimate of cold carcass weight.

As low pHu carcasses weighed more than high pHu carcasses they were more valuable to the producer for that reason alone. This may assist to offset the cost of programs to prevent dark cutting.

Muscle glycogen was weakly correlated with carcass weight (equation 1.06) but this was not significant ($p<0.01$) in the multi variate analyses (equation 1.08).

Conclusions

Lairage and transport had a relatively small impact on muscle glycogen in lambs. Suckers had lower muscle glycogen on farm and were more susceptible to stress than carry over lambs. Further research into feeding strategies for sucker lambs is warranted. Also the potential for stress to affect eating quality parameters other than muscle glycogen should be investigated as the stress seen in transport and lairage affected muscle glycogen in low value cuts only. The economic impact of low muscle glycogen in low value cuts where factors such as connective tissue predominately affect eating quality, should also be clarified.

MAIN REPORT EXPERIMENT 2

Feeding and shearing prior to consignment for slaughter

Hypotheses

- Muscle glycogen will increase when the energy in the diet is increased.
- Shearing will increase ME requirements and voluntary food intake.
- Muscle glycogen will decrease after shearing in sheep fed maintenance ME diet but increase in sheep fed a high ME diet.

Aims

- To compare muscle glycogen over time in lambs offered a high ME diet with lambs offered a maintenance ME diet.
- To measure the effect of shearing on voluntary food intake and muscle glycogen.

Methods

An experiment was conducted at CSIRO Yalanbee Research Station Bakers Hill using 12-month-old merino wether lambs penned in groups in an open paddock. Pens were rectangular, measured 3 metres by 4 metres, and constructed of ring lock wire. Experimental design was a 2 by 2 factorial, with 3 replicates per treatment and 7 sheep per cell. The treatments were shearing (shorn and unshorn) and feeding (maintenance and ad lib). Prior to the experiment the lambs were stratified according to live weight and allocated to groups randomly on May 9. They were fed 1.5kg of oaten hay per head per day in the experimental pens for 3 weeks prior to the experiment commencing on May 30 2000.

At commencement of the experiment sheep in the appropriate groups were shorn and the feed changed to a pellet for both ad libitum and maintenance sheep. Maintenance ME requirement was estimated using the Grazfeed™ model and was achieved by feeding a restricted level of pellets. Live weight loss in the first two weeks of the experiment was greater than expected for the shorn group on the restricted ration. To achieve maintenance in this group the amount fed to both the shorn and unshorn control group was increased from 0.6 kg to 0.8 kg per sheep per day, from day 15 on.

Introduction to the pellets was done over a 7-day period for the ad-lib groups starting at the commencement of the experiment on May 30. They were offered 0.3 kg/sheep/day on day 1, 0.6 kg/sheep/day on day 2, 1 kg/sheep/day on day 3, 1.5 kg/sheep/day on day 4, 0.6 kg/sheep/day on day 5, 1.5 kg/sheep/day on day 6 and 2.2 kg/sheep/day on day 7. After this introduction period sheep in the ad-lib group were offered 2.2 kg per head per day. In the restricted group introduction took only 2 days. Residues of pellets left uneaten were collected and weighed every second or third day depending on consumption and management factors. Intake was calculated from pellets fed minus residue.

Muscle glycogen was measured by taking biopsies from topside and eye round muscles starting 2 hours after shearing, then 7 days, 15 days and 30 days later. Local anaesthetic was used to enable sample collection. Live weight was measured after each biopsy and in the week between the third and fourth muscle biopsies. Rainfall was recorded at the research station and daily temperature obtained from the closest representative recording station, which was Bicton.

Results

Weather

The mean maximum daily ambient temperature was 16.7˚C and the minimum daily ambient temperature was 8.1˚C. Maximum daily temperature followed a slight downward trend whilst minimum temperature showed a weak upward trend for the duration of the experiment.

Equation 2.01 Trend of maximum daily temperatures

$y = -0.106x + 18.374$

y= maximum ambient daily temperature, x = days of experiment

$r^2 = 0.243$

Figure 2.01 Ambient air temperatures

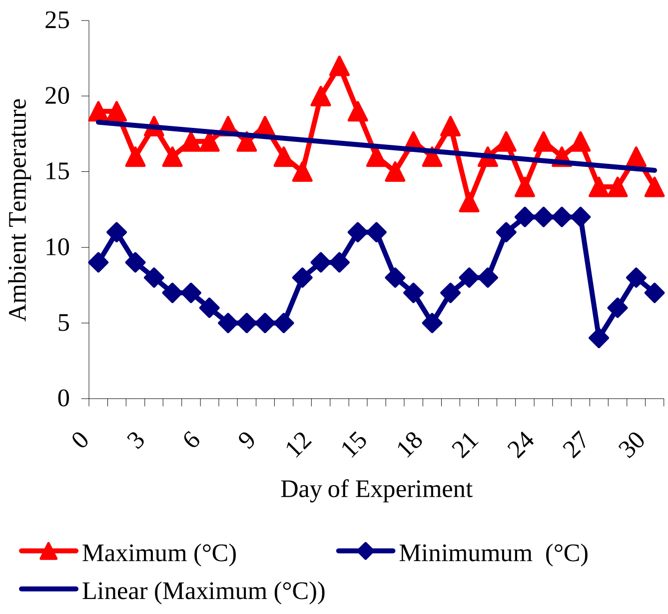
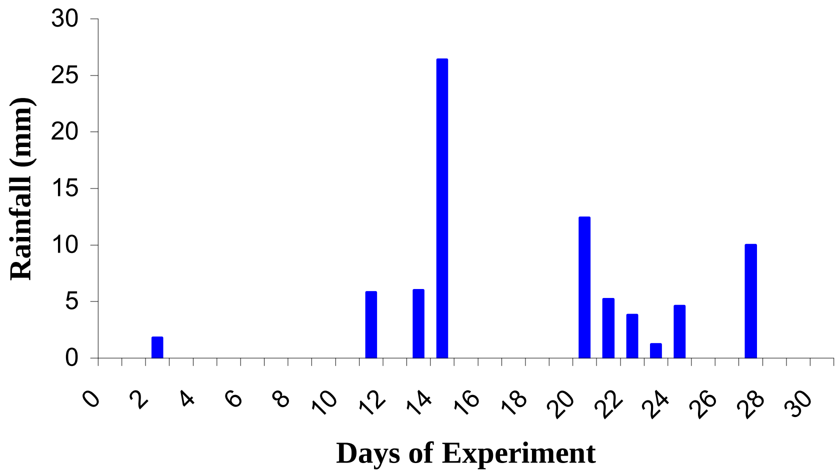


Figure 2.02 Daily rainfall



There were several major rainfall events particularly in the second and fourth weeks. Total rainfall for the duration of the experiment was 77.2 millimetres. Using the recorded weather data the Grazfeed model was used to predict the likely impact of the environmental conditions on the lower critical temperature (LCT) and the ME requirements of the sheep (table 2.01).

The predicted results show that both shearing and rainfall raised both lower critical temperature and ME requirements of the sheep. Shearing had a greater affect than rainfall on lower critical temperature.

Table 2.01 Predicted affects of rainfall on LCT and heat requirement for shorn and unshorn sheep

Daily Rainfall (mm)	Predicted LCT (°C)		Extra Heat Required (MJ/sheep/day)	
	Unshorn	Shorn	Unshorn	Shorn
0	4.3	18	0	1.4
5	5.4	19.1	0	1.8
10	6.4	19.6	0	2
15	7.2	19.8	0	2.2
20	7.8	20	0	2.2
25	8.3	20	0	2.2

Predictions were obtained using the Grazfeed^{TM} model. The assumption was made that wind speed was an average 5 km/hr, shorn sheep had 1 cm of fleece (minimum accepted by Grazfeed^{TM}), and unshorn sheep had 5 cm of fleece.

Feed Analysis

The pellets were a commercially available product that contained lupin seed, cereal hay and cereal straw, wheat grain, expeller canola meal, a mix of macro and trace minerals, vitamins and lasalocid (30mg/kg as fed).

From the feed analysis (table 2.02) the pellet was a medium ME pellet with a relatively high level of acid detergent fibre. It was formulated to have a low acidosis risk and suitable for rapid introduction. The hay fed prior to the trial starting was roughage and of lower nutritional value than the pellet diet (table 2.03).

Table 2.02 Nutritional analysis of pellets (dry matter basis).

In Vitro Digestibility (%)	ME (MJ/Kg)	Acid Detergent Fibre (%)	Neutral Detergent Fibre (%)	Crude Protein (%)	Sulphur (%)
74.3	10.6	23.8	37.8	14.5	0.21

Table 2.03 Nutritional analysis of hay fed during pre trial period (dry matter basis).

ME (MJ/Kg)	Crude Protein (%)
7.7	6

Feed Intake

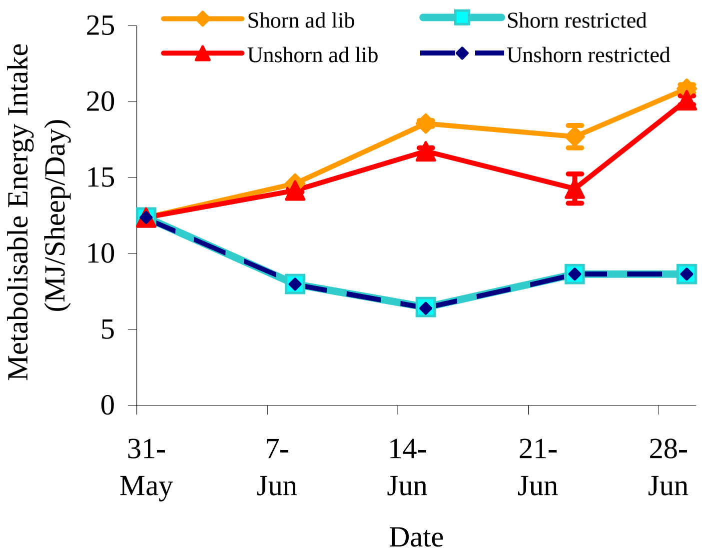
As was expected the difference in the daily metabolisable ME intake between the restricted and ad libitum groups (figure 1) was significant ($p<0.01$). Sheep in the *ad libitum* group ate 1.6 times the ME than the restricted group for unshorn animals and 1.7 times for shorn animals, over the 4-week period. Shearing significantly increased daily ME intake in the ad libitum group by 7% over the period of the experiment ($p<0.01$).

Table 2.04 Mean daily ME intake

Feed Level	Shearing Treatment		Significance ^{y}(P)
	Unshorn	Shorn	
Restricted	8.73±0.160	8.73±0.160	NS
Ad lib	14.32±0.368	15.39±0.398	**
Significance ^{y}(P)	**	**	

Values are mean ± standard error of the mean (sem) ^{y}ns - not significant, ** P<0.0

Figure 2.03 Mean ME intake at each sampling period (MJ/sheep/day)

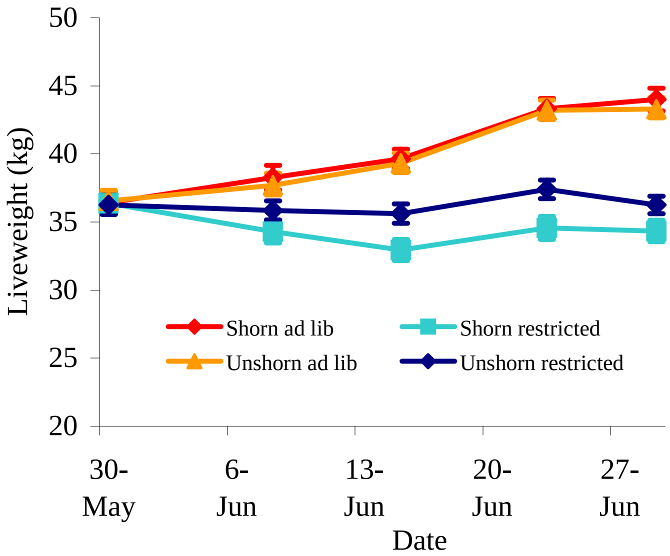


Values are means±sem

Live weight

There was a significant difference ($p<0.01$) in live weight between feeding treatments but the difference in live weight for the restricted feed group due to shearing was not significant ($p <0.05$).

Figure 2.04 Sheep live-weight for each treatment group



Muscle Glycogen

The rate of change

Muscle glycogen changed significantly ($p<0.01$) with time for both topside and eye round (table 2.05 and table 2.06). The trend for the change in muscle glycogen with time was the same for both muscles and is clearly demonstrated in figure 2.07. An initial rise occurred in the first 7 days that was followed by a decline the next 7 days then no change for the last 14 days of the trial.

The affect of ME level

Feeding level (table 2.05, table 2.06) had a significant effect on the level of muscle glycogen ($p<0.01$) in both muscles sampled. Muscle glycogen was higher in the ad-lib groups than the restricted groups for day 7, day 14 and day 28. However on day 28 the difference between restricted and ad lib groups was not statistically significant in the topside ($p<0.05$). In the eye round the difference was significant in the shorn group but not the unshorn group.

The affect of shearing

There was a significant difference (p<0.05) between the shorn and unshorn groups in the eye round but not the topside at approximately 2 hours post shearing (table 2.06). A significant interaction occurred between feed and shearing treatments for the topside and eye round such that shorn sheep on the restricted diet had a lower muscle glycogen than those not shorn (table 2.05, table 2.06figures 2.05 figure 2.06). These differences were significant at day 7 and day 15 but not at day 28. For sheep on the ad lib diet there was no difference between shorn and unshorn groups for both muscles at any time accept at approximately 2 hours post shearing in the eye round.

Table 2.05 Topside glycogen concentration (g/100g)

Treatment	Sampling Day				Significance
	Day 0	Day 7	Day 14	Day 28	^{y}(P)
Unshorn restricted	0.89±0.053^{ax}	1.74±0.068^{bx}	1.25±0.047^{cx}	1.31±0.062^{cy}	**
Unshorn ad lib	0.89±0.050^{ax}	2.26±0.120^{by}	1.62±0.099^{cy}	1.44±0.068^{cxy}	**
Shorn restricted	0.85±0.057^{ax}	1.40±0.065^{bz}	1.00±0.067^{acz}	1.32±0.082^{bdy}	**
Shorn ad lib	0.96±0.050^{ax}	2.17±0.120^{by}	1.76±0.099^{cy}	1.54±0.068^{cx}	**
Significance ^{y}(P)	NS	**	**	*	

Values are mean ± standard error of the mean (sem) ^{y} ns - not significant, ** - P<0.01, * P<0.05. Different superscripts a,b.c denote differences between rows. Different superscripts x,y,z denote differences between columns.

Figure 2.05 Topside glycogen concentration (g/100g)

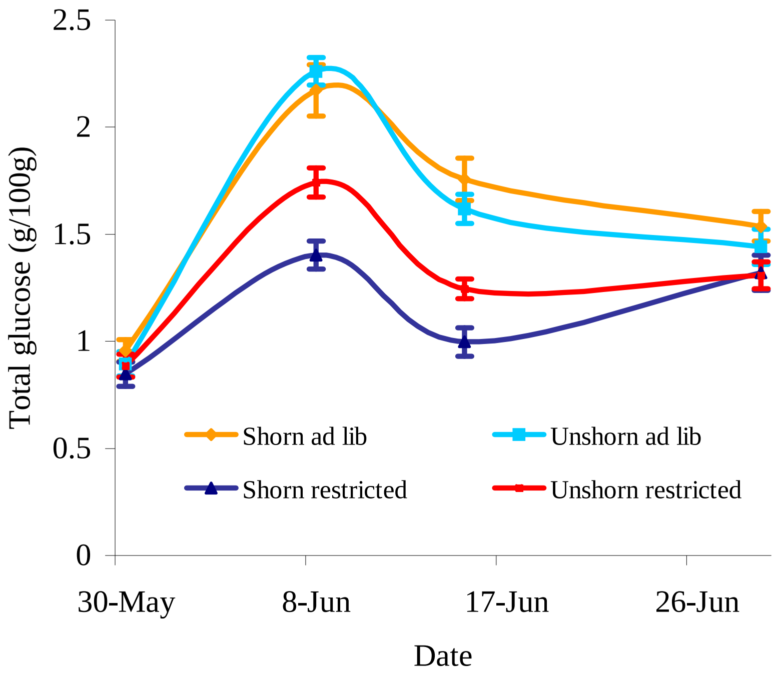


Table 2.06 Eye round glycogen concentration (g/100g)

Treatment	Sampling Day				Significance
	Day 0	Day 7	Day 14	Day 28	^{y}(P)
Unshorn restricted	$0.53{\pm}0.047^{ay}$	$1.18{\pm}0.058^{by}$	$0.85{\pm}0.044^{cy}$	$0.98{\pm}0.05^{xz}$	**
Unshorn ad lib	$0.54{\pm}0.031^{ayz}$	$1.72{\pm}0.77^{bx}$	$1.17{\pm}0.093^{cx}$	$1.07{\pm}0.053^{cx}$	**
Shorn restricted	$0.42{\pm}0.037^{ax}$	$0.94{\pm}0.064^{bz}$	$0.55{\pm}0.050^{az}$	$0.90{\pm}0.069^{byz}$	**
Shorn ad lib	$0.46{\pm}0.036^{axz}$	$1.71{\pm}0.117^{bx}$	$1.20{\pm}0.106^{cx}$	$1.10{\pm}0.048^{cx}$	**
Significance ^{y}(P)	*	**	*	*	

Values are mean ± standard error of the mean (sem) [y] ns - not significant, ** - P<0.01, * P<0.05. Different superscripts a,b.c denote differences between rows. Different superscripts x,y,z denote differences between columns.

Figure 2.06 Glycogen concentration in eye round muscle over time (g/100g)

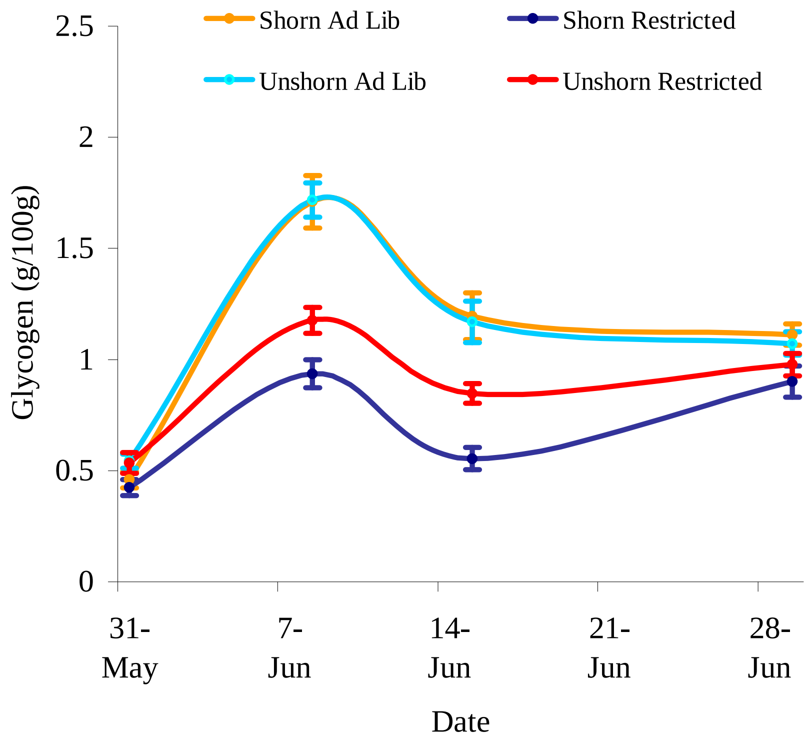


Figure 2.07 Comparison of eye round and topside mean glycogen concentration over time (g/100g)

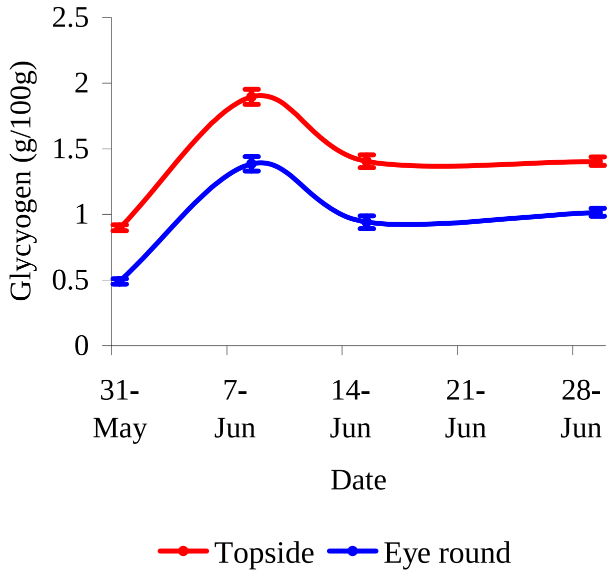
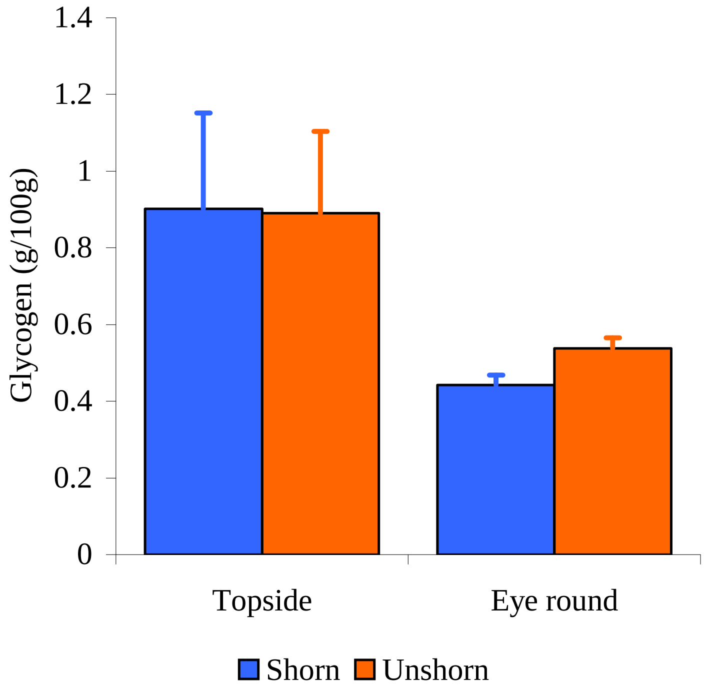


Figure 2.08 The acute affect of shearing on muscle glycogen



Correlations between ME, live weight and muscle glycogen

ME was correlated with live weight change for the period of the trial ($p < 0.001$, r^2 0.609). Live weight change was correlated with muscle glycogen change between biopsies 1 and 2 (r^2 0.335) but very poorly between other biopsies and over the whole experimental period (r^2 .039).

Equation 2.02 Correlation between daily ME intake and glycogen change in topside in the first week.

$y = 0.108x - 0.072$

y= glycogen change, x= daily ME intake.

$R^2 = 0.26$, $p<0.01$

Discussion

Weather

Rain occurred on several days in the second and fourth weeks of the trial and seemed to influence daily temperature. In the second week both maximum and minimum daily temperatures increased with rain. In the fourth week the maximum temperature tended to be lower but minimum temperature was higher. Cloud cover associated with rain may have had an insulating affect that caused minimum ambient temperature to increase on the days it rained.

In the predictions of LCT (table 2.03), shearing was much more important than rainfall in terms of sheep ME requirements. Predicted lower critical temperatures for shorn sheep was similar to maximum ambient temperature but for unshorn sheep they were similar to minimum ambient temperatures. Therefore shorn sheep experienced temperatures below lower critical temperatures for most of the time whilst unshorn sheep experienced temperatures above lower critical temperature for most of the time. Rainfall increased LCT more in shorn sheep than unshorn sheep but only by a few degrees for both groups.

Whilst the model predicted an extra heat requirement of 1.4 to 2 MJ of ME per sheep per day the difference in mean daily intake for shorn and unshorn sheep in the *ad libitum* groups was 1 MJ per sheep per day. Wind speeds were not measured at the trial site hence may have been lower than the 5 km/hr assumed in the model. Nevertheless the predictions demonstrate that the weather conditions were sufficiently cold to induce cold stress in shorn sheep.

Feed Intake

The difference between the ad-lib and restricted was significant ($p<0.01$). However, the level of intake in the ad-lib group was limited to some degree by the introduction period of 7 days required to avoid acidosis, and the affect of rainfall that reduced feed intake in the second and fourth weeks of the experiment (figure 2.01).

On the days that it rained feed intake went down in the *ad libitum* group but did not change in the restricted group. Rain made feed wet and unpalatable, as feeders were not covered. Sheep in the restricted groups ate their ration before rain could have any affect. Young (1983) reported that animals tend to reduce feed intake temporarily and become more cold susceptible during cold weather so sheltering feeders may not have prevented the reduction in the ad lib group on wet days completely.

Another difference between the two feed treatments was eating frequency. Feed intake in the restricted group occurred once per day with sheep eating their entire ration in one meal whereas with the ad-lib group feed was available throughout the day.

Animals that eat discrete meals show much larger changes in the insulin to glucagon ratio than animals that graze throughout the day Rook and Thomas (1983). High blood insulin facilitates transport of blood glucose into muscle and glycogen synthesis. If the restricted group experienced a higher post prandial insulin response than the ad lib group in response to once a day feeding this may explain the increase in muscle glycogen in this group. However this can only be speculated upon as no insulin measurements were made.

Muscle glycogen

Immediate affect of shearing

Eye round muscle glycogen was 18% lower in the shorn group compared to the unshorn group immediately after shearing (figure 2.06). There was no difference between shearing groups for the topside muscle so this affect was limited to the eye round muscle. This is most likely a reflection of the different fibre types in the two muscles with eye round being more sensitive to adrenaline than topside. The direct impact of stress caused by shearing before slaughter is likely to reduce glycogen in muscles that have similar fibre types to eye round and these tend to be the less valuable cuts. Whilst it may not be as important in an economic sense as factors that impact on glycogen levels in the higher value cuts, the affect of shearing seems to be part of a trend seen in experiment 1. That is transport (particularly in suckers), saleyards and shearing were factors that caused stress and reduced glycogen in eye round but did not change glycogen in topside. The absence of a reduction in topside glycogen would suggest that eating quality was not changed but this is not entirely clear as discussed in experiment 1 (Relative importance of eye round pHu, page 78).

Post shearing affect

Muscle glycogen was reduced during the post-shearing period but only when feed was restricted (figures 2.05 and 2.06). This is consistent with Bray et al. (1989) who concluded that shearing, exercise and poor nutrition had additive affects for high pHu in lambs.

Challis et al. (1987) demonstrated in rats that glycogen breakdown in response to adrenaline release increased during cold stress. They attributed this to adrenaline stimulating fructose 6 phosphate/fructose 1,6 biphosphate and glycogen/glucose 1 phosphate cycling to a greater extent in cold exposed animals. Martieau and Jacobs (1988) showed that in human's muscle glycogen was used as a fuel for thermogenic shivering during cold.

Whist shorn sheep in ad-lib and restricted groups would both have experienced cold stress and responded accordingly. The sheep in the ad-lib group presumably achieved a higher net rate of glycogen synthesis than those in the restricted group due to the higher ME intake. Sasaki et al. (1982) found that cold exposure decreased insulin secretion to a variety of stimuli including glucose and arginine infusion. However cold exposure makes tissues more sensitive to insulin and increases blood glucose turnover rate (Sano et al., 1999). Hence muscle tissues for sheep were likely to be more sensitive to insulin in the shorn group compared to the unshorn group facilitating greater glucose uptake by muscles and glycogen synthesis.

The interaction between shearing and feeding was not evident by the fourth week after shearing. Interestingly the susceptibility of summer-shorn sheep to hypothermia lasts for about 4 weeks as well (Holm-Glass and Jacob, 1993). The interaction between shearing and feeding in the post shearing period is likely to be of more significance in a commercial scenario than the affect seen immediately post shearing. This is because it was seen in both muscles such that both low and high value cuts of meats would be affected and also it lasted for 2 weeks between biopsy dates 2 and 3. If sheep are to be shorn in the wintertime prior to slaughter, cold stress needs to be considered as a potential cause of muscle glycogen loss. It can be compensated for by feeding extra ME or avoided by delaying slaughter until at least 4 weeks after shearing.

ME intake

Muscle glycogen changed rapidly and reached a maximum by the first week of the experiment. Muscle glycogen change was correlated with daily ME intake (Equation 2.03) in the first week. The time required to reach a maximum was the same for each treatment group suggesting this was independent of ME for the time interval measured. In practice this could mean that increasing the feeding time for a low ME diet will not achieve the same muscle glycogen as feeding a high ME diet.

In the second week of the trial glycogen decreased in all treatment groups and the rate of glycogen change was independent of ME intake during this period. It appears as though a control mechanism moderated the glycogen concentration to below the maximum level irrespective of the magnitude of the maximum level. In the restricted treatment groups, maximum muscle glycogen on biopsy date 2 was similar to the muscle glycogen in the ad-lib group on biopsy date 3.

The enzyme glycogen synthetase phosphatase activates the enzyme glycogen synthase by removing phosphate. The formation of glycogen from glucose-1-phosphate is catalysed by glycogen synthetase. In muscle glycogen synthetase phosphatase is inhibited by glycogen when glycogen concentration is greater than 1% (1g/100g) whereas in liver this enzyme is inhibited when glycogen exceeds 3%(White et al., 1973).

Glycogen concentration exceeded 1% in the first week in all treatment groups except in the eye round muscle of the shorn and restricted group, which reached a maximum of

0.94 g/100g. This may have resulted in inhibition of glycogen synthesis in the second week of the experiment. If the enzyme glycogen phosphorylase continued to be active in this period and the activity of glycogen synthase was reduced, then a reduction in muscle glycogen would be likely.

If this were the case there may be little advantage in feeding very high ME diets unless the animals can be slaughtered before muscle glycogen begins to decline. However, whilst the rate of change of muscle glycogen was independent of ME between the second and third biopsy dates, the absolute muscle glycogen value on the third biopsy date was positively correlated with ME intake for the period (r^2 =0 424, p<0.01). Hence ME intake appeared to have had a role in setting a basal glycogen concentrations, which were greater than 1% particularly in the topside, after the affects of the change to a higher ME had been moderated. Pethick and Rowe (1996) found a linear relationship between ME intake and basal glycogen in sheep fed for 60 days. The results suggest that basal glycogen levels may have been established from 2 weeks after the change in ME intake.

The differences in muscle glycogen between treatment groups on the last biopsy date was confounded by the increase in ME intake for the restricted groups after biopsy date 3. That is the apparent increase in muscle glycogen in the restricted group between these dates may have been due to the increase in ME from 6.6 MJ/sheep/day to 7.6 MJ/sheep/day after biopsy date 3. This was done to avoid compromising the welfare of the restricted shorn group that had lost live weight since the commencement of the experiment. The muscle glycogen on biopsy day 3 may be a better indication of basal glycogen for all groups as there was no change between biopsy date 3 and 4 for the ad lib group.

Whilst there was a positive correlation between the change in muscle glycogen and ME intake for the first week, there was still considerable change in muscle glycogen for the restricted group during this time. Topside glycogen was 2.4 times greater after one week for the ad-lib fed sheep and 1.8 times greater for the restricted sheep. Eye round glycogen was 3.4 times greater after one week for the ad-lib fed sheep and 2.2 times greater for the restricted sheep.

Weekes et al. (2000) showed that non-insulin mediated glucose utilisation accounted for 90% of glucose utilisation during fasting and utilization by muscles reduced but was not eliminated during fasting in sheep. Some reduction in glucose utilisation would assist muscles to maintain glycogen levels at low ME intakes, but net synthesis must still have occurred for glycogen levels to increase in the restricted group.

Feed intake was not measured during the pre experimental period so ME intake cannot be compared between the two periods. Sheep lost live weight during this period despite being offered hay at the rate of 9.96 MJ/sheep/day (DM), which theoretically was enough to maintain live weight. Palatability may have limited hay intake and the pen acclimatisation process may have also contributed to live weight loss.

Live weight loss suggests that ME intake was lower than maintenance before the trial commenced such that even the restricted diet may have supplied more ME than the hay fed before the trial. However the restricted ration also caused weight loss and the rate of change in live weight in the unshorn restricted group was similar to that before the trial. The live weight change in the shorn restricted group was apparently greater although not statistically different to the unshorn group (figure 2.02). None of the sheep were shorn before the experiment hence there was no affect of shearing on maintenance requirement in that period.

Other factors besides ME that changed at the commencement of the trial may have caused the increase in muscle glycogen during the first week in the restricted groups, notably the type of carbohydrate in the diet and the frequency of feeding. The pelleted ration contained wheat and lupin grain and would be expected to have produced more propionate than a hay diet at the same level of ME. Also the rumen fermentation modifying agent lasalocid directs rumen fermentation towards propionate production. Sano et al. (1999) stated that plasma insulin concentration was lower and the effect of insulin action on glucose metabolism was less for a high roughage diet than a high concentrate diet in sheep.

Conclusions

Concentrate feeding for 7-14 days was shown to be an effective strategy for increasing muscle glycogen prior to slaughter. A high ME diets was more effective than a low ME diet for boosting muscle glycogen in the short term. Shearing had a small impact on muscle glycogen. More importantly it was shown that shearing could lead to a reduction in glycogen by predisposing sheep to cold stress. High ME diets allowed sheep to compensate for cold stress. There was some evidence that the type of ME may be important for muscle glycogen, with grain being more effective than roughage diets, and further work is required in this area.

APPENDICES

1 Farm management questionnaire

Section 1 Name Address and Phone Number

Trading Name	
Postal Address	
Phone	
Fax	
Farm Locality	

Section 2 Sheep Management Calendar and Breed Details

1. On which date did lambing start for this mob of lambs?	
2. On which date did lambing finish for this mob of lambs?	
3. On which date or dates were this mob of lambs marked?	
4. On which date were these lambs weaned from their mothers? (If they were weaned onto the truck for slaughter please put that date)	
5. What breed or breeds were the mothers (ewes) of these lambs?	
6.What breed or breeds were the fathers (rams) of these lambs?	
7. Have these lambs been shorn? Please circle yes or no.	
8. If these lambs were shorn on which date were they shorn?	

Section 3 Animal Health Treatments

1. On which date or dates were these lambs given a drench to kill worms (if not drenched write not drenched)?	
2. On which date or dates were these lambs given a selenium treatment (if not treated please write not treated)?	
3. On which date or dates were these lambs given a cobalt treatment (if not treated please write not treated)?	
4. On which date or dates were these lambs vaccinated against pulpy kidney/cheesy gland. (if not vaccinated write not vaccinated)?	

Section 4 Feed and Pasture Details

	Feedlot	Paddock
1. Were these lambs in a feedlot or a paddock prior to sale for slaughter (tick Feedlot or Paddock).		

<u>If the sheep were in a feedlot prior to sale please go to question 2 and if they were on a paddock prior to sale please go to question 4.</u>

2. Please write down the feed ration used in the feedlot with the names of the feeds and the amount of each in the mixed ration. Include any supplements including minerals, vitamins, antibiotics etc.

Ingredient's Name (e.g. Oats, lupins, Limestone)	Weight of Ingredient
Total	

3. For what period of time were the lambs in the feedlot (days)?	

<u>Questions 4 to 7 are for lambs grown in a paddock. If the lambs have been in a feedlot and you have already answered questions 1 to 3 please ignore 4 to 7 and go to question 8.</u>

4. Was the feed in the paddock annual pasture, cereal stubble, lupin stubble, canola stubble, pea stubble or something else?		
5. For what period of time (number of days or weeks) were the lambs in this paddock?		
6. Were these lambs supplemented with grain? (Yes/No)		

7. If the answer to question 5 is yes then what type of grain was fed? Please use the following table to answer this. (The weight column applies to mixtures if 2 or more ingredients are used.)

Ingredient (e.g oats, lupins, limestone)	Weight of Ingredient
Total	

8. At what rate was the grain or grain mixture fed to the lambs (e.g. grams/head/day or bags/100 sheep)

Section 5 Mustering and Yarding Details

1. On what date and time was mustering started?
2. On what date and time was mustering finished?
3. What is the approximate distance from the paddock to the yards?
4. Were dogs used to assist with mustering (circle yes or no)?
5. Did you use a buyer to sell the lambs? (yes or no)
6. On what date and time were the lambs drafted into a sale line?
7. On what date and time were the lambs loaded on to trucks for transport to abattoirs?
8. Did the lambs have access to food for the period from drafting into a sale line until trucking out? (yes or no)
9. Did the lambs have access to water for the period from drafting into a sale line until trucking out? (yes or no)
10. Were the lambs crutched prior to sale?
11. Were the lambs weighed prior to sale?
12. Were the lambs' condition scored prior to sale?
13. Where were the lambs kept for the period from drafting into a sale line until trucking out (e.g. yards, holding paddocks, shearing shed). If this was in more than one place or the line was drafted several days before trucking please indicate how this was done.

Section 6 Trucking Details

1. Did you use a contractor to cart the lambs to abattoirs (circle Yes or No)?		
2. What is the approximate distance from the farm to the abattoir in kilometres?		
3. What type of truck was used (truck, semitrailer, B train etc)		
Transport Time		

4. Slaughter Date	

Thankyou very much for taking the time to complete this questionairre.

The End

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