final report

Project Code: SMEQ.002

Prepared by: Sarah Wiese, John Milton, Rob Davidson, and David Pethick
Department of Agriculture Western Australia and
Murdoch University

Date published: September 2009

ISBN: 1 74036 3396

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Teeth eruption and eating quality in young sheep

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Final Report

Meat and Livestock Australia Project SMEQ.002

Teeth eruption and eating quality in young sheep

Chief Investigators:

Dr Sarah Wiese
Agriculture Western Australia, Narrogin, 6312

Dr John Milton
Agriculture Western Australia, based at the University of Western Australia, Nedlands, 6907

Mr Rob Davidson
Agriculture Western Australia, based at the University of Western Australia, Nedlands, 6907

Associate Professor David Pethick
Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch, 6150

Industry Collaborators:

Mr Shane Edwards
PO Box 88, Quairading, 6383

Mr Jeff Murray
PO Box 53, Beverley, 6306

Mr Don Handscombe
PO Box 54, Quairading, 6383

Mr Phil Mulcahy and Mr Ron Whyte
WAMMCO International, GPO Box X2309, Perth, 6001

Published and printed by Agriculture Western Australia, Narrogin, 6312
July 2000

Table of Contents

Summary

This project considered the impact on eating quality of allowing young sheep with partially erupted permanent incisor teeth to be classified as lamb. Eating quality of meat from sheep at various stages of eruption (milk, partially erupted or fully erupted teeth), were evaluated using objective and sensory measures. The study was conducted with three flocks representing the three genotypes that contribute to the prime lamb industry in Australia; Merino, first cross and second cross.

Of the 19 attributes assessed over the three genotypes, only one attribute in one genotype showed a significant negative effect of allowing lambs to progress from having milk teeth to having partially erupted teeth. This was an increase in myoglobin content in the first cross lambs. Many of the attributes assessed showed changes that could be considered as positive for eating quality as the sheep progressed from milk teeth to partially erupted and even to fully erupted teeth.

The following significant differences in objective and sensory measures of eating quality were found between the three dentition groups.

For the Merino animals;

- The fully erupted group had a lower cooking loss than the other two groups.
- The fully erupted group had a higher myoglobin level than both the milk teeth and partially erupted groups.

For the first cross animals;

- The fully erupted group had darker coloured meat (L value) than the milk teeth group.
- Both the partially erupted and fully erupted groups had a higher myoglobin level than the milk teeth group.

For the second cross animals;

- The meat colour of the partially erupted group was not as red (a value) or as yellow (b value) as the meat from the other two groups.
- The fully erupted group had a higher myoglobin level than both the milk teeth and partially erupted groups.
- The fully erupted group was considered to be more tender by the consumer sensory panel than the other two groups.

The results of this project indicate that, for the genotypes studied, meat from young sheep with partially erupted teeth is unlikely to be inferior in eating quality than the meat currently classified as lamb.

Acknowledgments

This project was initiated by the Australian Stud Merino Breeders Association and the Western Australian Sheep Meat Research and Development Group, without their drive and support the project would never have been undertaken.

The generous contribution of the host farmers; Shane Edwards, Jeff Murray and Don Handscombe is gratefully acknowledged. Their provision of the animals, facilities and large amounts of assistance was invaluable in the conduct of the study.

WAMMCO International is gratefully acknowledged for allowing us access to their plant and to complete measurements on the carcasses. The assistance of Mr Ron Whyte and Mr Phil Mulcahy was invaluable in organising the logistics at the abattoir.

The assistance of Dr Brian McIntyre of Agriculture Western Australia in carrying out the electrical stimulation treatments is appreciated.

The assistance of Malcolm Boyce and Graham Gardner of Murdoch University in monitoring the pH and temperature decline of the carcases is gratefully acknowledged.

Heather Channon is gratefully acknowledged for completing the measurements of Warner Bratzler shear force and cooking loss.

Barbara Waldoch, Malcolm Boyce and Diana Pethick are gratefully acknowledged for conducting the myoglobin and glycogen assays.

Mr John Beesley is thanked for assisting with the analysis for intramuscular fat.

Ms Hannah Williams is gratefully acknowledged for establishing and undertaking the trained taste panel work.

The work of Alan Gee in sample preparation and Sensory Solutions in conducting the consumer sensory analysis is gratefully acknowledged.

The financial support of Meat and Livestock Australia and the Agriculture Western Australian Meat Program enabled this project to be carried out.

Introduction

The current system of classification for sheep meat in Australia, states 'a sheep ceases to be a lamb when any evidence of eruption of its first permanent teeth is present'. After this, the carcase is classified as hogget and the price paid is substantially less than that for lamb. In contrast, the New Zealand classification system enables a young sheep to continue to be branded as lamb after the two permanent central incisor teeth have erupted as long as the teeth are not in wear. This difference in classification disadvantages the Australian product and the Australian producer in several ways.

For the Australian lamb industry to achieve a consistent supply of large lean lambs over 12 months, more lambs need to be carried through summer and finished in the autumn and early winter period. By allowing lambs to be slightly older at slaughter the industry would be able to supply these lambs over a longer period. Merino lambs are a substantial part of the lamb industry and, being leaner and later maturing, are well suited to carryover production systems. In order to take advantage of these traits, producers need to be confident they can finish and market their lambs before facing the risk of having the lambs downgraded to hoggets.

With the current grading systems, New Zealand lamb can be older and therefore often heavier than lamb graded under the Australian system. The two highest priced world markets, the EU and the US, are both seeking larger, heavier lamb. The Australian definition of lamb limits the number of lambs carcasses that can attain the heavy weights desired by these premium priced markets.

The age of teeth eruption appears to be highly variable in lambs, ranging anywhere from 10 to 18 months. This makes it difficult for producers to grow-out lambs to higher weights and still be confident that the lambs can be marketed before their first permanent incisors begin to erupt. A system that could provide a warning period, in which the incisors have erupted but are not in wear, would allow producers to grow-out older lambs to heavier weights, with greater confidence.

The anomalies with the current lamb classification system lead to distrust and disharmony in the industry. For example, producers often do not believe that the animals they mouthed as lambs on the farm, erupt teeth and are then legitimately classified hoggets at slaughter, yet there are several reports to suggest that the stress of trucking and lairage may well precipitate teeth eruption. Costly problems can also arise for processors who buy lambs at the saleyard, and then find that a proportion of those lambs erupt teeth before slaughter.

The main concern with changing from the current system of classification is that by allowing the permanent teeth to be erupted but not in wear, the lambs will be slightly older and may have meat of less desirable eating quality. The period of teeth eruption could also be stressful or may cause the young sheep discomfort and unwillingness to bite hard feeds that could result in an intake-restricted-phase in a lambs growth path. Convincing results to demonstrate that eating quality is not compromised by allowing young sheep to have erupted their permanent central incisor teeth before slaughter are needed to address concerns with changing the current system.

Hypothesis

In young sheep of the same genotype, growth path and feed regime, there are significant differences in the eating quality of animals slaughtered with no teeth erupted, permanent teeth erupted but below the height of the central lateral milk teeth and permanent teeth fully erupted and in wear.

Materials and Methods

Animals and host farms

Young sheep from three flocks were monitored and slaughtered representing each of the following genotypes; Merino, Border Leicester sire by Merino ewe (first cross) and Poll Dorset sire by Border Leicester x Merino ewe (second cross). The Merino sheep were based on a Collinsville bloodline, May 1998 drop ewes belonging to Shane Edwards of Quairading and prior to slaughter were finished on good quality, short, green pasture with restricted access to lupins. The first cross sheep were mixed sex, June 1998 drop lambs belonging to Jeff Murray which had been run at Lake Grace before being trucked to Beverley for finishing on abundant spring pasture with restricted access to lupins. The second cross sheep were mixed sex, July to August 1998 drop lambs, belonging to Don Handscombe of Quairading and prior to slaughter were finished on dry pasture with a very high subterranean clover content.

Lamb management and monitoring

Lambs were weighed, condition scored and mouthed fortnightly from the commencement of monitoring on 21 June 1999. Each genotype of lambs were consigned to slaughter as one line when all three dentition categories; fully erupted, erupted but not in wear and not erupted, were as evenly represented as possible. The slaughter dates for the three genotypes were; Merino lambs 10 August; first cross lambs 8 September; second cross lambs 7 December. The lambs were monitored weekly in the final three weeks before slaughter, with a final weight, condition score and dentition status recorded the day before slaughter.

Description of dentition

In order to monitor the progressive eruption of teeth, dentition was described within the three categories as follows;

1. Milk teeth: intact milk teeth or loose milk teeth
2. Partially erupted: lost one milk tooth, lost two milk teeth, one permanent tooth erupted, both permanent teeth just erupted, permanent teeth on the pad, but below the central lateral milk teeth.
3. Fully erupted: both permanent teeth fully erupted to the height of the central lateral milk teeth.

Assessments at slaughter

Hot carcase weight, fat score and brand classification were recorded at slaughtered. All lambs were subjected to 90 seconds of high voltage electrical stimulation (800 V), 30 to 45 minutes post slaughter to minimise the risk of cold shortening. One electrode was attached to the neck and the other earthed on to the railing above the carcase. Temperature and pH decline of the *longissimus dorsi* muscle (LD) was monitored hourly for six hours post slaughter.

The following measurements were collected 48 hours post slaughter according to the methods described by Hopkins *et al* (1996); GR tissue depth, eye muscle area, C site fat depth, meat colour and ultimate pH of the LD muscle. Meat colour was measured using a Minolta Chromameter set on L, a and b. L measures lightness, higher readings are lighter and 34 is considered the lowest acceptable reading. a measures redness/greeness with higher readings being more red and b measures yellowness/blueness with higher readings being more yellow. The pH of the muscle was measured using an Orion pH meter with a Phillips electrode (C64/1) using temperature compensation. Low ultimate pH readings are associated with superior meat quality, pH 5.7 is the commonly accepted maximum desirable level. Muscle temperature was measured using a Digimulti thermometer (Takara, model 611).

Objective measurements

One side of the anterior LD was collected from 30 carcasses in each of the three dentition categories and used for objective analyses. Measurements were made of post-slaughter glycogen, intramuscular fat, myoglobin content, Warner Bratzler shear force and cooking loss. Samples for Warner Bratzler and cooking loss analysis were aged for a further two days (giving a total of four days) before freezing. The remaining samples for objective analyses were frozen immediately allowing only two days of aging.

Shear force was estimated on cooked meat samples using a Warner Bratzler shear blade fitted to an Instron Universal Testing machine. Lower shear force values indicate more tender meat, with values below 5 kg considered to be acceptably tender. Glycogen was measured using a modified method of Chan and Exton (1975). Intramuscular fat was determined using solvent extraction (3:2 hexane: isopropanol) from freeze dried samples of muscle according to the method described by Harris (1998).

Sensory measurements

The posterior LD and the full LD from the other side of the carcase were excised from 20 carcasses in each dentition category for sensory analysis. These meat samples were vacuum packed and aged for a further two days (giving a total of four days) before freezing. Ten samples from each dentition group were evaluated by a consumer sensory panel and ten samples by a trained sensory panel.

The consumer panel used 10 panelists per sample and was conducted by Sensory Solutions according to the established sensory evaluation protocols (MLA, 1999). The consumer panel rated the samples on a scale of 1 (worst) to 100 (best) for tenderness, juiciness, flavour strength, flavour liking and overall liking and then rated the acceptability of the sample on a scale of one to five, with five being most acceptable. A sheep meat eating quality score (SEQ) was calculated as follows (MLA, 1999);

$$SEQ = 0.4 \times \text{overall liking} + 0.3 \times \text{flavour liking} + 0.2 \times \text{tenderness} + 0.1 \times \text{juiciness}.$$

The trained panel used six panelists per sample and was conducted at Curtin University according to the protocol developed by Williams (1999). Samples were cut to a constant thickness and then grilled on a silex cooker to an internal temperature of 65°C. The trained panel rated the samples on a scale of 1 (worst/least) to 10 (best/strongest) for tenderness, juiciness and flavour intensity.

Merino mutton

Sixteen four-year-old Merino wethers were slaughtered and the mutton samples collected and used in the consumer panel to widen the spectrum of samples evaluated. The wethers were from the same bloodlines as the Merino ewe lambs used it the trial. Prior to slaughter the wethers were grazing dry pasture with a small amount of green pick at high stocking rates. The wethers were slaughtered at the same abattoir and subjected to the same electrical stimulation and aging treatments as the trial sheep.

Statistical analyses

All measurements were analysed using analysis of variance (SYSTAT microcomputer program). Carcase weight and GR tissue depth were used as covariates for the objective and sensory measures, where they were significant. Data for the three dentition groups were compared within genotypes and then across genotypes, using genotype as a factor.

Results

Merino lambs

Growth and carcase attributes

There were no significant differences in the initial or final live weight between the three dentition groups. However, the carcase weight of the fully erupted group was significantly heavier than the partially erupted group, due to a higher dressing percentage ($P < 0.05$). Growth rate was slightly lower in the partially erupted group but this difference was not significant. Animals in the partially erupted group were leaner at the GR site than the fully erupted group, while animals in the milk group had a smaller eye muscle area than those in the fully erupted group ($P < 0.05$).

Table 1. Growth and carcase attributes of Merino sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Number of animals	30	30	26	
Initial live weight (kg)	47.6	46.2	49.2	0.93
Initial condition score (1-5)	1.8	1.8	2.0	0.08
Final live weight (kg)	53.2	51.0	54.6	1.03
Final condition score (1-5)	2.4	2.3	2.6	0.10
Growth rate (g/day)	268	243	261	10.4
Carcase weight (kg)	22.8^{ab}	21.9^{a}	24.2^{b}	0.54
Fat score (1-5)	3.1	3.0	3.4	0.13
Dressing percentage (%)	42.8^{a}	42.9^{a}	44.2^{b}	0.39
GR tissue depth (mm)	10.7^{ab}	9.3^{a}	12.3^{b}	0.69
C site fat depth (mm)	3.5	3.1	3.9	0.29
Eye muscle area (cm^2)	13.0^{a}	13.8^{ab}	14.6^{b}	0.31

Numbers in the same row with different superscripts are different ($P < 0.05$).

Temperature and pH decline

The decline in muscle pH following slaughter and electrical stimulation was rapid. All but one of the carcasses monitored had a pH below 6.0 before the temperature fell below 12°C, minimising the risk of cold shortening.

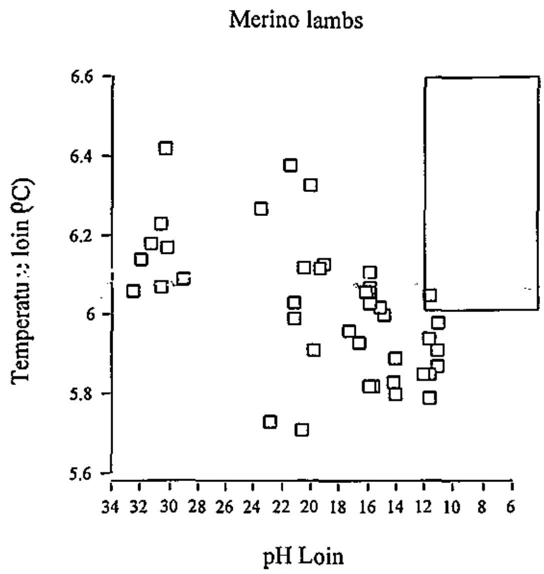

Figure 1. Temperature and pH decline in the loin (M. longissimus dorsi) of Merino sheep following slaughter.

Objective measures of meat quality

The objective measures of meat quality did not indicate any detrimental effects associated with teeth eruption. There were no differences between the dentition groups in meat colour, ultimate muscle pH, Warner Bratzler shear force, muscle glycogen or intramuscular fat. Cooking loss was greater and myoglobin content was lower in the milk and partially erupted groups compared to the fully erupted group ($P < 0.05$). GR tissue depth was a significant covariate for myoglobin content and intramuscular fat ($P < 0.05$) and when used with myoglobin content made the differences between dentition groups non-significant. More sheep in the milk teeth group had shear force values above 4 than in the other dentition groups (Figure 2).

Table 2. Objective measures of meat quality for Merino sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Meat colour L	34.6	34.8	34.4	0.37
Meat colour a	21.0	20.5	21.2	0.32
Meat colour b	9.9	9.7	10.2	0.19
Muscle pH LD (48 hours)	5.58	5.56	5.56	0.014
Cooking loss (%)	33.8^{a}	33.8^{a}	33.0^{b}	0.24
Warner Bratzler shear force (kg)	2.48	2.33	2.39	0.153
Glycogen (g/100g)	0.45	0.36	0.36	0.073
Myoglobin (mg/g)	9.18^{a}	9.44^{a}	10.19^{b}	0.291
Intramuscular fat (% fresh wt)	8.68	9.18	9.57	0.675

Numbers in the same row with different superscripts are different ($P < 0.05$).

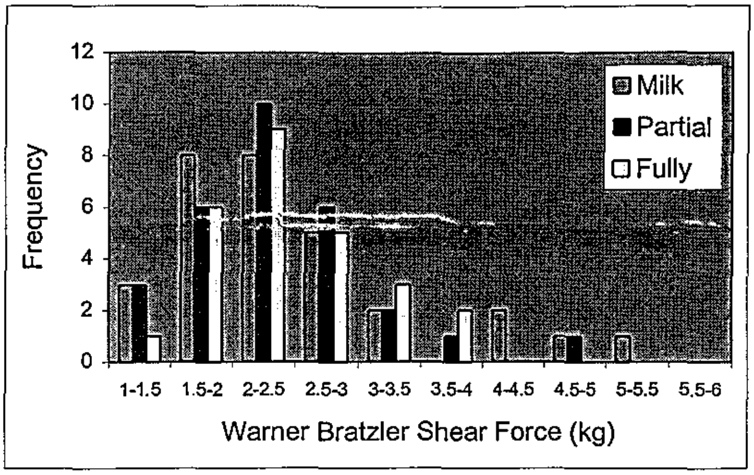

Figure 2. Frequency histogram of Warner Bratzler shear force of meat from Merino sheep with milk, partially erupted or fully erupted teeth.

Sensory evaluation of eating quality

Consumer and trained sensory evaluation panels did not detect any significant differences for any eating quality attribute between the three dentition groups. The overall rating given by the consumer panel showed a preference for the samples from the partially and fully erupted groups, but this was not significant. GR tissue depth was a significant covariate for tenderness in the consumer panel evaluation ($P < 0.05$).

Table 3. Eating quality attributes of meat from Merino sheep with milk, partially erupted or fully erupted teeth evaluated by consumer and trained panels

	Milk teeth	Partially erupted	Fully erupted	SEM
Consumer panel				
Tenderness	66.4	70.2	72.4	2.87
Juiciness	55.9	60.3	62.9	2.88
Flavour strength	55.8	60.8	62.2	2.32
Flavour liking	64.2	67.4	68.5	2.27
Overall liking	63.9	69.5	70.2	2.30
Consumer rating	3.37	3.66	3.69	0.099
SEQ score	63.7	68.1	69.4	2.29
Trained panel				
Tenderness	7.05	7.15	6.63	0.372
Juiciness	6.54	6.65	6.54	0.323
Flavour intensity	6.72	6.91	6.80	0.193

Numbers in the same row with different superscripts are different ($P < 0.05$).

First cross lambs

Growth and carcase attributes

There was no difference between the three dentition groups in live weight, carcase weight or growth rate. The carcasses from lambs with fully erupted teeth had a higher manually palpated fat score than the other two groups ($P < 0.05$) but this was not supported by a significant difference in the measured fat depth at the GR or C site.

Table 4. Growth and carcase attributes of first cross sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Number of animals	30	30	28	
Initial live weight (kg)	35.2	35.0	35.3	0.51
Initial condition score (1-5)	1.4	1.4	1.4	0.07
Final live weight (kg)	50.5	49.7	50.0	0.74
Final condition score (1-5)	2.6	2.5	2.8	0.11
Growth rate (g/day)	228	220	218	6.6
Carcase weight (kg)	22.3	21.7	22.5	0.39
Fat score (1-5)	2.4^{a}	2.4^{a}	2.7^{b}	0.09
Dressing percentage (%)	44.1	43.8	45.0	0.51
GR tissue depth (mm)	9.1	7.9	9.2	0.51
C site fat depth (mm)	2.4	2.6	2.8	0.20
Eye muscle area (cm^2)	15.7	14.9	15.4	0.38

Numbers in the same row with different superscripts are different ($P < 0.05$).

Temperature and pH decline

The decline in muscle pH following slaughter and electrical stimulation was rapid. However, some of the carcasses monitored did not attain a pH below 6.0 before their temperature fell below 12°C, indicating they were potentially at risk of cold shortening.

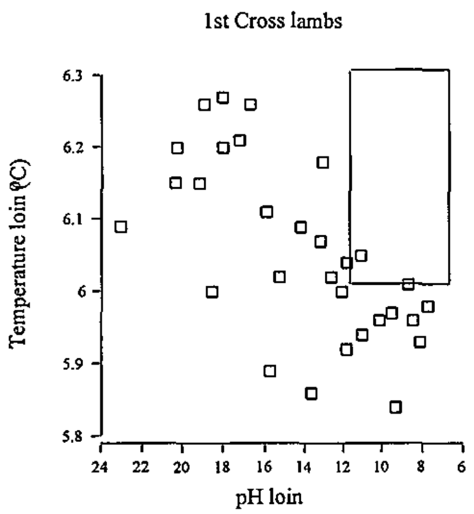

Figure 3. Temperature and pH decline in the loin (M. longissimus dorsi) of first cross sheep following slaughter.

Objective measures of meat quality

There were no significant differences between the dentition groups in ultimate muscle pH, Warner Bratzler shear force, cooking loss or muscle glycogen. However, in the silverside (*M. semi tendinosis*), a muscle more susceptible to changes in pH, the pH was slightly higher in the fully erupted group than in the other two groups (Table 5). There were differences between the groups in meat colour lightness (L), with the milk teeth group having meat of lighter colour than the fully erupted group. This was supported by differences in myoglobin content, where both the fully erupted and partially erupted groups had a higher concentration of myoglobin than the milk teeth group ($P < 0.05$). Carcase weight was a significant covariate for cooking loss ($P < 0.05$). The distribution of shear force values was similar for the three groups, although the two highest readings were from sheep in the fully erupted group (Figure 4).

Table 5. Objective measures of meat quality in meat from first cross sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Meat colour L	34.4[a]	34.0[ab]	33.1[b]	0.32
Meat colour a	21.8	21.5	21.5	0.33
Meat colour b	10.0	10.0	10.0	0.19
Muscle pH LD (48 hours)	5.52	5.52	5.53	0.009
Muscle pH SM (48 hours)	5.51	5.52	5.53	0.007
Muscle pH ST (48 hours)	5.69	5.68	5.75	0.025
Cooking loss (%)	32.9	32.9	32.6	0.32
Warner Bratzler shear force (kg)	3.23	3.00	3.25	0.19
Glycogen (g/100g)	0.26	0.29	0.22	0.022
Myoglobin (mg/g)	9.96[a]	10.68[b]	10.88[b]	0.258

Numbers in the same row with different superscripts are different ($P < 0.05$).

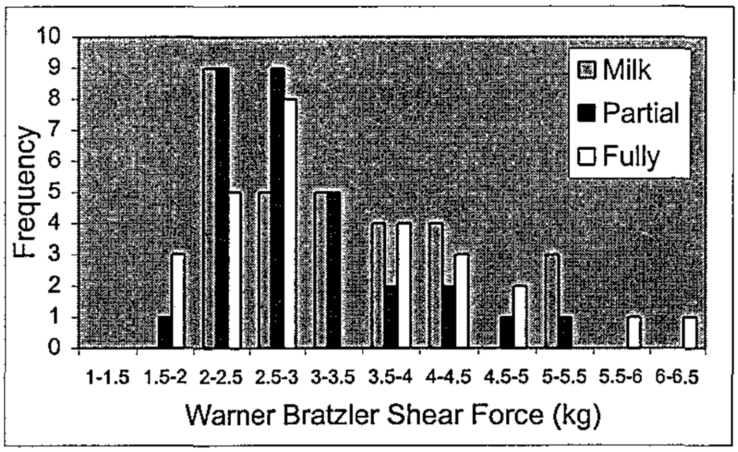

Figure 4. Frequency histogram of Warner Bratzler shear force of meat from first cross sheep with milk, partially erupted or fully erupted teeth.

Table 6. Eating quality attributes of meat from first cross sheep with milk, partially erupted or fully erupted teeth evaluated by consumer and trained panels

	Milk teeth	Partially erupted	Fully erupted	SEM
Consumer panel				
Tenderness	58.0	59.0	61.2	2.68
Juiciness	46.4	51.3	52.8	2.36
Flavour strength	56.8	58.4	59.5	1.72
Flavour liking	57.6	62.1	61.9	2.25
Overall liking	57.9	61.0	61.4	2.20
Consumer rating	3.11	3.34	3.32	0.096
SEQ score	56.7	59.9	60.7	2.14
Trained panel				
Tenderness	5.41	6.15	5.12	0.333
Juiciness	5.29	5.09	4.93	0.297
Flavour intensity	6.54	6.59	6.27	0.198

Numbers in the same row with different superscripts are different ($P < 0.05$).

Sensory evaluation of eating quality

The consumer and trained sensory evaluation panels did not detect any significant differences between the three dentition groups, although the partially and fully erupted groups ranked numerically higher than the milk teeth group in all of the attributes evaluated by the consumer panel. The tenderness score given by the trained panel tended to show ($P < 0.1$) a preference for the samples from the partially erupted group. Carcase weight was a significant covariate for flavour strength in the consumer panel results ($P < 0.05$).

Second cross lambs

Growth and carcase attributes

The sheep in the fully erupted group were heavier and had a slower growth rate than the other two dentition groups ($P < 0.05$). The carcasses of the fully erupted group were also heavier and fatter at the GR and C site than the milk group, with the carcasses in the partially erupted group in between the two ($P < 0.05$). There were no differences between the groups in dressing percentage or eye muscle area.

Table 7. Growth and carcase attributes of second cross sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Number of animals	26	20	20	
Initial live weight (kg)	40.1^{a}	40.5^{a}	48.0^{b}	1.90
Initial condition score (1-5)	2.3^{a}	2.2^{a}	2.8^{b}	0.16
Final live weight (kg)	66.8	69.2	70.9	1.84
Final condition score (1-5)	3.3	3.6	3.6	0.24
Growth rate (g/day)	160^{a}	170^{a}	136^{b}	8.1
Carcase weight (kg)	28.4^{a}	29.9^{ab}	31.3^{b}	0.81
Fat score (1-5)	4.4	4.4	4.6	0.15
Dressing percentage (%)	42.6	43.2	44.2	0.51
GR tissue depth (mm)	17.4^{a}	19.1^{ab}	21.4^{b}	1.02
C site fat depth (mm)	6.8^{a}	7.8^{a}	9.7^{b}	0.64
Eye muscle area (cm^2)	16.0	16.2	15.8	0.39

Numbers in the same row with different superscripts are different ($P < 0.05$).

Temperature and pH decline

The decline in muscle pH following slaughter and electrical stimulation was variable in the carcasses monitored. Most carcasses had a pH below 6.0 well before their temperature fell below 12°C, but there were some carcasses at risk of cold shortening.

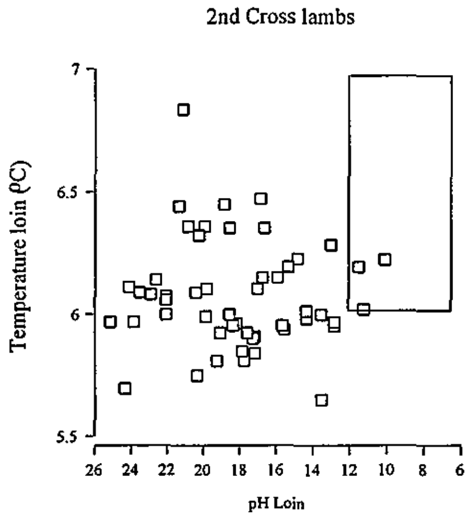

Figure 5. Temperature and pH decline in the loin (M. longissimus dorsi) of second cross sheep following slaughter.

Objective measures of meat quality

The objective measures of meat quality did not indicate any detrimental effects associated with teeth eruption. There were no differences between the dentition groups in meat colour lightness (L value), ultimate muscle pH, Warner Bratzler shear force, cooking loss, muscle glycogen or intramuscular fat. The meat colour of the sheep in the partially erupted group was not as red (a value) or as yellow (b value) as the meat from the other two groups ($P < 0.05$). The myoglobin content of the muscle was higher in the fully erupted group than in the other two groups ($P < 0.05$). GR tissue depth was a significant covariate for ultimate muscle pH, meat colour L, a and b, shear force and cooking loss ($P < 0.05$). Including GR tissue depth as a covariate did not alter the significance of the analyses. Carcase weight was a significant covariate for ultimate muscle pH and colour lightness. All dentition groups had very low mean shear force values and a narrow distribution of values, with the fully erupted group having the narrowest range of the three groups (Figure 6).

Table 8. Objective measures of meat quality for meat of second cross sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Meat colour L	35.4	34.9	35.0	0.55
Meat colour a	21.3 [a]	20.0 [b]	21.7 [a]	0.36
Meat colour b	9.8 [a]	9.1 [b]	9.9 [a]	0.21
Muscle pH LD (48 hours)	5.63	5.64	5.61	0.013
Cooking loss (%)	35.9	35.9	36.1	0.36
Warner Bratzler shear force (kg)	2.24	2.10	2.13	0.096
Glycogen (g/100g)	0.51	0.49	0.49	0.057
Myoglobin (mg/g)	9.76 [a]	10.04 [a]	10.97 [b]	0.329
Intramuscular fat (% fresh wt)	7.09	6.07	6.77	0.445

Numbers in the same row with different superscripts are different ($P < 0.05$).

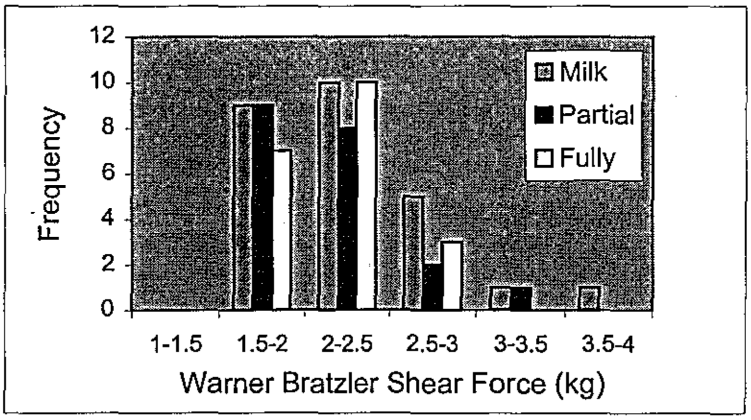

Figure 6. Frequency histogram of Warner Bratzler shear force of meat from second cross sheep with milk, partially erupted or fully erupted teeth.

Sensory eating quality evaluation

The consumer panel detected that the meat from the fully erupted group was significantly more tender ($P < 0.05$) and slightly more juicy than the other two groups. Flavour strength and flavour liking was rated slightly higher in the partially erupted group than the other two groups, which resulted in the partially erupted and fully erupted groups having a slightly higher SEQ score than the milk teeth group. The trained panel rated the samples from the partially erupted group lowest on tenderness, juiciness and flavour intensity but the differences were not significant.

Table 9. Eating quality attributes of meat from second cross sheep with milk, partially erupted or fully erupted teeth evaluated by consumer and trained panels

	Milk teeth	Partially erupted	Fully erupted	SEM
Consumer panel				
Tenderness	59.0^a	64.0^a	70.4^b	2.99
Juiciness	56.9	61.1	63.8	2.81
Flavour strength	60.4	63.9	61.0	1.75
Flavour liking	64.0	67.0	65.8	2.77
Overall liking	62.5	66.7	66.7	3.26
Consumer rating	3.41	3.51	3.62	0.119
SEQ score	61.7	65.7	66.9	2.89
Trained panel				
Tenderness	6.62	6.13	6.37	0.357
Juiciness	5.61	5.05	5.99	0.293
Flavour intensity	6.80	6.54	6.93	0.214

Numbers in the same row with different superscripts are different ($P < 0.05$).

Combined genotypes analyses

Growth and carcase attributes

When the data from the three genotypes were combined and analysed with genotype as a factor, the final live weight, condition score and growth rate did not differ between the three dentition groups. However, the fully erupted group had a heavier carcase weight, higher dressing percentage and more fat at the GR and C sites than the milk teeth or partially erupted groups ($P < 0.05$).

Table 10. Mean values over the three genotypes for growth and carcase attributes of young sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Number of animals	86	80	74	
Initial live weight (kg)	41.0^a	40.6^a	44.2^b	0.65
Initial condition score (1-5)	1.8^a	1.8^a	2.0^b	0.06
Final live weight (kg)	56.8	56.6	58.5	0.69
Final condition score (1-5)	2.8	2.8	3.0	0.08
Growth rate (g/day)	219	211	205	5.0
Carcase weight (kg)	24.5^a	24.5^a	26.0^b	0.33
Fat score (1-5)	3.3^a	3.2^a	3.6^b	0.07
Dressing percentage (%)	43.2^a	43.3^a	44.4^b	0.28
GR tissue depth (mm)	12.4^a	12.1^a	14.3^b	0.42
C site fat depth (mm)	4.2^a	4.5^a	5.4^b	0.22
Eye muscle area (cm^2)	14.9	14.9	15.3	0.21

Numbers in the same row with different superscripts are different ($P < 0.05$).

Table 11. Mean values over the three genotypes for objective measures of meat quality for meat from young sheep with milk, partially erupted or fully erupted teeth

	Milk teeth	Partially erupted	Fully erupted	SEM
Meat colour L	34.8	34.5	34.2	0.23
Meat colour a	21.3^a	20.7^b	21.5^a	0.20
Meat colour b	9.9^a	9.6^b	10.0^a	0.12
Muscle pH LD (48 hours)	5.57	5.57	5.56	0.006
Cooking loss (%)	34.2	34.2	33.9	0.18
Warner Bratzler shear force (kg)	2.65	2.47	2.59	0.093
Glycogen (g/100g)	0.41	0.38	0.36	0.033
Myoglobin (mg/g)	9.63^a	10.05^a	10.68^b	0.169

Numbers in the same row with different superscripts are different ($P < 0.05$).

Objective measures of meat quality

When the objective measures of meat quality were combined for the three genotypes there were no differences between the dentition groups in meat colour lightness (L value), ultimate muscle pH, Warner Bratzler shear force, cooking loss or muscle glycogen. The meat colour of the sheep in the partially erupted group was not as red (a value) or as yellow (b value) as the meat from the other two groups ($P < 0.05$). The myoglobin content of the muscle was higher in the fully erupted group than the other two groups ($P < 0.05$). GR tissue depth was a significant covariate for ultimate muscle pH, meat colour b, cooking loss and myoglobin content ($P < 0.05$). The difference in meat colour b was not significant once adjusted for GR tissue depth.

Sensory eating quality evaluation

When the sensory measures of meat quality were combined for the three genotypes, the consumer panel detected that the meat from the fully erupted group was more tender ($P < 0.05$) than the meat from the milk teeth group. Meat from both the partially and fully erupted groups was more juicy and attained a higher consumer rating and SEQ score than meat from the milk teeth group ($P < 0.05$). Flavour strength, flavour liking and overall liking were rated slightly higher in the partially erupted and fully erupted groups than the milk teeth group, but these differences were not significant. GR tissue depth was a significant covariate for tenderness, juiciness, flavour liking and consumer rating ($P < 0.05$) but did not alter the significance of the effects of dentition. Carcase weight was also a significant covariate for juiciness ($P < 0.05$).

The trained panel rated the meat from fully erupted group the lowest on tenderness and the meat from the partially erupted group lowest on juiciness but these differences were not significant. Neither GR tissue depth nor carcase weight were a significant covariate for any of the trained panel results.

Table 12. Mean values over the three genotypes for eating quality attributes of meat from young sheep with milk, partially erupted or fully erupted teeth evaluated by consumer and trained panels

	Milk teeth	Partially erupted	Fully erupted	SEM
Consumer panel				
Tenderness	61.2[a]	64.4[ab]	68.0[b]	1.78
Juiciness	53.1[a]	57.6[b]	59.8[b]	1.73
Flavour strength	57.7	61.0	60.9	1.14
Flavour liking	61.9	65.5	65.4	1.45
Overall liking	61.4	65.7	66.1	1.58
Consumer rating	3.30[a]	3.50[b]	3.54[b]	0.064
SEQ score	60.6[a]	65.7[b]	64.7[b]	1.50
Trained panel				
Tenderness	6.36	6.48	6.04	0.204
Juiciness	5.81	5.60	5.82	0.176
Flavour intensity	6.69	6.68	6.67	0.117

Numbers in the same row with different superscripts are different ($P < 0.05$).

Merino Mutton

Sensory evaluation of mutton samples

Sixteen mutton samples were collected from four year old wethers with a mean (±SE) live weight of 58.7 (±1.66) kg and carcase weight of 26.1 (±0.88) kg. Nine animals were score 1, four score 2 and three score 3 giving an average GR tissue depth of 5.9 (±1.0) mm. Many of the pH values were high with an average of 5.76 (±0.03) and only five of the carcasses were below pH 5.7. The meat colour was dark in some animals, with an average lightness reading of 34.8 (±0.39) and five animals in the undesirable range below 34. The results of the consumer panel are presented in the table below.

Table 13. Consumer panel sensory evaluation of samples from four year old Merino wethers

	Mean	SEM	Minimum	Maximum
Tenderness	42.1	2.90	16.3	58.4
Juiciness	43.4	2.73	17.3	61.8
Flavour strength	51.0	2.00	35.7	63.6
Flavour liking	50.7	2.38	30.7	65.7
Overall liking	47.9	2.63	24.1	64.9
Consumer rating	2.8	0.09	2.2	3.5
SEQ score	47.1	2.51	23.8	62.6

Temperature and pH decline

The decline in muscle pH following slaughter and electrical stimulation was rapid. All carcasses monitored had a pH well below 6.0 before their temperature fell below 12°C, minimising the risk of cold shortening.

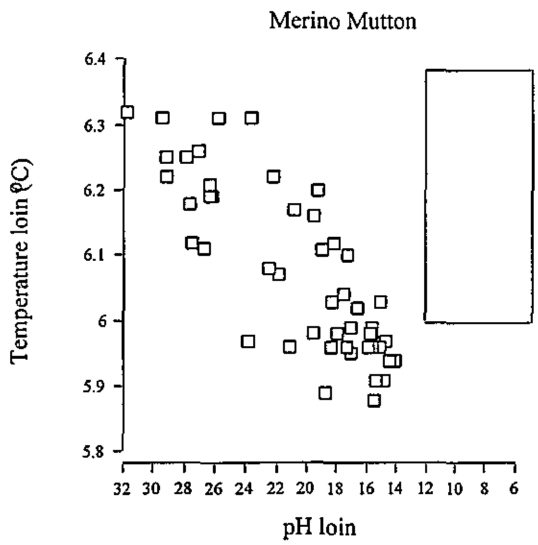

Figure 7. Temperature and pH decline in the loin (M. longissimus dorsi) of Merino mutton following slaughter.

Duration of teeth eruption

The time taken to erupt teeth varied greatly between individual sheep. The results presented in Table 14 are the number of days from the first date partial teeth eruption was detected to the first date full teeth eruption was detected. The sheep were mouthed fortnightly in the early stages of the trial and weekly in the last few weeks before slaughter. It is possible sheep may have had partially erupted teeth up to two weeks before they were detected and fully erupted teeth up to two weeks before they were detected. Therefore the actual duration of eruption may have been up to two weeks longer or shorter than recorded.

Table 14. The number of days between partial teeth eruption and full teeth eruption detected in young Merino, first cross and second sheep

	Merino	First cross	Second cross	SEM
Mean	30.4	23.4	29.0	2.20
Minimum	9	11	10	
Maximum	48	56	56	

The average duration of eruption recorded across all three genotypes was 27.4 days. The first cross lambs tended to erupt their permanent teeth more rapidly than the Merino and second cross sheep, however the difference between genotypes was not significant (P = 0.062). All three genotypes showed a large variation in the duration of eruption (Figure 7) with a range from 9 to 56 days.

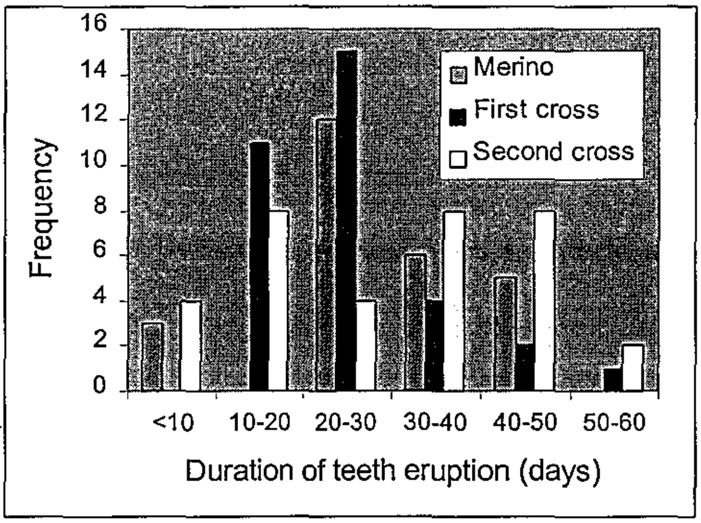

Figure 7. Frequency histogram of the number of days between the detection of partial teeth eruption and full teeth eruption in young Merino, first cross and second sheep.

Conclusions

Growth and carcase characteristics

The animals used in the trial were relatively uniform in their growth and carcase characteristics across all three dentition categories. The second cross animals had the greatest variation between dentition groups with the fully erupted group being heavier and fatter, which lead to them having a significantly slower growth rate than the other two groups.

The Merinos were the only genotype where it appeared that the process of teeth eruption may have contributed to reduced performance. The partially erupted group had a slightly lower final live weight and growth rate and a significantly lower carcase weight and fat cover. However, it is unlikely that these minor differences reflect a depression in intake severe enough to contribute to a reduction in meat eating quality.

When the three genotypes were analysed in a combined analysis, the fully erupted group had significantly higher dressing percentages, heavier carcase weights and more fat cover at both the GR and C site ($P < 0.05$). These heavier and fatter carcasses are likely to be less susceptible to cold shortening due to the insulating effect of the fat, which may have contributed to differences in eating quality.

Temperature and pH decline

Temperature and pH decline in the carcasses was monitored at all four slaughters. High voltage electrical stimulation appeared to be effective at minimising the risk of cold shortening in the majority of the carcases. However, some of the first cross animals had a pH and temperature decline profile conducive to cold shortening. This may have contributed to the poorer performance of the first cross animals in the subsequent sensory analysis.

Despite the Merino mutton samples not being at risk of cold shortening, the consumer panel rated the samples as much tougher than any of the young sheep. This suggests that factors related to the animals age and growth path can make an important other contribution to toughness even when processing factors are controlled.

Objective measures of eating quality

There were some differences in meat colour and myoglobin levels between the three dentition groups. Within the first cross genotype, animals with partially or fully erupted teeth had higher myoglobin levels than animals with milk teeth. These higher myoglobin levels resulted in darker coloured meat. However, meat colour was only different between the fully erupted and milk teeth groups and not between the partially erupted and milk teeth groups.

In the Merino and second cross genotypes, those animals with fully erupted teeth had significantly higher myoglobin levels than the other two groups, but there were no differences in meat colour lightness. When all three genotypes were analysed in a combined analysis myoglobin content was higher in the fully erupted group than the other two groups and there was a non-significant trend to darker colour with increasing stage of dentition.

In the second cross sheep, the partially erupted group had lower redness and yellowness values than the other two groups. The Merino sheep showed a similar trend but the differences were not significant. When the three genotypes were combined, the meat from the partially erupted group was significantly less red and less yellow than the meat from the other two groups. The amount of emphasis which should be placed on these measures is questionable as meat colour redness and yellowness have not as yet been identified as important factors in visual or sensory consumer acceptance of meat.

There were no significant differences between the dentition groups in glycogen, ultimate muscle pH or Warner Bratzler shear force in any of the genotypes. However, in all three genotypes the partially erupted group had the highest level of glycogen and the lowest shear forces values. This suggests that sheep with partially erupted teeth do not experience any detrimental effects on eating quality associated with reduced feed intake and lower glycogen levels.

Stage of dentition did not have any negative affects on shear force. Shear force values for all the samples measured were very low with only seven out of 240 animals above 5 kg, the range considered unacceptably tough by consumers. These animals included 4 with milk teeth, 2 with fully erupted teeth and only one with partially erupted teeth.

Sensory measures of eating quality

Sensory evaluation of the samples from the three dentition groups by both consumer and trained panels did not indicate a decline in eating quality as stage of dentition progressed. Conversely, eating quality attributes tended to improve as stage of teeth eruption progressed. On an individual genotype basis, the consumer panel only found a significant difference in tenderness in the second cross animals. However, the same trends existed across all three breeds and across most of the attributes assessed by the consumer panel.

When the three genotypes were analysed in a combined analyses, the partially and fully erupted groups were significantly more juicy and had a higher consumer rating and SEQ score than the milk teeth group ($P < 0.05$). The fully erupted group was also considered significantly more tender than the milk teeth group ($P < 0.05$).

The trained panel rated the partially erupted group highest for tenderness, juiciness and flavour intensity in the Merino animals and for tenderness and flavour intensity in the first cross animals but gave the lowest rating to the partially erupted group in all three attributes in the second cross animals. However none of these differences were significant and all scores were quite high.

Merino mutton

The Merino mutton samples were rated much lower by the consumer sensory panel than any of the samples from the three genotypes and three dentition groups used in the trial. These results serve two purposes. Firstly, they demonstrate the ability of the consumer panel to differentiate between groups of samples and identify those of higher or lower eating quality. Secondly, the mutton results highlight the high consumer scores all three of the dentition groups attained, and show the high consumer acceptability of young sheep prior to, during and immediately post eruption of permanent central incisor teeth.

Duration of teeth eruption

The average duration of teeth eruption over the three genotypes was 27.4 days. Allowing sheep with partially erupted teeth to be classified as lamb would therefore provide producers with a four-week warning period in which to market their sheep. However, the large variation between animals in the duration of eruption means producers would still be faced with the risk of some animals reaching full teeth eruption more quickly than anticipated. The fortnightly frequency of monitoring dentition status in this trial will have created large errors in the recorded duration of eruption. Particularly in sheep with a duration of eruption recorded below 12 days, the actual duration of eruption is likely to be anything up to double that recorded. More frequent monitoring of dentition status is required to provide more accurate information about the duration of teeth eruption.

Conclusions

This project considered the eating quality implications of allowing sheep with partially erupted teeth to be classified as lamb. Of the 19 attributes assessed over three genotypes, only one attribute in one genotype showed a significant negative effect of allowing lambs to progress from having milk teeth to having partially erupted teeth. This was an increase in myoglobin content in the first cross lambs. Many of the attributes assessed showed changes that could be considered as positive for eating quality as the sheep progressed from milk teeth to partially erupted and even to fully erupted teeth.

The results of this project indicate that, for the genotypes studied, meat from young sheep with partially erupted teeth is unlikely to be inferior in eating quality than the meat currently classified as lamb.

References

Chan, D.M. and Exton, J.H. (1976). A rapid method for the determination of glycogen content and radioactivity in small quantities of tissue or isolated hepatocytes. *Analytical Biochemistry*, **71**, 96-105.

Harris, D. (1998) Feeding grain treated with alkali to Merino lambs to improve meat quality. Honours. The University of Western Australia, Perth.

Hopkins, D.L., P.J. Holst, N.M. Fogarty, and D.F. Stanley (1996) Growth and carcass characteristics of first and second cross lambs lot-fed to heavy weights. *Animal Production in Australia*, **21**, 181-184.

Meat and Livestock Australia (1999) Consumer sensory perception of lamb and sheepmeat. Final project report.

Williams, H. (1999) Training a sensory panel for evaluation of lamb eating quality. Honours. Curtin University of Technology, Perth.