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CHAPTER 6. FEEDING GRAIN TO CONFINED SHEEP

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Introduction

A feedlot is defined as 'a management system in which naturally grazing animals are confined to a small area which produces no feed and are fed on stored feeds' (Blood and Studdert 1990). In the classic sense of the definition, a feedlot is a specialised facility where the operator has strict control over the diet. In practice, the sheep meat industry currently uses a wide variety of grain feeding systems that fit the definition of feedlotting but due to varying degrees of control over the diet, these may result in different growth rates and performance. The main systems of feeding in feedlots are:

1. *ad libitum* access to loose total mixed rations fed in open troughs;
2. *ad libitum* access to balanced pelleted diets usually fed in self-feeders;
3. *ad libitum* access to loose grain mix (with minerals) fed in open troughs or self-feeders with *ad libitum* access to roughage.

There are several comprehensive guides published by various Australian State Departments of Agriculture that cover the practicalities of setting up and running a feedlot (Bell *et al.* 1998; Milton 2001; Davis 2003; Giumelli 2003).

Growth rates and feed conversion ratios indicated in Departments of Agriculture extension literature have evolved over the past 15 years, presumably on the basis of available scientific literature and anecdotal evidence from industry experience. There are many recommendations but little in the way of comparative trials to demonstrate how the conclusions have been reached. The figures in Table 6.1 are examples of those provided in the literature as a guide to performance of lambs in feedlots and are not related to particular feeding systems or equipment used in feedlots.

Table 6.1. Average production targets for feedlot finishing of lambs taken from Australian State Departments of Agriculture extension publications.

Growth rate (g/day)		Feed conversion ratio		Reference
Crossbred lamb	Merino lamb	Crossbred lamb	Merino lamb	
140-160	130-140	5:1	6:1	1
200	130	6:1	7:1	2#
150-300		8:1 to 5:1		3
250-350	150-250	7:1 to 5:1	8:1 to 6:1	4
250-350	220-320	7:1 to 5.5:1	7.5:1 to 6:1	5
250		6.5:1		6*
200-320		10:1 to 5:1		6**

After 2-3 weeks adaptation to feedlot conditions; * Average 40 kg finishing lamb; ** Finishing lamb from 30 to 50 kg.

[1] Suiter (1990); [2] Hack *et al.* (1997); [3] Bell *et al.* (1998); [4] Seymour (2000); [5] Milton (2001); [6] Bell *et al.* (2003).

Confinement feeding for purposes other than finishing

In response to poor seasons during recent years there has been an interesting evolution of feeding systems. The feeding systems are many and varied. Individual producers have developed systems that make use of resources available on their farm and integrate with their farming system. The common theme between feeding systems is that sheep are confined, usually in a small paddock, and all nutrients are supplied to the animals. Confinement feeding systems differ from production feedlots in that they are used for purposes in addition to finishing, e.g. deferred grazing, feeding pregnant and lactating ewes, maintenance of dry stock and backgrounding lambs (J.T.B. Milton 2003, pers. comm.; Bryant and Kirby, refer appendix).

Confinement feeding systems are generally simple and low-cost. Profitability is hard to determine and is often not a priority because it is difficult to assign a monetary value to many of the benefits such as preserving breeding stock, avoiding agistment and associated problems, preventing erosion, deferring grazing, flexibility and alternative feeding options. Nevertheless, there is an opportunity to draw on the expertise and innovation of industry leaders who are developing simple and profitable feeding systems.

The remainder of this review considers only confinement feeding and feedlotting systems that focus on backgrounding and finishing of prime lambs.

Loose total mixed rations fed in open troughs

Specialised milling and mixing equipment is utilised to process roughage, combine ingredients and feed out into troughs. Feed mixes are prepared immediately prior to feeding and feeding may occur once or twice daily. Feeding frequency is a compromise between available labour and providing an adequate quantity of fresh feed to maximise intake by all animals. The main disadvantages of this feeding system are the high level of up-front capital investment to purchase the necessary feeding equipment and the ongoing labour required. The primary advantage of the system is that the producer has complete control over the nutritional specification of the ration by incorporating specific amounts of roughage, grain and minerals into the mix. This system also offers the flexibility of altering the ingredient composition to prepare introductory and finishing diets, and the flexibility of incorporating low-cost, novel or by-product ingredients, e.g. chaff cart residues, bakery waste, brewer's grain.

There are very few examples in the scientific literature of the biological performance of sheep fed loose, mixed, rations and even fewer that describe this system in relation to modern genetics and target market specifications. The market specifications for prime lambs and the role of intensive grain feeding have changed significantly since reports of early feedlotting research conducted in the 1970s and 1980s. The common slaughter weight of prime lambs at that time was approximately 35 kg and liveweight at feedlot entry was 20-25 kg. Loose mixed ration feeding systems produced growth rates ranging from 100-240 g/day for crossbred lambs and around 160-205 g/day for Merino lambs with feed conversion ratios of 6.2:1 to 3.5:1 (Table 6.2). The relevance of early data to modern feeding systems is questionable. Comparisons with modern production systems are unlikely to be valid due to improved sheep genetics, production of increasingly heavy carcases and the evolution of intensive grain feeding systems that are often focused primarily on the finishing phase.

Table 6.2. Performance of lambs fed loose mixed rations in feedlots and grown from 20-25 kg to 35 kg liveweight. Feed conversion ratio (FCR), calculated crude protein of diet (CP), calculated metabolisable energy of diet (ME).

Growth rate (g/day)	FCR	Diet composition	CP (%)[1]	ME (MJ/kg DM)[1]	Reference
Crossbred lambs					
243	3.5:1	barley, oaten straw, lupins	14.7	11.4	1
242	4:1	barley, oaten straw, lupins	18.9	11.9	1
240	4.5:1	wheat, lucerne hay, meat meal	17.2	12.3	2
100*		barley, fishmeal, straw	16.0#	11.8	3
143		wheat, pelleted lucerne	15.1	12.2	4
Merino lambs					
162	4.2	oats, oaten chaff, lupins	18.5#	11.2	5
205	5.4	triticale, pasture hay, lupins	19.5#	12.6	6
171	6.2	oats, pasture hay, lupins	16.9#	11.4	6

Measured crude protein reported in paper; * Average growth rate during 6 week period from 23 to 27 kg.

[1] Tomes and Dymond (1976); [2] Davis *et al.* (1976); [3] Ikin and Pearce (1978); [4] Cotterill and Roberts (1979); [5] McDonald and Suiter (1982); [6] Roberts *et al.* (1984).

Key issues

Several key issues arise from experimental examination of the loose mixed ration feeding system. Not all of the issues are unique to this feeding system but the complexity of the system creates some challenges that need to be overcome.

Sheep will selectively consume preferred feeds and have a recognised ability to separate components of a mixed ration. For example, White Suffolk x Merino lambs fed a loose mixed diet had lower feed intake and a growth rate of 138 g/day compared to 210 g/day for lambs offered the same diet as a pellet (Jones *et al.* 2000). Examination of feed residues showed that lambs avoided the straw component of the loose diet and therefore altered the intended nutrient specification of the ration. One of the advantages of a loose mixed ration feeding system is the level of control that the producer has over the nutritional specification of the diet. This control is negated if the lambs are able to actively select preferred feed components. The success of a loose mixed feeding system is dependent on optimising the diet to avoid selection either by including palatable roughage, or by processing and mixing the diet in a manner that precludes selection.

The producer has control over the nutritional composition of the loose mixed ration but in order to exercise the control, the nutritional composition of feed ingredients must be measured. Early work investigating feedlot finishing of Merino lambs in Western Australia concentrated on performance of lambs fed oats and lupins, the most commonly feed grains of the time (McDonald and Suiter 1982; Suiter *et al.* 1982). Lambs were fed in either indoor or outdoor feedlots on loose mixed rations consisting of 1.7 per cent minerals, 9.9 per cent oaten chaff and either 88.4 per cent Swan oats, 88.4 per cent West oats or 53.0 per cent West oats plus 35.4 per cent lupins. The nutritional specification of the oat/lupin diet was adequate but the oat-based diets were deficient in protein compared to current recommendations and this was reflected in the poor performance of the lambs. Lambs offered the oat/lupin diet had a modest growth rate of around 140 g/day from the starting

1 Values calculated for crude protein and metabolisable energy using average book values reported in : Croker, K. and Watt, P. (eds) (2001). *The Good Food Guide for Sheep*. Government of Western Australia, Department of Agriculture, Perth, Bulletin 4473.

liveweight of ~27 kg to 45 kg and feed conversion ratio of 6.4:1 and 6.2:1 for outdoor and indoor feedlots[2]. In contrast, the growth of lambs fed the oat-based diets was around 90-110 g/day indicating that these animals were restricted by the poor nutritional specification of the diets. It is important to have feed analysed and use this information to formulate a ration that will match nutritional requirements to maximise growth rate.

Adaptation of the rumen to high grain diets is the biggest hurdle to success of intensive grain feeding systems. It is evident from some of the early reports, that despite an introductory period, lambs took some time to reach an acceptable growth rate. Ikin and Pearce (1978) investigated the possibility of strategically feedlotting lambs at different stages of growth and found that in each instance, lambs lost liveweight at the beginning of the feedlot period. Similarly, lambs in indoor and outdoor feedlots performed poorly over the first 34 days of the experiment, despite a 12-day introductory program at the commencement of feedlotting (Suiter and McDonald 1987). Subclinical acidosis was considered to be a primary reason for poor performance during feedlot introduction in both of these experiments. Introduction to intensive grain feeding becomes even more critical when the feeding system is targeted at finishing rather than growing lambs, because the time frame for growth is restricted.

Potential to use novel feed ingredients

Feed mixing equipment can be used to incorporate a wide range of ingredients into a loose total mixed ration. This provides the opportunity to reduce the cost of a feedlot diet by utilising by-products from cropping enterprises such as chaff cart residues and grain screenings or novel by-product ingredients from human food industries such as bakery waste and brewer's grain. The main constraints to inclusion of by-product feed sources are the variable nutritional composition and the presence of anti-nutritive compounds, chemical or physical contaminants.

Chaff residues and grain dust arise as by-products of the grain industry. Chaff cart collection systems were developed to remove herbicide resistant ryegrass seeds from affected paddocks at harvest and grain dust is produced and collected during bulk handling of grain. Chaff and weed seeds collected at harvest have a higher nutritional specification than the remaining stubble and could be incorporated into feedlot diets as a source of roughage (Roberts and Devenish 2001). The nutritive value of chaff residues is variable and is influenced by the type of crop from which it was collected and the equipment used for collection (Roberts and Devenish 2001). The nutritional specification of grain dust is similar to that of cereal grain (Knott and Hyde 2001). Chaff residues are readily accepted by sheep, although they tend to select the more digestible components when grazing chaff heaps (Roberts and Devenish 2001). Inclusion in feedlot diets is restricted by the relatively low nutritional value and the potential presence of toxins, e.g. toxins produced by *Rathayibacter toxicus* [Annual ryegrass toxicity] and *Diaporthe toxica* [Lupinosis]. The level of inclusion of grain dust is restricted by the potential risks of acidosis, the presence of chemical residues, and mycotoxins (Knott and Hyde 2001).

Canola screenings and lentil screenings are suitable for inclusion in lamb feedlot diets at low to moderate inclusion levels (Stanford *et al.* 1999, 2000). Grain screenings produced during seed cleaning consist of small, immature and cracked grains of the parent crop, grains from volunteer crop species, weed seeds, chaff and dust (Beames *et al.* 1986). Although Stanford *et al.* (1999, 2000) reported proximate analyses, screenings were incorporated into diets as a replacement for barley and/or canola meal at fixed percentages rather than formulated on the basis of their nutritive value. Growth rate of lambs decreased linearly with increasing inclusion of grain screenings but due to the relative cost difference between traditional

[2] Calculations based on data presented in: Suiter, R.J. and McDonald, C.L. (1987). 'Growth of Merino weaners fed grain-based diets while grazing dry pasture or housed in feedlots'. *Australian Journal of Experimental Agriculture,* vol. 27, pp. 629-632. Intake and growth data for oat-based diets extrapolated beyond measured period to calculate averages to 45 kg liveweight.

ingredients and grain screenings, cost of gain in these examples was maximised at inclusion rates of approximately 33 per cent canola screenings and 25 per cent lentil screenings (Stanford *et al.* 1999, 2000).

Frost damaged grain that does not meet delivery standards is generally sold as feed grain at heavy discounts. Assessment of the nutritive value of frosted wheat from the 1998/99 harvest in New South Wales showed that although severe frosting reduced the estimated ruminant metabolisable energy by 0.8 MJ, the metabolisable energy still fell well within the expected range for wheat (Richardson *et al.* 2001). The price discount reflects the perceived reduction in nutritional value but there are indications that the feeding value for ruminants may not be affected to the same degree as that for monogastrics so frosted grain may be a relatively good, low cost feed source for inclusion in lamb feedlot diets (Richardson *et al.* 2001).

By-products of human food industries are accepted as alternative feed sources in the beef feedlot industry (Blackwood *et al.* 2000; Kubik and Stock 1990) but there has been relatively little evaluation of by-product feeds for lambs in feedlots. Hetherington and Krebs (2002) demonstrated that bakery waste can be incorporated into lamb feedlot diets. Merino lambs fed bakery waste at up to 50 per cent of the diet grew at the same rate (around 190 g/day) as those fed a grain-based diet of similar nutrient specification. Citrus peel, potatoes and grape marc have been recommended as alternative feed sources during drought (Hack and Moreby 1997). Other human food industry by-products have varying nutritional value for ruminants, e.g. citrus pulp, grape marc, brewer's grain, distiller's grain, molasses, malt combings, mill run, bran, pollard (Cottle 1991; Hack and Moreby 1997). Waste by-product ingredients are often available for the cost of transport or low-cost relative to their nutritive value so incorporation of by-product ingredients represents a good opportunity to reduce the overall cost of a lamb feedlot diet.

Despite the variable nature of by-product ingredients, careful sampling and analysis would enable these useful feed sources to be incorporated into feedlot rations. Recommendations for inclusion levels of by-products must be modified according to the nutritional analysis of the sample that will be used. In addition, consideration must be given to the presence of anti-nutritional factors, mycotoxins, chemical residues from crop treatment, and other chemical or physical contaminants when deciding appropriate inclusion levels for these feed sources.

Conclusions

Anecdotal evidence suggests that the use of loose total mixed rations is increasing in popularity, but there has been very little experimental verification of sheep performance in these systems. The lack of literature indicates a basic need to assess finishing performance and economic viability of this system compared to other intensive grain finishing systems. The suitability of loose diets for sheep should be assessed at a commercial level to determine whether performance is affected by the ability of sheep to selectively consume diet components. Finally, there may be some benefit in evaluating alternative feed sources for inclusion in feedlot diets, especially those that could be available as part of the farming system, e.g. chaff residues and grain screenings.

Balanced pelleted diet in self-feeders

Commercial pelleted diets generally provide a complete balanced diet, consisting of roughage, grain and minerals. Pelleted diets are commonly used in conjunction with self-feeders but may be fed in troughs or trailed on the ground. The main disadvantages of pelleted feed are the cost of processing and potentially, an increased risk of acidosis. During the pellet manufacturing process, the grain is hammer-milled and then steam treated prior to pelleting. This procedure does not improve the digestibility of the ration for sheep and can increase the risk of acidosis by presenting the rumen with a highly digestible starch substrate.

Self-feeder systems in combination with formulated pellets offer the advantage of convenience due to the reduced frequency of feeding and the ability to supply a complete balanced diet. Pelleted feed can be stored and handled using basic equipment and the physical presentation of the feed prevents selection.

Early research

There is a long history of the use of pelleted diets in intensive sheep feeding. Early work by researchers in the United Kingdom investigating the nutrition of early weaned lambs was based on pelleted cereal-based diets primarily because these diets had been used successfully for cattle (Andrews and Orskov 1970a, 1970b). Ørskov (1976) provides an interesting commentary of the discovery that highly processed diets were adversely affecting fat metabolism and in fact, diets based on whole grains gave equal performance in young lambs without the negative metabolic implications.

Despite the potential metabolic implications, pelleted diets have been widely used in the sheep industry at various times. In the early 1980s, researchers in Western Australia commented that 'feeding pelletised rations to sheep has become a popular practice' and 'commercially prepared sheep pellets are now being widely used both by the stud industry and occasionally in finishing sheep' (Kessell 1982; McDonald and Suiter 1982). Although there was a perception of widespread use of pellets, evaluations of oat-based pellets fortified with urea demonstrated poor growth and feed conversion performance on these diets compared to oat/lupin loose mixed diets (Kessell 1982; McDonald and Suiter 1982). Kessell (1982) reported a weight loss due to poor voluntary feed intake for 31.3 kg sheep fed *ad libitum* pellets and McDonald and Suiter (1982) reported average growth rates of < 100 g/day for Merino weaners grown from 26.6 kg to 45 kg liveweight. In contrast, wheat-based pellets were used successfully to finish Border Leicester x Merino store lambs from liveweights of approximately 30 kg to ~37 kg during the 1982/83 drought in New South Wales. Growth rates of 230 g/day and 180 g/day with feed conversions of 5.0:1 and 5.8:1 were reported for two drafts of lambs finished on a diet of 32 per cent wheat-based pellets, 53 per cent wheat, 4 per cent hay, 9 per cent minerals and 2 per cent monensin (Donnelly and Morrison 1984). All authors commented that there were advantages related to handling and presentation of pelleted diets despite the mixed production performance.

More recently, pelleted diets have been used to examine a variety of principles related to sheep meat production. The biological performance of different genotypes and sexes fed pellets has been recorded in these situations but was not always the primary focus of the experiment. The literature reporting biological performance of lambs has been segregated on the basis of mating system so there is some repetition where experiments involved lambs from different mating systems.

First-cross

The growth rates reported for pellet-based finishing systems using first-cross lambs range from 184-359 g/day and feed conversion ratios range from 8.2:1 to 5.1:1 (Table 6.3). Although there is a two-fold variation in the range of reported growth rates, data from scientific literature generally supports the expected performance recommendations given in extension material (Table 6.1).

Table 6.3. Breed and performance of first-cross lambs fed on pelleted diets with metabolisable energy (ME) and crude protein specifications of diet indicated. Feed conversion ratio (FCR), liveweight (LW).

Breed (sire x dam)	Growth rate (g/day)	FCR	Initial LW (kg)	Final LW (kg)	Carcase weight (kg)	Diet specification		Reference
						Crude protein (%)	ME (MJ/kg DM)	
BL x M	336[a]	6.0	40.5	47.9	21.0	16.0	10.8	1
EF x M	295[a]	6.4	41.9	48.4	21.2			
PD x M	318[a]	6.1	42.4	49.4	22.3			
SAMM x M	359[a]	5.4	40.5	48.4	21.2			
WS x M	210	5.9	36.4	41.3		18.0	10.6	2
(T x PD) x M	220[x]	7.0	32.0	42.9	19.9	14.4	10.5	3
	242[x]	6.8	32.0	43.7	20.3	14.4	10.5	
	272[y]	6.2	32.0	45.2	20.5	14.4	10.5	
T x M	256[m]					15.0	11.8	4,5
PD x M	278[m]							
PD x M	296	5.1	35.2	43.5	19.4	15.0	11.0	6
S x M	197[x]	7.7	33.0	44.6	20.7	15.9	10.8	7
	184[x]	8.2	33.0	44.1	20.4	16.2	10.1	
PD x M	190*	7.0	31.6	42.9	20.1	17.4	10.8	8

BL: Border Leicester; EF: East Friesian; M: Merino; PD: Poll Dorset; S: Suffolk; SAMM: South African Meat Merino; T: Texel; WS: White Suffolk; * Feed was restricted to 1.3 kg/day in this experiment. Within each experiment, growth rates with the same superscript are not significantly different.

[1] Davidson *et al.* (2000); [2] Jones *et al.* (2000); [3] Wiese *et al.* (2000); [4] Hopkins *et al.* (1996); [5] Holst *et al.* (1998); [6] Wiese *et al.* (2003); [7] Pethick *et al.* (2003b); [8] Gardner *et al.* (1999).

The experiments reporting better performance tended to be those where there was more control over individual feed intake. Sex of lambs used in different experiments may also have contributed to the variation in reported growth rates. First-cross wethers gained an average of 327 g/day when fed for 22 days housed in individual indoor pens with *ad libitum* access to a pelleted diet of barley, lupins, canola meal, cereal hay, minerals and vitamins (Davidson *et al.* 2000). Although there was a large numerical range of growth rates reported for different terminal sires, this investigation involved only a small number of animals per treatment and there were no significant differences between sires for growth rate or feed conversion ratio (Table 6.3). Jones *et al.* (2000) reported a growth rate of only 210 g/day over 23 days in a similar experiment where first-cross lambs were housed indoors in individual pens with *ad libitum* access to a pelleted diet containing barley straw, barley, lupins, canola meal, minerals and vitamins. There were some differences in the diet composition compared to that used by Davidson *et al.* (2000) and the animals were ewe lambs rather than wether lambs but it is unlikely that these two variables would entirely account for the large difference in growth rates.

The feed conversion ratios recorded in these two experiments were similar (average 6.0:1 vs 5.9:1) so the main factor contributing to differences in growth rate was feed intake. In a commercial feeding situation, the lower growth rate may have less significance because the cost of feed to produce liveweight gain is the same, however, slow growing animals would take longer to reach their target liveweight so the cost of labour and other overheads would be higher.

Intermediate growth rates of 220-272 g/day were reported for wether lambs housed indoors in individual pens, fed isonitrogenous and isocaloric pelleted diets with three different protein sources (Wiese *et al.* 2000). Lambs fed a canola meal-based diet grew faster than those fed either a lupin or a urea-based diet. Feed conversion of lambs fed the canola meal diet was 6.2:1 and this tended to be more efficient than those fed other diets. Feed conversion of lambs fed lupin or urea-based diets was numerically less efficient in this experiment compared to other animals housed in similar conditions (Davidson *et al.* 2000; Jones *et al.* 2000).

Some feeding systems that emulated commercial scenarios reported good growth rates in the 250-300 g/day range (Hopkins *et al.* 1996; Wiese *et al.* 2003). Small groups of first-cross induced cryptorchid lambs were confined in paddocks and offered a pelleted diet of lupins, wheat, oats and minerals through a self-feeder plus 200 g/head/day of lucerne chaff in a replicated experiment (Hopkins *et al.* 1996). The use of cryptorchids may have contributed to high growth rates in this experiment, although higher growth rates were reported by Wiese *et al.* (2003) for a large scale experiment using wether lambs housed indoors in group pens of 6 animals. The average growth rate of 120 lambs fed a pelleted diet containing straw, lupins, oats, barley and minerals over a 28-day feeding period was 296 g/day with a feed conversion ratio of 5.1:1. In contrast, lambs housed indoors in small group pens and fed either a 'high' energy pelleted diet of hay, lupins, barley, wheat, minerals and vitamins or a 'moderate' energy pellet of hay, lupins, wheat, minerals and vitamins achieved only moderate growth rates of around 190 g/day (Pethick *et al.* 2003b). A similar growth rate of 190 g/day was reported for first-cross wether lambs housed indoors in small group pens and offered a pelleted diet of straw, lupins, barley, canola meal, minerals, vitamins and monensin (Gardner *et al.* 1999). These two experiments also had similar feed conversion ratios of around 7:1 to 8:1. However, feed offered in the latter experiment was restricted to 1.3 kg/head/day and the authors observed that feed was consumed in less than one hour so these lambs had the potential to consume more feed which may have improved growth rate and feed efficiency.

Most current research has concentrated on finishing systems that produce 18-22 kg carcases, e.g. Table 6.3. More recently some focus has moved to evaluating finishing systems for lean, heavyweight lambs (24+ kg) in response to the continual market demand for heavier carcases. Feedlot finishing is suitable for producing heavyweight lambs and good growth rates have been demonstrated in a group pen scenario (Shands *et al.* 2002). Performance of progeny from high estimated breeding value (EBV) sires was monitored in a feedlot finishing system as part of the Central Progeny Test program. Mixed ewes and cryptorchids from first- and second-cross matings were housed in group pens and offered a diet consisting of 60 per cent commercial pellets, lucerne hay, lupins and cottonseed meal (C.G. Shands 2003, pers. comm.). The composite diet contained 11.3 MJ ME/kg DM and 19.0 per cent crude protein. The average growth rate across both sex and mating types was 275 g/day and feed conversion was 4.55:1 with growth rates ranging from 200-360 g/day during the 60-day feeding period. Lambs had an average carcase weight of 27.9 kg and at the end of the 60-day feeding period, 49 per cent of lambs produced carcases in the desired range of 22+ kg and 8-20 mm GR depth.[3]

Second-cross

Growth rates reported for second-cross lambs in pellet-based finishing systems are 300-350 g/day (Table 6.4). There are a limited number of investigations of growth performance of second-cross lambs. The highest growth rate was achieved in a commercial simulation where small groups of second-cross induced cryptorchid lambs were confined in paddocks and offered a pelleted diet (Hopkins *et al.* 1996). This experiment included both first- and second-cross lambs and has been described in the above section. There was no difference between the performances of second-cross lambs of different genotypes but growth of second-cross lambs by Poll Dorset sires had a significantly higher growth rate than

3 The 12th rib GR site is 110 mm from the backbone (vertebral column).

first-cross lambs (Table 6.3 and Table 6.4). The use of induced-cryptorchid lambs may have contributed to high growth rates in this experiment. These growth rates are in agreement with expected growth rates promoted in State Agriculture Department extension material (Table 6.1).

Table 6.4. Breed and performance of second-cross lambs fed on pelleted diets with metabolisable energy (ME) and crude protein specifications of diet indicated. Feed conversion ratio (FCR), liveweight (LW).

Breed (sire x dam)	Growth rate (g/day)	FCR	Initial LW (kg)	Final LW (kg)	Carcase weight (kg)	Diet specification		Reference
						Crude protein (%)	ME (MJ/kg DM)	
T x (BL x M)	301[a]					15.0	11.8	1, 2
PD x (BL x M)	349[a]							
PD x (BL x M)	180*	7.5	32.1	42.4	20.2	17.4	10.8	3
PD x (BL x M)	206		28.2	54.0	25.3	11.4	10.7	4

BL: Border Leicester; M: Merino; PD: Poll Dorset; T: Texel; * Feed was restricted to 1.3 kg/day in this experiment; Within each experiment, growth rates with the same superscript are not significantly different.

[1] Hopkins *et al.* (1996); [2] Holst *et al.* (1998); [3] Gardner *et al.* (1999); [4] Hegarty *et al.* (1999).

Other authors have reported lower growth rates for second-cross lambs but evaluation of growth performance was not the primary aim of these experiments so growth rate may have been compromised by other factors (Gardner *et al.* 1999; Hegarty *et al.* 1999). Second-cross lambs fed a pelleted diet of lucerne and triticale for an extended period of time maintained an average growth rate of 206 g/day when grown from 28 kg initial liveweight to 54 kg final liveweight (Hegarty *et al.* 1999). These animals were housed indoors in individual pens and the lengthy feeding period (128 days) was used to create a contrast for further investigations rather than evaluate finishing performance. Nevertheless, it is interesting to note that moderate average growth rates can be maintained over an extended intensive feeding period.

The potentially superior growth rate of second-cross lambs is related to their higher and faster feed intake compared with first-cross lambs (Holst *et al.* 1998). Feed intake was restricted to 1.3 kg/head/day in the experiment reported by Gardner *et al.* (1999) so the potential growth rate was not realised. The authors observed that the daily feed ration was consumed in less than one hour, indicating that lambs would have consumed more feed if it was available and this would probably have improved growth rate.

Merino

The scientific literature contains a few reports on the performance of prime Merino lambs that are relevant to modern sheep meat production systems and each report has unique aspects that make it difficult to draw general conclusions. Growth rates range from 143-286 g/day and feed conversions from 8.7:1 to 6.1:1 (Table 6.5). Recent extension publications suggest expected growth rates of 150-320 g/day for Merino lambs in commercial feedlot finishing systems (Milton 2001; Seymour 2000). The small volume of literature does not support the higher end of this range.

Higher growth rates were reported in controlled feeding situations that were further removed from commercial pellet feeding. Merino wethers gained 286 g/day when fed for 22 days housed individually in indoor pens with *ad libitum* access to a pelleted diet of barley, lupins, canola meal, cereal hay, minerals and vitamins (Davidson *et al.* 2000). In comparison, when animals were housed in small groups in indoor pens the reported growth rates were 243 g/day and 160 g/day on pelleted diets containing straw, lupins, oats, barley and minerals or straw, lupins, barley, canola meal, minerals, vitamins and monensin (Gardner *et al.* 1999;

Wiese *et al.* 2003). The feeding system that most closely correlated with a commercial situation produced growth rates of 148 g/day (Pethick *et al.* 2003a). In this experiment, 150 Merino ewes were confined in a small paddock and offered a pelleted diet of hay, lupins and barley from a self-feeder.

Table 6.5. Performance of Merino lambs with metabolisable energy (ME) and crude protein specifications of diet indicated. Feed conversion ratio (FCR), liveweight (LW).

Growth rate (g/day)	FCR	Initial LW (kg)	Final LW (kg)	Carcase weight (kg)	Diet specification		Reference
					Crude protein (%)	ME (MJ/kg DM)	
286	6.1	38.9	45.2	19.4	16.0	10.8	1
243	6.1	37.0	47.2	19.9	15.0	11.0	2
160	8.7	30.3	39.2	17.9	17.4	10.8	3
148			40.9	18.2	17.9	10.5	4
176	6.3	38.0	~50.3	23.6	15.0	11.9	5

[1] Davidson *et al.* (2000); [2] Wiese *et al.* (2003); [3] Gardner *et al.* (1999); [4] Pethick *et al.* (2003a); [5] Pethick and Rowe (1996).

This approach oversimplifies the variables present between different experiments. The work reported by Pethick *et al.* (2003a) was undertaken using ewes while the remaining three experiments involved wether lambs. Social interactions in addition to those created by the large group may also have occurred because 25 ewe lambs were confined with 125 mixed age Merino ewes. In the experiment reported by Gardner *et al.* (1999) intake and growth rate were potentially restricted through the feeding of a fixed amount of 1.3 kg pellets/head/day. There were also small differences in the nutritional specification of the diets and liveweight ranges between experiments that may have affected growth rate (Table 6.5).

During a longer feeding period of 10 weeks, individually penned Merino wethers fed a pelleted diet of straw, lupins, barley, minerals, vitamins and virginiamycin maintained an average growth rate of 176 g/day (Pethick and Rowe 1996).

Conclusions

Generally, pelleted diets are more expensive to purchase than unprocessed grain. However, pellets have the advantages over unprocessed grain of convenience, ease of handling and purchasing a formulated ration. In order to assess the cost-benefit of feeding a pelleted diet, it is necessary to establish the expected growth rate and feed conversion rate of lambs in this feeding system. A considerable amount of the recent scientific literature describes pellet-based feedlot finishing systems and these systems have become popular due to their use by producer/processor alliances (e.g. Q Lamb and Prime Merino Lamb Alliance). Although more data are available for these feeding systems than other feeding systems, the growth performance reported in the literature is quite variable and may not reflect what would occur in a commercial situation. Further experimental verification of biological performance in pellet-based feeding systems at a commercial scale would be beneficial.

Loose grain mix fed in open troughs or self-feeder and separate roughage

A whole grain mix is prepared using existing on-farm grain handling equipment and delivered to a self-feeder or troughs. Minerals and other additives may be incorporated with the grain or offered free choice. Hay, silage or other roughage is offered separately, either on the ground or fed in hay racks. There are many variations to this simple feeding system but the common principles are the adaptation of existing basic equipment to facilitate mixing and delivery of feed and *ad libitum* access to grain and roughage, which allows animals to select their own diet. The disadvantage of this system is that allowing sheep to select their own diet can compromise growth rate and feed conversion. Intake of grain and roughage components will vary and individual animals may consume excess grain, increasing the risk of acidosis or excess roughage thus reducing their growth rate. Low capital investment and reduced labour requirements are the key advantages of this feeding system. This system is the predominant feeding method adopted in opportunistic feedlots where costs are kept to a minimum by utilising existing infrastructure and equipment.

Animal performance

In current industry feeding systems, roughage is commonly provided *ad libitum* and placed on the ground in the feedlot with grain mix supplied *ad libitum* via a self-feeder, or less often in troughs (Bryant and Kirby, refer appendix). When grain and roughage are fed separately, growth rate of lambs is generally higher if the roughage component is restricted or when more grain is available. Brook *et al.* (1996) reported that when roughage was available *ad libitum*, lambs selected up to 38 per cent of their diet as roughage and consequently had growth rates of around 150 g/day. Similarly, lambs with *ad libitum* access to wheat from a self-feeder and offered either lucerne hay or oaten hay selected 42 per cent and 29 per cent of their diet as roughage and grew at 167 g/day or 132 g/day (File 1976). In contrast, Brand and van der Merwe (1994) reported average growth rates of 190 g/day for South African Mutton Merino lambs fed triticale or maize-based diets with access to lucerne hay at 10 per cent of *ad libitum* intake. Similarly, Kenney (1986) reported growth rates of around 200 g/day for second-cross lambs fed cereal-based diets with lupin supplementation and access to 10 per cent hay. Most recently, Davis and Quilford (2001) reported growth rates of around 260 g/day for second-cross lambs fed cereal-based diets with hay at 12 per cent of the diet. Limiting the proportion of roughage invariably increases the digestibility and energy density of the diet leading to higher growth rates.

The presentation of roughage affects the level of wastage and therefore affects feed conversion ratio. Presentation of hay in racks or restriction of access so that lambs cannot spoil the feed can reduce wastage of hay. Milton *et al.* (2002) reported that 77 per cent more hay was required to achieve the same growth rate when prime lambs were fed hay on the ground compared to a covered hay rack. The cost of feed to achieve the same liveweight gain was around 35 per cent higher for the lambs fed on the ground due to the amount of hay that was wasted. Fibre length also affects wastage. Milling hay into smaller lengths has been shown to reduce wastage. File (1976) estimated that 32 per cent of lucerne hay and 43 per cent of oaten hay was wasted when presented in a long form in hay racks. The author commented that poorly designed hay racks and damp conditions accentuated the wastage. Feed conversion ratio of lambs tended to be improved when hay was presented milled or milled and mixed compared with long in hay racks (File 1976). While it is clear that wastage of roughage can be reduced by improved feeding equipment, the impact on profitability depends on the number of lambs that will be fed using the equipment.

In a commercial scenario, when grain and roughage are fed separately, there will be more variation in intake of feed components between individuals compared to a pellet-based feeding system. In a pellet feeding system, total intake may vary between individuals, but the balance of diet that each animal is receiving is controlled. Animal performance could therefore be compromised when diet components are fed separately. It is difficult to draw conclusions as to whether this concept is supported by the literature because there has been limited evaluation of loose grain mix feeding for finishing lambs to current market specifications. Davis and Quilford (2001) investigated performance of second-cross lambs grown from an average of 35 to 46 kg over 42 days in a commercial scale feedlot. Growth rates of 241-271 g/day and feed conversion from 6.7:1 to 8:1 were achieved on a range of diets with similar energy and protein but different protein sources. The range of growth rates achieved in this simple feedlot system are lower than those reported by Hopkins *et al.* (1996) for second-cross lambs fed pellets but within the wide range reported for various feeding systems (Table 6.2 to Table 6.5).

In some cases, growth rate can be closely related to the total intake of metabolisable energy. The grain component of the diet generally has a higher concentration of metabolisable energy than the roughage component so growth rate increases linearly with intake of grain or energy (Figure 6.1, Brook *et al.* 1996; Holst *et al.* 1999).

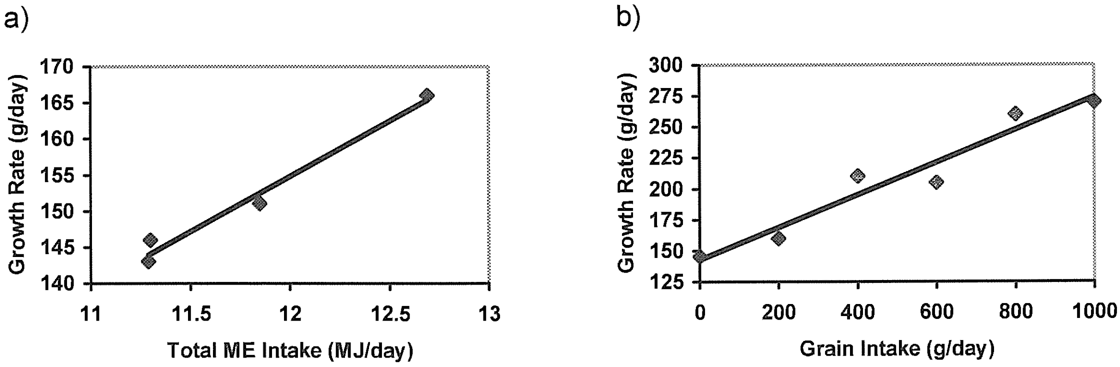

Figure 6.1. **Relationship between energy intake and growth rate in mixed grain and roughage diets; a) calculated from Brook *et al.* (1996) and b) adapted from Holst *et al.* (1999).**

Interactions between grain and forage

Interactions between grain and forage can affect both digestibility and intake of the dietary components (Dixon and Stockdale 1999). Fermentation of the fibrous components of forage and starch from grains are facilitated by different species of rumen microflora. The microbial population in the rumen adapts to maximise the rate of fermentation of dietary components for example when sheep are fed a grain-based diet, there is a proliferation of amylolytic bacteria and a decrease in the number of fibrolytic bacteria leading to a decrease in the rate of digestion of forage (El-Shazly *et al.* 1961). In addition to a depression of digestibility, intake of forage is reduced due to substitution for grain and this results in inefficiencies in the utilisation of grain (Dixon *et al.* 1993; Dixon and Stockdale 1999).

The degree of interaction between grain and forage is variable, depending on the quality and availability of the different feed components. The type of grain supplement can influence the extent of the effect on roughage intake and digestibility, even when the different supplements provide similar amounts of metabolisable energy (Dixon *et al.* 1993). Dixon *et al.* (1993) reported a decrease in roughage intake but overall increase in metabolisable energy intake when roughage was supplemented with barley or lupins but when it was supplemented with cottonseed meal, there was little effect on roughage intake and a small increase in digestibility. The interaction between grain and forage may also depend on the presentation of the two components. When lambs on a silage-based diet were supplemented with grain, growth rate was generally increased more when grain and silage were offered separately than when the two dietary components were mixed (Holst *et al.* 1999). There are clearly significant digestive and metabolic interactions when grain and forage diets are fed and an improved understanding of interactions between dietary components is particularly important in a feedlot system where grain mix and separate roughage are offered *ad libitum*.

Conclusions

It has been noted, particularly in the cattle industry, that even when grain is offered *ad libitum*, animal performance in conserved fodder feeding systems is not as good as feedlot systems (Dixon and Stockdale 1999). It could be expected that this would also be true for lamb finishing systems where the animals have some choice between diet components; however, conclusive data is lacking to support this concept. Further investigation is warranted of simple feedlotting systems with either *ad libitum* or limited access to forage.

Anecdotal reports of growth rate

There is little information available in the scientific literature on commercial scale monitoring of biological performance in modern finishing systems and available data are quite variable. Anecdotal reports of animal performance and expected growth rates and feed conversion reported in extension material are consequently a valuable source of performance information. For example, of the commercial producers who responded to a recent survey, 19 per cent measured growth rate; 71 per cent of this group indicated growth rates of 200-300 g/day, 21 per cent indicated growth rates of 100-200 g/day and 7 per cent indicated growth rates of 300-400 g/day (Bryant and Kirby, refer appendix). This suggests that growth rates commonly achieved by industry are at the lower end of expected performance indicated in extension material. In response to a similar survey from the early 1970s, producers indicated growth rates of around 100 g/day, so it would appear that there has been some improvement in the growth rates reported by producers for feedlot finishing systems over the last 30 years (Tomes and Dymond 1976).

Biological performance of older sheep in intensive feeding systems

Adult sheep that are slaughtered for mutton have a low potential growth rate compared to lambs because they have already reached mature size. McDonald (1982) reported growth rates of 143 g/day for store wethers on dry pasture supplemented with oat/lupin diets from self-feeders. A range of lupin inclusion rates was evaluated and no difference found between the growth rates of animals offered 50 per cent, 75 per cent or 100 per cent lupins (McDonald 1982). When lupin content of the diet was reduced to 25 per cent, the growth rate was reduced to 119 g/day but all animals still met market specifications. Thus the most cost effective feeding strategy may be to meet market targets rather than maximise growth rate.

Higher growth rates have been reported when greater control was exercised over individual intake. Individually penned two-year old Merino wethers were offered 200 g/day of chaff plus 1 kg/day of barley, maize, sorghum, wheat or flaked sorghum for an 8 week period (Pethick *et al.* 1995). The resulting growth rates were around 145-180 g/day. It is likely that the young wethers in this experiment were still not expressing their maximum potential growth rate because the amount of feed offered was limited.

From an industry perspective it may be more meaningful to consider the performance of older sheep in a group feeding situation. Pethick *et al.* (2003b) reported growth rates ranging from 105-173 g/day for adult ewes aged from 20 months to 68.5 months offered a pelleted diet from a self-feeder. Interestingly, ewes in the 44.5 and 56.5 month categories had a significantly higher growth rate than either younger or older animals (173 g/day vs. 125 g/day). The animals with the highest liveweight gain had lower carcase weights than animals in other groups suggesting that they may have been in poorer condition at the commencement of the feeding period. Liveweight change in response to feeding is mainly due to fat deposition so potential growth rate will depend on initial body condition.

Use of maize and sorghum in growing and finishing diets for lambs

Grain finishing systems in Australia are commonly based on winter cereal grains; however, there is widespread use of summer cereal grains such as maize and sorghum in lamb grain finishing systems in other countries. Because of limited data on the use of summer cereal grains in Australia, research from other parts of the world has been included in this review.

Table 6.6. Growth rate and feed conversion ratio (FCR) of lambs fed grain diets. Summary of trials.

Animals				Grain			Response				Ref.
Breed	LW (kg)	Age (days)	No.	Source	Processing	(%)	Growth rate (g/day)	FCR (kg/kg)	DMI (kg/day)	Days on feed	
(S x FL x DH)	15	35-49	64	Maize Barley Wheat Oats	Whole	90 *ad lib.*	345 340 303 241	2.52 2.75 2.97 3.07	0.87 0.94 0.90 0.74		1
----	----	----		Maize Barley			227 217	6.80 6.34	1.54 1.37		2
SAMM	19	56	60	Maize Triticale		90 *ad lib.*	202 192	4.97 5.71	0.99 1.04		3
R x S	29	----	80	100 Maize 75 Maize:25 Wheat 50 Maize:50 Wheat 25 Maize:75 Wheat 100 Wheat	Whole:Ground	70 *ad lib.*	340 330 320 290 250	4.13 4.16 4.25 4.46 4.80	1.40 1.37 1.36 1.29 1.20	70	4
----	----	36	143	Maize Wheat		100	195 172			166	5
HX	38		80	Maize Maize + Soybean Meal Maize + Feather Meal Maize + Feather Meal + Soybean Meal	Dry Rolled	75 Adj.	346 346 405 378	4.48 4.42 4.07 3.95	1.55 1.53 1.65 1.49	63	6
HX	38		80	Maize Maize + 0.3% Urea Maize + 0.6% Urea Maize + 1% Urea	Dry Rolled	74 Adj.	477 485 485 477	3.51 3.54 3.54 3.44	1.67 1.72 1.72 1.64	98	7
X	38		74	Maize + 6% rup Maize + 7% rup Maize + 8% rup Maize + 9% rup	Dry Rolled	75 *ad lib.*	279 302 306 302	4.85 4.60 4.85 4.76	1.35 1.39 1.46 1.44	74	8
MX	20	60		Maize 80 Maize:20 Sorghum 60 Maize:40 Sorghum		85	375 326 315	3.24 3.61 3.78	1.22 1.18 1.19	63	6
----	----	----	454	Sorghum 40 Sorghum:60 Wheat		100	223 204				9
X	----	----		Sorghum Barley			300 247	6.48 6.47			2

Grain (%): Percentage of grain in the diet, offered *ad libitum* (*ad lib.*) or daily adjusted (adj.); FCR: Feed conversion ratio, kg feed/kg gain; DMI: Dry matter intake; H: Hampshire; LW: Liveweight; M: Merino; No.: number of animals used; rup: rumen undegradable protein; R: Rambouillet; SAMM: South African Meat Merino; S: Suffolk; X: Crossbred.

[1] Ørskov *et al.* (1974); [2] Lardy (1999), average of various trials from North Dakota Sate University reported by this author; [3] Brand and van der Merwe (1994); [4] Kreikemeier *et al.* (1987); [5] Phillips (1993); [6] Loe *et al.* (2000); [7] Loe *et al.* (2001); [8] Reed *et al.* (2002); [9] Krajinovic *et al.* (1992).

The response to the inclusion of grain in diets for growing and finishing lambs depends on the ratio of grain to forage. More variation in animal response is expected in supplementary systems due to the lower relative importance of the grain in the diet and the strong interactions between grain and forage. Different feeding systems may be described by the varying proportion of grain in the diet, including 100 per cent whole-grain diets (Umberger 1997) to 30:70 ratio (Dulce *et al.* n.d.). As the proportion of forage in the diet increases, forage quality and interaction between forage intake and grain digestion becomes more important. Associative effects between the two components may affect the efficiency of nutrient utilisation.

Lamb performance on whole-grain diets

Umberger (1997) describes whole grain diets as those consisting of whole, unprocessed grains mixed with a pelleted protein, vitamin and mineral supplement. Roughage is not incorporated into whole-grain diet or supplemented on the side. Table 6.6 summarises results of lamb performance when fed maize or sorghum in grain feeding trials, where grain constituted more than 70 per cent of the diet.

There are few studies comparing performance of lambs offered different types of grain in the same trial. Data reported in Table 6.6 mostly correspond to performance of lambs fed maize grain. Less information is available on the use of sorghum in finishing systems and none of the research is specific for conditions in Australia. Mitchell and Roberts' study (1976) comparing different grains in whole-grain diets versus a pelleted stock feed as control using 26 kg Dorset x Merino lambs, is the only Australian study that reports performance data for lambs fed sorghum or maize compared to other grains. These authors reported lower liveweight gain for oats. Liveweight gain did not differ between sorghum, maize, barley and wheat-diets, but barley and sorghum-based diets produced similar liveweight gain to the control group.

All data in Table 6.6 are for crossbred lambs from different genotypes. Expected liveweight gains will vary depending on genotype, however data for performance in grain-feeding systems based on maize or sorghum generally falls within the expected range (Latif and Owen 1980; Seymour 2000). Feed conversion ratios are reported to vary between 7:1 to 5:1 (Seymour 2000). Reported values for maize and sorghum are closer to or even lower than 5:1. Age, sex and genotype would affect these variables, but a higher efficiency associated with all concentrate diets may also explain these values. Latif and Owen (1980) report that feed conversion ratios of about 3:1 should be expected for early-weaned lambs raised on all-concentrate diets to slaughter. Additional variation could be associated with *ad libitum* versus adjusted grain feeding. Feed delivery systems have been reported to affect animal performance. Fluharty *et al.* (1999) evaluated feedlot performance of lambs fed whole or ground maize *ad libitum*, or adjusted daily or weekly. In this study, lambs with weekly adjusted feeding had lower liveweight gains (288 g/day) when compared to lambs with daily adjusted feeding (378 g/day) or *ad libitum* access to feed (387 g/day). The difference in liveweight gain was mainly due to variation in intake of whole grain maize, with no differences in feed conversion ratio between the groups (3.5-3.8:1).

Lambs fed maize as the only grain source gained on average 363 g/day and registered a feed conversion ratio of 4:1 (Table 6.6). Partially or totally substituting maize with another grain or by-product reduced daily gain and increased feed conversion ratio (304 g/day and 4.4:1).

Early weaned lambs fed a 90 per cent concentrate diet until slaughter at around 35 kg liveweight performed better when fed maize in comparison to barley, wheat or oats. This suggests that the source of grain affects liveweight gain (Ørskov *et al.* 1974). Umberger (1997) reported that in whole grain feeding systems, lamb performance was reduced by approximately 10 per cent when barley was fed rather than maize. He suggested that lambs preferred maize to barley and because of this, these grains should not be fed together

(Umberger 1997). This tendency was confirmed by Lardy (1999) from an analysis of data from several trials on the performance of lambs fed different grains at the North Dakota State University (Table 6.6). On average, liveweight gains for lambs fed maize or sorghum were 4 per cent and 5 per cent higher than with barley. However, feed conversion ratio was increased when lambs were fed maize, but no difference was observed for sorghum. Lardy (1999) also reported that carcase weight, dressing percentage and back fat were higher in lambs fed sorghum compared to barley and that no benefit was noted from the inclusion of barley in sorghum diets.

Brand and van der Merwe (1994) comparing different triticale cultivars to maize concentrate in lamb feedlot diets reported no differences in liveweight gain, grain or forage intake between treatments, but lambs receiving maize tended to have a better feed conversion ratio (13%) than those consuming triticale. Feeding value of triticale based on these parameters ranged from 65 per cent to 94 per cent of that of maize diets, depending on the triticale cultivar.

In Australia, there is limited availability of maize and the price is much higher than for other grains or by-products, however due to the high nutritive value of maize, some research is required to quantify the effect of partially substituting it into rations. Dhakad *et al.* (2002) concluded from their study that half of the maize grain can be safely and economically replaced with wheat bran in the concentrate mixture of growing lambs without any adverse effect on their performance.

Phillips (1993) evaluated the effect of substituting maize with wheat grain in the diet offered to feeder lambs for a 166-day period. He observed that as the proportion of wheat in the lambs' diet increased, feed conversion ratio was not affected but liveweight gain decreased. When sorghum was substituted with wheat, as the amount of wheat in the diet increased from 0 to 60 per cent, average daily weight gain decreased from 223 to 204 g/day. Dry matter intake was similar across all treatments but feed conversion ratio was poorer for diets containing more than 20 per cent wheat.

Some authors have hypothesised that feeding maize or sorghum in whole grain diets, may limit available rumen degradable protein, microbial protein synthesis and total metabolisable protein for lamb production (Loe *et al.* 2000, 2001; Reed *et al.* 2002). Loe *et al.* (2001) evaluated different levels of rumen degradable protein in maize whole-grain diets, finding that for lambs with the ability to gain at least 470 g/day, the optimal level of rumen degradable protein does not appear to be greater than 6.1 per cent of the diet dry matter; however feeding levels between 6.1 and 11.0 per cent does not affect gain or feed efficiency. Increasing rumen undegradable protein in this feeding system did not affect lamb performance, except that rib-eye area tended to increase linearly with increasing level of rumen undegradable protein (Reed *et al.* 2002).

Performance of lambs fed maize or sorghum on high roughage ration

Table 6.7 reports lamb performance data when sorghum or maize were fed as part of a feedlot diet where forage represented more than 50 per cent of the diet. The inclusion of a forage source affects feed conversion ratio. Reducing whole maize grain while increasing the alfalfa proportion from 0 to 100 per cent in the diet of lambs and maintaining an isoenergetic diet adjusted to animal requirements, did not affect liveweight gain but it increased feed conversion ratio from 4.5:1 when 100 per cent grain was fed, to 7.8:1 when only alfalfa was fed (Fluharty 1999).

Table 6.7. Liveweight gain (LWG) and feed conversion ratio (FCR) of lambs fed whole grain diets. Summary of trials.

Animals			Grain		Forage		Response			Ref
Breed	LW (kg)	Number	Source	g/day	Source	g/day	Growth rate (g/day)	FCR (kg/kg)	FI (g/day)	
	9.8	12	60 Maize:40 Wheat Bran 30 Maize:70 Wheat Bran 100 Wheat Bran	115 112 106	Wheat Straw	*ad lib.*	79 [ab] 88 [b] 68 [a]	6.0 5.7 6.5	174 194 128	1
M x BL	19.3		Control Maize Sorghum Oats Meat meal	0 79[1] 87 92 100	Oaten Chaff	*ad lib.*	75 81 88 112 148		639 418 497 560 661	2
T	25		Control Sorghum Wheat	0 250[2] 250[2]	Lucerne Hay	*ad lib.*	168 208 256	6.7 5.9 5.2		3
T	25		Control Sorghum Wheat	0 250[2] 250[2]	Pasture Silage	*ad lib.*	-28 130 52	 7.8 20		3
SX	47	230	Maize (whole grain)	100[3] 80 60 40 20 0	Alfalfa Pellets	0[3] 20 40 60 80 100	347 365 351 351 364 342	4.5 4.6 5.5 6.2 6.9 7.8		4

[1] Grams/animal isoenergetic quantities (estimated based on NRC, 1996); [2] Grain adjusted to 1.0 per cent BW during the experimental period; [3] Proportion of the diet.
ad lib.: *ad libitum*; BL: Border Leicester; FI: Forage intake; FCR: Feed conversion ratio; LW: Liveweight; M: Merino; No.: Number of animal used; S: Suffolk; SX: Suffolk Crossbred; T: Texel.

[1] Dhakad *et al.* (2002); [2] Kempton (1982); [3] Dulce (n.d.); [4] Fluharty (1999).

The role of maize and sorghum in simple feeding systems

Simple systems of grain feeding have been proposed for cattle supplementation in Australia, to meet the need for alternative systems that reduce labour and costs, while maintaining liveweight gain and feed conversion rates (Rowe and Zorrilla-Rios 1993). The introductory period has been identified as one of the constraints to be overcome from conventional lot feeding.

Acidosis or sub-acute acidosis can occur when cattle and sheep over-consume readily fermentable carbohydrates (Al-Jassim and Rowe 1999; Kaiser 1999). The highest risk of acidosis is during the introductory period to high grain diets and it results in variable intake patterns that may cause reduced weight gains. Low weight gains during the adaptation period may compromise the whole efficiency of the grain-feeding program, depending on the duration of this period. Maize and sorghum, given their lower rumen degradability, appear to be safer grains compared to wheat or barley. Kreikemeier *et al.* (1987) suggest that when diets are based on grains which have rapid fermentation, a mixture with slow degradable grains may be a method for overcoming acidosis. They fed lambs on a 70 per cent grain diet, and observed that increasing the proportion of whole dry maize with respect to wheat from 25 per cent to 100 per cent increased the lambs' intake during the 21-day adaptation period. Liveweight gain and feed conversion ratio showed a significant quadratic effect.

Mendoza *et al.* (1999) feeding different combinations of high moisture maize and dry rolled sorghum grain in a 75 per cent grain diet found that even when there was no evidence of subacute acidosis the highest starch intake was registered for the mixture containing 33 per cent high moisture maize and 67 per cent dry rolled sorghum.

Conclusions

Limited data exist describing the performance of lambs fed maize or sorghum grain under Australian conditions. Research from other countries shows that lambs fed high concentrate diets of summer cereal grains perform as well or better than when fed winter cereals in terms of liveweight gains and feed conversion ratios.

Processing maize does not appear to improve total tract digestibility. Lambs fed whole maize in high concentrate diets have higher liveweight gains and lower feed conversion ratios than when offered ground maize. The effect of processing on sorghum fed to lambs is not as clear as for maize. Some evidence indicates processing may be used to manipulate carcase fat characteristics.

Higher variability in terms of liveweight gain and conversion rates may be expected when feeding maize or sorghum in diets with high levels of forage compared with high concentrate diets. Increasing forage in the diet increases feed conversion ratios and even reduces liveweight gains depending on forage quality.

Because of their low rate of fermentation, maize and sorghum appear to be safer grains than wheat and barley and could play an important role in simple grain feeding systems where there is less control of grain intake.

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