Proc. Assoc. Advmt. Anim. Breed. Genet. ***17****: 483-490*

DEVELOPMENTS IN BREEDING OBJECTIVES FOR THE AUSTRALIAN SHEEP INDUSTRY

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SUMMARY

Ram breeders within the Australian sheep industry have used selection indexes for a number of years, but recent developments in the industry have created a renewed need for research on breeding objectives. The main change has been an increase in meat prices relative to wool, which has lead to both the adoption of dual purpose enterprises with terminal sires from meat breeds mated to Merino dams, and higher awareness of the value of first cross and maternal composite ewes. These trends have resulted in increased interest in meat traits and reproduction in Merinos. Optimal breed development under this scenario points to the development of specialised breeds, with terminal sire breeds selected for meat traits and reproduction, and the Merino selected for both improved wool quality and reproduction. Ideally, ram breeders should be encouraged to increase recording of reproduction and other fitness related traits so that these goals can be realised. A second important development has been an increase in the amount of genetic information available to breeders, from the Sheep Genetics Australia evaluation system, and a related industry funded progeny testing system. Customised breeding objectives software (OBJECT and SheepObject) will enable breeders to use this information to its full potential.

INTRODUCTION

In recent years the sheep industry has gone through a period of major change. In particular, a significant shift in the relative prices of wool and meat has lead to the adoption of different types of commercial enterprises. In addition, the amount of genetic information available to breeders has increased, from a new genetic evaluation system, Sheep Genetics Australia (SGA, Brown *et al.* 2007), and from initiatives such as the Sheep CRC Information Nucleus flock (Banks *et al.* 2006). In this paper we review these changes and their impact on breeding objectives, considering appropriate breeding directions in relation to new commercial enterprises, the emphasis to place on trait groups including meat, wool, and fitness, and the value of new sources of genetic information. Delivery of selection indexes will also be discussed.

MARKET TRENDS AND THEIR IMPACT ON BREEDING OBJECTIVES

The Australian sheep industry has changed substantially since the early 1990's, mainly as a result of market trends, but also through the impact of productivity developments and drought. Wool has faced strong competition from synthetic fibres and cotton, and while prices have fluctuated from year to year, the long term trend has been downward. Sheep meat prices on the other hand have increased

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dramatically in both domestic and export markets. In relative terms, specialist sheep producers in 1993/94 obtained 84% of their sheep related income from wool and only 16% from sheep sales, but by 2003/04 these figures were 54% from wool and 46% from sheep sales (ABARE, 2006).

These changing price relativities have led to demographic changes in the sheep population, with ewes making up a higher proportion of the adult flock than they have in the past. High meat prices have led to wethers being sold as young animals rather than being retained for wool production. In addition, large numbers of Merino ewes are now mated to rams from meat breeds to generate progeny with high value lamb carcases. For example, a survey reported by Curtis and Croker (2005) estimated that one quarter of Merino ewes were mated to meat rams in 2005. These trends have stimulated interest in the Merino's contribution in meat enterprises, and a number of ram breeders have shown interest in modifying their breeding objectives to shift more emphasis towards meat and reproduction traits.

Within the wool market there were strong premiums for finer diameter wool throughout the 1990's, and wool producers responded by taking their flocks finer by a variety of means. As a result, the average diameter of the NSW wool clip reduced by 1.5 microns by 2000 (Atkins and Casey 2000) and the diameter of the Australian flock reduced by a further one micron between 2000 and 2005 (Peart *et al.* 2006). At the finer end of the market, wool buyers have tended to be much more discriminating of other wool quality traits, particularly staple strength and wool style. Specialist wool ram breeders therefore need to ensure they consider these traits in their breeding objectives.

BREED DEVELOPMENT FOR SHEEP ENTERPRISES OF THE FUTURE

Traditionally the sheep industry has been dominated by Merinos maintained for wool, with lamb and mutton production essentially a by-product. Crossing terminal sires from meat breeds to both Merino and first cross ewes has always been a feature of the industry, but is now becoming more important in an environment of high meat prices.

Under current markets with wool and meat contributing approximately equally to returns, dual purpose enterprises have become more common. Such enterprises are often based on crossing meat breed sires to Merino dams rather than on dual purpose breeds. In an analysis comparing the gross margins of a variety of enterprises, Warn *et al.* (2006) showed that dual purpose enterprises crossing meat sires to fine wool Merino ewes were generally more profitable than either wool or meat focussed enterprises. Studies like that of Warn *et al.* (2006) show that both wool and meat ram breeders need to consider their breeding objectives in relation to the type of commercial enterprise they are targeting, and it is quite likely that in future this will involve crossbreeding.

Van der Werf (2006) investigated how Australian sheep breeds should be developed in relation to each other, and importantly, how the Merino could be developed to maximise profitability across the industry. For a range of wool and meat price ratios a simulation model showed that development of a crossbreeding system using specialised breeds was favoured over the development of a single dual purpose breed. This is because the crossing system results in heterosis for profit, with the breeding ewe flock producing a high value wool clip, and the terminal cross progeny giving high returns from meat.

Optimal development of specialised breeds over time is shown in Table 1 (from van der Werf 2006), resulting in increased growth in the meat breed, and improved wool production with no increase in growth in the wool breed. Reproduction rate should be increased in both breeds, although it should be noted that in the wool breed this is not necessarily consistent with the reduction in body

size shown in Table 1. Nevertheless the sheep industry would benefit from the development of a Merino ewe with a high quality fine fleece, modest mature size, high reproductive rate, and good disease resistance.

Table 1. Optimal development of wool and meat breeds under different price scenarios from van der Werf (2006). Trait means are relative values: wool relative to wool breed mean and meat relative to meat breed mean in the current year; reproduction = number of lambs weaned per ewe; M × W, meat breed sire × wool breed dams; M × M, pure meat breed

Wool/meat price ratio*	Wool breed trait means			Meat breed trait means			Optimum system	Relative profit	% wool
	Wool	Meat	Repro	Wool	Meat	Repro			
				Current means					
12/1.2	100	80	0.90	67	100	1.20	M × W	1.00	54
				Means after 20 years of selection					
12/1.2	120	60	1.04	65	145	1.46	M × W	1.37	55
10/1.2	118	67	1.11	65	114	1.49	M × W	1.25	50
8/1.5				73	130	1.65	M × M	1.40	14

* Wool price in $ per Kg clean / meat price in $ per Kg liveweight

While this study takes a very broad view of the ideal development of Australian sheep breeds, in reality the large ranges in production environments, strain performance within the Merino breed, and skill levels of producers means that there is no one size fits all solution. In speculating about future production systems in the sheep industry Peart *et al.* (2006) predict the widespread use of 19 micron fine-medium Merino ewes mated to meat sires within the wheat-sheep zone, specialist ultra-fine Merino flocks in the high rainfall zone, and either 19-21 micron Merinos or easy care meat breeds in the pastoral zone. While there is some evidence for these general trends, enterprise diversity will continue to characterise the Australian sheep industry.

TRAITS IN SHEEP BREEDING OBJECTIVES

Wool. Methodology to include wool traits in Merino breeding objectives is well developed. The key economic traits are clean fleece weight, fibre diameter and staple strength. Wool quality traits such as diameter and strength are included in objectives using price premiums, defined as the percent increase in price resulting from a unit change in the trait, and Merino objectives are usually described in terms of their fibre diameter (or micron) premium. There is a window of practical micron premiums between 3 and 20%, constrained by the unfavourable genetic correlation between fleece weight and fibre diameter (reviewed by Safari *et al.* 2005) that allows simultaneous improvement of both traits. Selection on objectives with premiums less than 3% can result in increased fibre diameter, while premiums greater than 20% can result in reductions in fleece weight. Breeders can choose a micron premium to achieve their desired balance between increasing fleece weight and reducing fibre diameter, and this choice can be determined by their attitude towards the likely future market. For example, high micron premiums focussing primarily on fibre diameter reduction may contain an

element of risk, but are likely to lead to considerably higher returns in market scenarios favouring fibre diameter than alternative selection policies focussed largely on fleece weight.

Staple strength also has an unfavourable genetic correlation with fibre diameter (Safari *et al.* 2005), and selection on high micron premium objectives will lead to significant reductions in strength unless the trait is included in the breeding objective. Again, opportunities can exist to improve staple strength as an economically attractive objective, particularly in very fine wools.

While the market has been depressed in recent years, wool still makes an important contribution to the income of most sheep producers. Unless wool prices fall even further with no prospect of long term recovery, it is important that Merino breeders maintain an appropriate focus on improving wool traits. The key traits of fleece weight, fibre diameter and staple strength are relatively inexpensive to measure, heritable, and despite several unfavourable genetic relationships, amenable to simultaneous improvement.

Meat. To date, meat traits have received less attention in Merino breeding objectives. There has usually been a small level of emphasis (less than 5% contribution to economic gain) on increasing early weight, and maintaining adult weight to limit increases in ewe flock feed costs. More recently, "dual purpose" Merino objectives have been developed for SGA users, and these have a higher level of emphasis on body weight, as demonstrated in Table 2.

It should be noted however that the current interest in improving body weight in Merinos is not necessarily consistent with the optimal path for developing the Merino predicted by van der Werf (2006), which suggests that the focus should primarily be on improving fleece traits and reproduction. Improvement in growth of crossbred lambs from the maternal breed is often small in economic impact compared with the cost of a concomitant increase in mature size of Merinos leading to higher feed costs or lower stocking rates. This potential conflict and the case for measuring and improving carcass traits in Merinos would seem to require further research in a range of likely production environments.

By contrast, meat traits have been the key drivers of breeding objectives for terminal sire breeds, with the most common index used (Carcass Plus) placing 60% emphasis on post weaning weight, 20% on reducing fat depth, and 20% on eye muscle depth. Improvements in these traits in terminal sire breeds have played an important role in increasing lamb carcass weights and loin weights and thus providing access to a broader range of export markets.

Reproduction. In Merinos, reproduction makes a small marginal contribution to economic gain in wool focussed breeding objectives, but as shown in Table 1, increasing reproduction rate is an important component of the improvement of specialised lines for dual purpose and meat enterprises in the longer term. Merino ram breeders may therefore have to increase emphasis on reproduction in their objectives. The potential to improve reproduction rate has been limited in the past by low levels of recording, particularly in the Merino. Indirect selection is possible through body weight, which has a moderate positive genetic correlation with reproduction (0.33 averaged across studies by Safari *et al.* 2005), and many ram breeders in effect rely on body weight as a proxy trait for reproduction. The problem with this approach is that gains in reproduction are realised through increased body weight, which will lead to increased feed costs in the ewe flock.

Ideally, reproduction should be included not only as a trait of the breeding objective, but also as a selection criterion. SGA is currently developing recording systems to capture more comprehensive

reproduction data, while at the same time implementing an improved analysis model for reproduction. Although recording of reproduction data has been limited in the past, particularly in Merino flocks, use of new data capture systems built around radio frequency animal tags would allow breeders to efficiently collect the required information, including mating, scanning, lambing and weaning records.

The value of additional information on male fertility traits such as scrotal circumference to increase the accuracy of selection for reproduction is another area which has not been fully exploited by ram breeders (Apps *et al.* 2005).

Fitness. One of the consequences of long term selection on production traits in other species has been a decline in fitness traits such as reproduction, offspring survival, longevity, and disease resistance. The Australian sheep industry relies heavily on maintaining breeding ewes in the flock for a number of years and so, as rates of genetic gain begin to accelerate, it is relevant to question what effect the production trait selection indexes may have on fitness. One example which has received recent attention is an unfavourable genetic relationship between fleece weight and reproduction (Safari *et al.* 2007). Although Piper *et al.* (2007) found no evidence of a negative correlated response in reproduction in a fleece weight selection line, Adams *et al.* (2006) speculate that high fleece weight sheep have lower body reserves available to divert to reproduction when feed resources are scarce.

Van der Waaij (2004) used a resource allocation model to show how fitness traits may decline when finite resources are diverted to production traits. To overcome this limitation it becomes critical to include the important fitness traits in the breeding objectives and as selection criteria for Australian sheep.

Genotype by environment (G by E) interaction. G by E interaction has been observed in the SGA Merino database (Carrick and van der Werf 2007). Genetic correlations between environments (defined by production level for various traits) were low enough to lead to some re-rankings of sire breeding values for four of the twelve traits studied, including fleece weight, body weight, carcass traits, and worm egg count. Using a different type of analysis, significant sire by flock variances have been observed for most traits in the SGA Merino database (Brown, 2007, personal communication), and as a result of these findings, it is likely that sire by flock interactions will be included in SGA evaluations in mid 2007. The effect of this modification will be that breeding values become more predictable, as they will represent estimates of average performance across environments. While this may be a desirable outcome for most traits, it may not be for those with the largest G by E interactions where it may be more efficient to have specific breeding values for a limited number of defined environments. This is an important issue which should be researched by SGA, because at the extremes G by E will make across flock breeding values and selection indexes much less reliable.

Sheep CRC Information Nucleus Flock. A key development for genetic improvement in the Australian sheep industry was the establishment of the Sheep CRC Information Nucleus Flock in 2007 (Banks *et al.* 2006). This flock will progeny test 100 high genetic merit sires annually, sampled across the main wool and meat genotypes in the SGA database, in five different environments. Progeny will be measured for a much greater range of traits than those recorded by breeders, with the information flowing back into SGA genetic evaluations. In addition, DNA genotyping will be

conducted to accelerate the development of markers and their integration into industry breeding programs. The flock will therefore provide the industry with a powerful resource for genetic improvement.

From the perspective of breeding objectives, the flock will provide measurements on traits which are expensive to measure, such as feed intake and fitness. Although one of the attractions of selection indexes is that it is not necessary to measure traits in the objective directly, in practice it is valuable to obtain breeding values with higher accuracy from direct measurements, particularly for high merit sires that are likely to be used widely. In this sense the flock will provide a safety net to ensure that unfavourable trends in traits not normally measured can be addressed before they become problematic.

Equally importantly, the flock will be able to evaluate new traits as candidates for breeding objectives. For wool and meat, the main interest is in animal traits which relate directly to processing performance and consumer desirability. In the case of wool, consumer desirability equates mainly to garment comfort, and for meat, eating quality and health benefits. Objective trait measurement will be able to identify the extent of genetic variation.

DELIVERY OF SELECTION INDEXES

Selection indexes for a variety of objectives and breeds have been delivered through SGA. At the time of writing there were a wide range of indexes available for Merinos, partly because of the diversity and size of the breed, and partly because of the availability of customised breeding objective software. An important part of the SGA extension program has been to describe these indexes in terms of the production systems they are targeting.

The index options for terminal and maternal breeds have been more limited, perhaps because the roles of these breeds are more narrowly defined in comparison to the Merino. Nevertheless, the indexes that are available have been widely used in terminal and maternal breeds.

There are two software systems used by SGA to derive selection indexes based on bio-economic models for target commercial production systems, OBJECT (Semple *et al.* 1994) and SheepObject. While these systems will be used to derive both standard and customised indexes, there may also be a role for desired gains or sub-index approaches where the breeder has finer control over the emphasis to place on individual traits and trait groups.

Object. This system has been in use since the early 1990's and was developed largely for Merino production systems. It has recently been updated to be compatible with the SGA evaluation system, and around 90 standard and customised indexes have been re-worked and are being used by SGA breeders. A spreadsheet tool has been developed to compare responses and trait emphasis in different indexes, as shown in Table 2 for three SGA indexes. In addition, dual purpose indexes have been developed for Merino ram breeders targeting a production system with terminal sires mated to Merino ewes.

Table 2. Predicted 10 year response to selection and % contribution to economic gain for traits in 3 SGA Merino indexes: M7 = Merino 7% micron premium, DP7 = Dual Purpose 7% micron premium, and F10+ = Fine wool 10% micron premium + staple strength + worm egg count

	Selection response			% contribution to gain		
	M7	DP7	F10+	M7	DP7	F10+
Clean fleece weight (%)	5.1	2.9	4.1	48.7	25.5	31.5
Fibre diameter (μm)	-0.8	-0.6	-0.6	38.0	24.0	28.2
Staple strength (N/Ktex)	0.1	0.2	1.6	5.4	6.1	17.4
Body weight (Kg)	2.2	4.9	1.2	5.4	30.2	0.6
Number of lambs weaned (%)	0.6	2.5	0.2	2.4	14.2	1.0
Worm egg count (%)	-1.4	-2.6	-20.0	0.0	0.0	21.3

SheepObject. This is the most recent system developed for customised indexes. In common with OBJECT it takes a formal approach to index calculation, defined by economic and biological inputs which describe the target commercial production system. It does however have several additional features including the ability to model more complicated crossing systems, and to include additional traits, such as carcass traits. As such, it is suitable not only for Merinos but also for terminal and maternal breeds. At present, SheepObject is undergoing validation prior to delivery through SGA as a web based system.

Desired gains and sub-indexes. While systems such as OBJECT and SheepObject are often viewed by scientists as the preferred tools for setting breeding objectives, desired gains indexes, where breeders determine the level of emphasis on the traits they consider to be important, can also have a role. One use for desired gains indexes may be as a tool to balance selection emphasis on production and visual traits. However, caution is required when using desired gains indexes because selection response is dependent on the traits measured.

An alternative approach is to split economic indexes into sub-indexes. This is the approach used by the New Zealand sheep genetic improvement program SIL (see http://www.sil.co.nz for details), in which sub-indexes are formed by combining groups of economically or biologically related traits Selection can still be based on the economic index, but breeders can easily eliminate animals whose high index values are driven by traits of lesser interest in their breeding programs. The sub-index approach may be worth considering in the delivery of indexes for SGA.

CONCLUSION

The Australian sheep industry has undergone a period of change with meat becoming more important relative to wool, and as a consequence, continued investment in breeding objectives research is important. More detailed modelling of the optimal development of breeds for future enterprises is necessary, and the role of traits which have not been considered in the past must be explored. The appropriate balance between growth rate, mature size and reproduction is an issue requiring greater clarity, particularly for the dominant maternal breed, the Merino.

ACKNOWLEDGEMENTS
This research was supported by Meat & Livestock Australia, Australian Wool Innovation, and the Australian Sheep Industries CRC. Members of the SGA Technical Committee provided valuable feedback.

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