Summary

Automatic monitoring of liveweight and weight change is now possible with walk–through weighing systems. Computer–based drafting can incorporate a range of measurements such as pregnancy status, past performance, value–for–wool and value–for–meat to implement decisions on supplementary feeding. The combination of these technologies will provide the option of allocating animals likely to give the best response to improved nutrition to supplementary feeding regimes or of giving them priority in rotational grazing systems.

The advent of new walk–through–weighing equipment and improved automated drafting systems makes it imperative that we initiate research into the new era of sheep nutrition that has been facilitated by this new technology. Potential effects of precision nutrition in the sheep industry include improved lifetime productivity, better reproductive performance, production to specification, reduced death rates and improved parasite management.

Keywords: precision nutrition, sheep, pregnant ewes, staple strength

Introduction

Recent increases in returns from sheep–meat relative to those of wool have induced changes in the structure of the Australian sheep flock towards a higher proportion of ewes and fewer wethers. In addition to constituting the basis of the Australian wool industry, Merino ewes are the foundation for the sheep–meat industry. Therefore, it is essential that the care and management of this sector of the flock is well understood and given high priority. The purpose of this paper is to review strategies for individual management of ewes within a Merino breeding flock and to report recent developments in automated monitoring and drafting technology.

The importance of managing ewes as individuals

It is likely that a Merino ewe flock will have a wider range of individual nutritional requirements than other classes of domesticated livestock. Variation in individual animal requirements occurs as a result of phenotypic variation in the ewe flock, genetic characteristics associated with the use of specialist rams, and physiological differences associated with pregnancy status and variable parasite loads. Although twin–pregnancies are rare in cattle herds, in sheep flocks, at least 20% of ewes carry twins and 10% are non–pregnant. As the nutritional requirements of twin–bearing ewes are approximately 25% greater than those of ewes with single foetuses and nearly twice those of non–pregnant ewes, no single nutritional management regime will be suitable for the whole breeding flock; flock–feeding will thus result in inefficient use of available feed resources. Despite this, most flocks of pregnant ewes are not segregated according to number of foetuses because of the cost of scanning and the complexity of differential management.

The presence of a fleece makes it more difficult to assess and monitor body condition of pregnant ewes than of cows or sows. To monitor body condition in sheep, it is necessary to restrain individual animals and manually assess fat and muscle cover. This practice is the only way of monitoring nutritional status prior to joining and during pregnancy. Given the large number of animals in sheep flocks compared to cattle herds, it is evident that the job of monitoring ewes is time–consuming. Regular monitoring of pregnant ewes is normally restricted to estimation of group means and is not used to manage the nutrition of individual animals according to the number of foetuses, potential wool production or parasite status.

Problems associated with variability of nutrient requirements within the breeding flock are compounded by the adverse consequences of short periods of severe under–nutrition. With cows and sows, the only concern is survival and safe delivery of the offspring. However,
with the Merino sheep, ewe’s wool makes a significant contribution to the profitability of the enterprise, and poor nutrition and rapid weight loss can significantly reduce the tensile strength of the wool fibre with consequent discount penalties. Long-term under-nutrition of the ewe can result in lower fleece weights, reduced value of lambs and increased risks of mortality. Therefore, while it is more difficult to monitor and manage ewes than cows or sows, the potential production benefits are greater. Recent developments in technology make monitoring and management of individual ewes a practical goal; market demands, which have changed towards more ewes and a greater emphasis on lambing percentage, create a well-defined need for more sophisticated nutritional management.

### Phenotypic variation within flocks

Phenotypic variation within a flock can result from lack of phenotypic selection, pregnancy status and variable parasite burden. The interaction of these factors can result in extreme variation in nutrient requirements between individuals within a single flock.

(i) **Random** phenotypic selection. There appear to be three reasons for significant phenotypic variation. Firstly, there is normally little or no selection of the ewes within flocks because culling is normally done according to age group and not phenotypic characteristics. Secondly, selection for both wool and body conformation is rare in most flocks, even in stud flocks. Thirdly, wool obscures characteristics such as body condition; this means that even when there is selection for body conformation, it is difficult to apply the same objectivity that is possible with cattle and pigs.

Phenotypic ranges for a number of important production characteristics within typical flocks are summarised in Table 1. These data show that some of the animals that have heavier body weights and more wool have higher nutritional requirements than those that are lighter and produce less wool.

(ii) **Pregnancy status and number of lambs.** Apart from the phenotypic and genetic differences that occur within a flock, significant physiological differences are associated with pregnancy status and the number of foetuses carried by ewes, which influence nutritional requirements. Although ultrasound scanning is used by many producers to separate twin-bearing ewes, it is used on a relatively minor fraction of the flock and is mainly confined to dry seasons when supplementary feeding is used. Even when twin-bearing ewes are identified by scanning, these animals are normally only marked with a raddle or paint mark and are managed differently only during the final third of pregnancy. The full effect of raising twin lambs is not normally taken into consideration when preparing ewes for the subsequent pregnancy. The consequences of managing all ewes in an identical manner are discussed in more detail in a subsequent section.

(iii) **Effect of parasites.** The level of parasite infection and the effect of parasites on the individual can be extremely variable within a flock. Currently, there are no rapid diagnostic tests that allow cost-effective monitoring of parasite loads in individuals. Because of the difficulty of measuring individual weights and weight changes in relation to parameters such as pregnancy status, number of foetuses, wool growth potential and previous performance, it has not been possible to identify those animals likely to be suffering from parasitism or other health problems.

(iv) **Interaction between phenotype, pregnancy and parasites.** Variation in nutritional requirements resulting from random phenotypic selection, individual differences in requirements for reproductive function, and individual differences in the impact of parasitism can all have major effects on weight change. The combination of different phenotypes with a variety of nutritional requirements for pregnancy and lactation is likely to result in predictable interactions that

<table>
<thead>
<tr>
<th>Trait</th>
<th>Mean</th>
<th>Range that covers 95% of individuals in a population</th>
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<tbody>
<tr>
<td>Fleece weight (kg)</td>
<td>6</td>
<td>3.5</td>
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<tr>
<td>Fibre diameter (mm)</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Staple strength (N/k tex)</td>
<td>35</td>
<td>40</td>
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<tr>
<td>Slaughter body weight (kg)</td>
<td>50</td>
<td>20</td>
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<tr>
<td>Fat depth at slaughter (mm)</td>
<td>12</td>
<td>10</td>
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<tr>
<td>Eye muscle area (cm²)</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Average lambs weaned per ewe</td>
<td>0.7</td>
<td>2</td>
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Table 1 Phenotypic diversity within the Merino flock creates major opportunities for selection and management (Fogarty 1995; Atkins 1997).
have major implications for parasitism and the performance of individual animals.

**Pregnancy and twins represent risks for Merino ewes**

The program, 'GrazFeed' (Freer et al. 1997), facilitates simulation of nutrient requirements and weight changes of ewes with various numbers of foetuses in utero and their nutrient requirements for lactation. A simulation was made in which pasture characteristics were set at 0.4 t/ha green feed, 1.5 t/ha dry feed and 5% clover. The class of sheep was set as a medium Merino mature ewe with default values of 50 kg mature weight and 3 cm fleece. Two scenarios were examined. The first entailed the hypothetical pasture described previously, which provided a constant maintenance level of feed for a dry ewe weighing 50 kg for a 12-month period. The pasture for the second scenario was the same as that used for the first scenario, but ewes carrying twin lambs were fed a supplement of lupins (300 g/d) during the last third of pregnancy. Figures 1a and 1b show the weight changes of ewes with 0, 1 or 2 lambs for the two scenarios, respectively.

The most rapid rates of weight loss occurred during lactation for ewes with twin (–233 g/d) or single lambs (–141 g/d). There were also rapid rates of maternal weight loss during the last third of pregnancy for ewes with single (–74 g/d) or twin (–130 g/d) pregnancies. Although competent grazing management and supplementary feeding will ensure that extended periods of weight loss do not occur, in the absence of close monitoring it is likely that there will be at least one or two periods of rapid weight loss of pregnant ewes during late pregnancy and lactation.

Even when twin-bearing ewes are supplemented (300g lupins/d) during the last third of pregnancy, they are likely to be about 3 kg lighter (0.75 of a condition score unit) than ewes raising single lambs and 13 kg lighter than dry ewes. These weight differences are likely to be significant because of the effects of body condition on ovulation rate and lamb survival rate. Under-nutrition of the developing lamb in utero will also depress lifetime wool production. Kelly et al. (1996) reported that a loss in ewe liveweight of 12 kg during pregnancy resulted in lambs that produced less wool of a higher fibre diameter during the first 1.4 years of life than lambs from ewes fed at maintenance.

**Rate of weight loss is an important factor influencing staple strength**

There have been a number of attempts to identify the key factors that determine staple strength. The study of Robertson et al. (1996) is an example of a multi-factorial analysis; there are also many single-factor experiments in which nutrition, stocking rates and pregnancy status were varied. There has also been considerable analysis of fibre profiles to understand and manage staple strength. It is clear from these studies that nutrition is an underlying cause of variation in staple strength, but the exact nature of the relationship is poorly understood.

Because measurement of staple strength requires a length of fibre representative of several months' wool growth, there are few experiments in which nutrition and management factors were controlled sufficiently to ensure that the change in staple strength was related to any one factor. Murray et al. (1992) reported an experiment in which mature wethers were kept in single pens and fed a chaff-based diet supplemented with minerals at a level just above maintenance for approximately three months before and after a four-day nutritional disturbance in the form of grain overload. The aim of the experiment was to investigate the effect of fermentative acidosis on staple strength; animals that were challenged with carbohydrate received excess grain over a four-day period. Although there were

![Figure 1](image)

**Figure 1** Results of a Grazfeed simulation for 50 kg ewes (condition score 3) grazing a pasture providing 0.4 t/ha green feed, 1.2 t/ha of dry feed and with a 5% legume content. Data for pregnant ewes depict maternal weight, not the total weight of ewe and conceptus. (a), sheep receiving no supplementation; (b), twin-bearing ewes supplemented with 300 g/d lupin during the final third of pregnancy.
effects of different treatments on the severity of acidosis, the level of voluntary feed intake and liveweight gain for the two–week period around the time of carbohydrate overload were most closely related to staple strength (Figure 2).

In another carefully–controlled experiment using individually fed wethers, Thompson and Hynd (1998) varied intakes of various groups of animals to achieve maintenance of weight or weight losses of 50 g/d or 100 g/d for 112 days. This period was followed by a 112–day period of weight gain to recover the lost weight. The reduction of staple strength was closely related to the rate of weight loss. The results of the studies of Murray et al. (1992) and Thompson and Hynd (1998) are shown in Figure 4. It is noteworthy that the regression coefficients for the relationships between weight change and tensile strength are similar (16 or 17 N/ktex per 100 g/d liveweight loss) even though the periods of weight loss were different (14 vs. 112 days).

Gherardi and Oldham (1998) also reported a strong relationship between liveweight loss and staple strength across a range of ages and classes of sheep under field conditions. Liveweight change up to the point of minimum fibre diameter accounted for 30–90% of the variation in staple strength. Although these relationships indicate that there is potential to manage liveweight change for improvement within a flock, the high variation in staple strength across flocks demonstrates that other factors such as initial liveweight, condition, stage of maturity and reproductive status should be considered part of any supplementation strategy designed to improve staple strength. These factors may be used as additional inputs for setting targets for liveweight change.

Determining the relationship between rate of weight change and staple strength in pregnant ewes is more difficult than in wethers because maternal weight change cannot be measured directly. In the study of Robertson et al. (2000a), weight change was manipulated in pregnant ewes by reducing feed intake for two–week periods at various stages of pregnancy. In this experiment, ewes were fed in groups containing both single and twin–bearing ewes. The effect of this restriction in feed intake on daily weight change was estimated using Grazfeed as described previously, and the relationship between rate of weight loss and reduction in staple strength is shown in Figure 4. Although weight change was related to change in staple strength, there was a clear interaction between the extent of weight change and the stage of pregnancy. Weight loss late during pregnancy caused a significantly higher depression in staple strength than weight loss in early pregnancy, particularly in twin bearing ewes.

The consequences of the additional nutrients required for bearing and raising one or two lambs are clearly reflected in reduced staple strength. Figure 3 summarises data from a number of studies in which ewes carrying 0, 1 or 2 lambs were grazed or fed as single groups in which additional nutrients were not supplied to ewes pregnant with singles or twins. The results show a decrease in staple strength of about 10 N/ktex for each lamb, an average decrease of nearly 20 N/ktex for ewes bearing twin lambs, compared to non–pregnant ewes. Such a decrease in staple strength results in significant discounts, particularly in the case of superfine wool production. It is noteworthy that the decreased staple strength shown in Figure 3 and the rates of maternal weight loss for single and twin bearing ewes relative to dry ewes (Figure 1) are consistent with the relationship between these two parameters that was calculated from data derived from other experiments (Figure 4).

The reduction in staple strength per unit of liveweight loss in wethers shown in Figure 4 (Murray et al. 1992; Thompson and Hynd 1998) is greater than that of pregnant ewes (Robertson et al. 2000a and data from the current study). This may, in part, be explained by the interaction between extent of weight loss and
stage of pregnancy or lactation. It is generally believed that pregnant and lactating ewes are particularly prone to ‘tender’ wool because of nutrient partitioning away from wool to support the foetus and growing lamb. It is now well documented that in early pregnancy, reproducing ewes are comparable to non–pregnant sheep, but in late pregnancy and early lactation, there is a critical period of about two weeks close to the time of parturition during which weight maintenance or even gain is essential for maintenance of staple strength (Masters and Stewart 1990). During lactation, the situation changes: a number of authors reported maintenance of wool growth and/or staple strength even during periods of rapid weight loss (Williams 1978, Masters et al. 1993, Robertson et al. 2000a). In ewes under practical grazing conditions, staple strength was increased by up to 25 N/ktex by increasing the availability and quality of feed in late pregnancy (Masters and Mata 1998; Robertson et al. 2000b). The published information demonstrates that weight change is important in determining staple strength, even in reproducing ewes. However, the interaction with stage of the reproductive cycle indicates that close monitoring of weight change, body condition, parity and stage of the reproductive cycle is the key to precision management for high staple strength.

The studies reviewed here indicate that monitoring and management of the rate of weight loss of animals may be the most important interventions necessary to maintain high staple strength, particularly when a period of weight loss is followed by a period of weight gain. The ability to monitor individual sheep provides an opportunity to selectively supplement sheep and improve the cost–effectiveness of supplementation by reducing variation in liveweight and improving staple strength.
Walk–through weighing can facilitate monitoring and management

Automatic monitoring of liveweight and weight change is now possible using walk–through weighing systems. The first prototypes developed by the Sheep CRC will soon be ready for commercial deployment. Close monitoring of weight and weight–change will help to reduce the risk of low staple strength wool, perinatal mortality in lambs from underfed twin–bearing ewes and numbers of weaners below target liveweight. The technology will also be valuable in achieving uniform growth rates and target liveweight within required timeframes. The current recommendation to use condition score for determining the nutritional status of ewes is based on differences between frame sizes and the fact that pregnant animals can gain weight while the maternal tissues are being depleted because of the development of the foetus. Although assessment of mean condition score for a flock of ewes provides useful information on whether additional nutrition is needed for the group as a whole, it does not provide a means of monitoring individual animals. Provided that ewes are scanned to identify pregnant ewes and to establish whether pregnant ewes are carrying twins, and that they are weighed and condition scored at that time, it is possible to determine the appropriate pattern of weight change for each individual ewe for pregnancy, lactation and subsequent joining. The performance of each animal can then be monitored via walk–through weighing on a regular and cost–effective basis. Regular monitoring can be used to develop programs for supplementary feeding or rotational grazing. Animals that under–perform relative to their cohort group should be investigated for parasite load. This framework for monitoring and more precise nutritional management has the potential to include additional characteristics of animals.

Weight and condition score are closely related in individual animals: 4 kg liveweight is equivalent to one condition score unit (Freer et al. 1997). For a 12–month simulation, the weight loss of ewes that successfully bear– and raise twin lambs (relative to non–pregnant, dry ewes that maintain body weight) is 17 kg (4 units of condition score). The weight difference between ewes facing singles and twins is approximately 7 kg (nearly 2 units of condition score). These data illustrate the importance of providing better nutrition for twin bearing ewes not only during pregnancy but for a period sufficient to allow ewes to return to optimal liveweight and condition score prior to joining and lambing the following year.

Converting monitoring information to feeding systems

Automatic drafting based on weight alone is quite common but does not allow for decisions based on weight changes of individuals and other factors such as stage of pregnancy and number of foetuses. The ability to draft animals equipped with radio frequency identification tags (RFID) introduces the possibility of using drafting criteria based on indices. An index could include factors such as pregnancy status, initial liveweight and condition score, weight change, wool production records and other factors that determine those animals most likely to give the best economic response to improved nutrition. When the process of identifying these animals and drafting them is automated, the animals can be allocated to supplementary feeding treatments as they pass through a weighing/drafting unit each day on their way to drink water. The sophistication of the new automated RFID and drafting technology means that it is possible to determine which animals to feed and how often each animal has access to supplementary feed. This means that it is possible to keep single and twin–bearing ewes together in the same flock, provided that all animals are identified with RFID tags and that the data base contains information on the date of joining and results of ultrasound scanning for twins.

Frequency of feeding for wool and meat

It is clear from the work of Hill et al. (1968), Birrell and Bishop (1970) and Robards (1974) that when feed is offered to sheep once weekly, there is a significant increase in wool production over that achieved when the same total amount of feed is offered in daily portions. In the experiment of Hill et al. (1968), sheep fed a wheat ration once weekly grew approximately 55% more wool than those given the same total amount of grain in daily portions. For oat grain, Robards (1974) observed an increase in wool growth relative to sheep fed daily of more than 100% for sheep feed every sixth day. In the experiments of Birrell and Bishop (1970), sheep fed a roughage diet once weekly grew 10% more wool than those given the same total amount of feed is offered in daily portions. While it appears that there is little, if any, negative effect of weekly feeding with wheat on liveweight gain, it is clear that weekly feeding of roughage–based diets significantly reduces weight gain compared to daily feeding.

In the studies discussed in the previous paragraph, entire rations were fed at variable intervals. The potential to obtain similar benefits with supplementary feeding regimes was investigated by Masters et al. (2002). The basal diet of oat hay and straw (3:1) was fed daily at sub–maintenance levels, and supplements of lupin or canola meal were fed either daily or weekly. The supplements comprised about 23% of total DM intake. Although weekly feeding of canola meal resulted in slightly higher wool growth rates, there was no evidence of improved tensile strength. There was no increase in wool growth in response to weekly feeding of lupin grain compared to daily feeding. It is
possible that this lack of response was due to an imbalanced amino acid supply for wool growth. Given that automatic monitoring and drafting is now possible and that major increases in wool growth have been observed with weekly—compared to daily feeding of cereal grain, it is important to study the effect of interval of supplementary feeding on wool growth and tensile strength under grazing conditions. It appears likely that selection of a supplement to complement the available pasture together with infrequent feeding may offer practical opportunities to increase both wool production and staple strength.

Research is required to devise methods of controlling the level of feed intake in systems of supplementary feeding that are managed by drafting sheep into feeding treatments. Research into managing intake should include a study of the interval between feeding and the role of additives such as salt and urea. The possibility of using physical methods of dispensing fixed amounts of feed from feed hoppers also exists.

**Conclusions**

Significant phenotypic variation within a flock of sheep makes flock–level nutritional management inefficient and often cost–ineffective. The problem is exacerbated by difficulties in determining the condition scores and nutritional requirements of individual animals. The development of RFID technology to automatically identify animals means that it is now much easier to collect, manage and use information that defines the characteristics and nutritional requirements of individual animals. Walk–through weighing enables regular monitoring of individual animals and automatic drafting has potential for daily nutritional management of sheep within a flock. A new approach to precision nutritional management of sheep will be of particular value in managing Merino ewes, in which maternal weight loss can result in reduced lifetime performance of progeny and a significant discount in the value of the maternal fleece because of lower staple strength.

**References**


