ABSTRACT: The New Zealand (NZ) sheep flock is increasingly located in hill country environments where feed quality and quantity can be sub-optimal. Emphasis on feed efficiency in breeding objectives, therefore, has significant potential to improve the productivity and profitability of the NZ sheep flock. However, there is currently no data available on the genetic variability of feed efficiency in NZ maternal sheep breeds. In addition, evidence from some cattle studies suggests unfavourable genetic correlations between feed efficiency and reproductive traits. Given the strong emphasis on reproductive traits in NZ maternal sheep breeds, if the same relationships exist in sheep, it may be detrimental to select for improved feed efficiency. A facility is currently under development that will collect feed intake data and other production traits including maternal traits to develop an understanding of the genetics of feed efficiency and its correlation with key production traits in NZ maternal sheep breeds.

Keywords: feed efficiency; puberty; sheep

Introduction

The national sheep flock in New Zealand (NZ) has declined from nearly 60 million in 1990 to approximately 31 million in 2013 (B+LNZ, 2013b). Despite this decline, the productivity of the NZ flock has remained relatively constant through increases in lambing percentage and the weight of lamb produced per ewe (B+LNZ, 2013b). This drop in sheep numbers is also resulting in a change of demographics for the NZ sheep flock with an increasing percentage of the national flock located in “hill country” environments where feed can be a limiting factor, both in terms of quality and quantity. In order to at minimum maintain, if not increase, the productive output from the hill country environment there is an increasing need to consider aspects of feed intake and efficiency. Feed efficiency has been identified by sheep genetics funding bodies in NZ to be one of the traits of highest importance for genetic progress that should be incorporated in to breeding objectives to improve the productivity and profitability of the NZ flock. However, to date it is a trait that has not been investigated in NZ sheep and there is no international literature relevant to maternal sheep breeds in NZ such as the Romney and Coopworth. The importance of the need to establish a facility to measure feed efficiency in NZ maternal sheep breeds is outlined in this paper, together with a description of a research programme being established to address this need.

The trait of feed efficiency

The concept of feed efficiency and the genetics surrounding it for production species, is not new and there is an extensive list of papers relating to this topic, indeed a paper on the genetics of feed intake, feed efficiency, and other post-weaning traits in Angus cattle by Arthur et al. (2001) is the second most highly cited paper in the Journal of Animal Science. There are many methods of describing feed efficiency, however, the most common is Residual Feed Intake (RFI, or Net Feed Intake NFI), which is the difference between actual feed intake and that predicted on the basis of requirements for maintenance of BW and production, with a negative value indicating improved efficiency.

Feed efficiency is of interest for a growing animal that is to be finished and slaughtered, but is also important in the context of mature animals as it relates to their ongoing maintenance requirements. An important question then is whether or not the trait of feed efficiency is repeatable from the growing stage through to maturity. From a genetic progress point of view, there are significant advantages in being able to measure a growing animal, only, however, if it is an accurate proxy for the adult. Other key considerations are the genetic correlations between feed efficiency and other traits that influence productivity and profitability.

Methods for generating feed intake data

Feed efficiency is described as a hard to measure trait in sheep extensively grazing pasture. Comparative to indoor housed production species (pigs and poultry) or beef and sheep animals that are being feed-lot finished where it is easy to measure feed intake based on the actual feed that the animals are being fed (specific balanced ration diets), the ability to estimate the feed intake of animals grazing pasture is limited. There have been techniques established which involve the dosing of animals with alkane or chromium sesquioxide capsules with the concentration of the marker measured in fecal samples to estimate intake at pasture. Whilst genetic parameter estimates have been obtained using this methodology (Forgarty et al. (2006); (2009)), it is recognized that the error associated with the methodology requires large numbers of to be phenotyped to provide significant estimates. The method now more commonly used is similar to that used in feed-lots where animals are penned, and feed sourced from a feeder which is automated using electronic technology to measure the amount of feed consumed by an individual animal (Cockrum et al., 2013).
Because the recording of the feeding event occurs in real time other information including the number of, and length of feeding events can also be recorded. A number of predictor methods are being investigated by different groups in the world as reviewed by Berry and Crowley (2013) that include the use of Near-infrared spectropscopy, however, any such technology would require validation in sheep.

**Genetics of feed efficiency in cattle**

A discussion of literature relating to feed efficiency in cattle precedes a review of literature in sheep, as there is considerably more literature relating to cattle. A review of the literature relating to the genetics of feed efficiency for dairy and beef cattle has recently been published by Berry and Crowley (2013). In their review they carried out a meta-analysis of approximately 39 scientific publications and estimated a pooled heritability for RFI of 0.33 ± 0.01, although the range from the literature was 0.07 to 0.62. The variation in estimates reflects significant variation between studies as to the sex (entire male, castrate male or female) and the age (growing or mature) of the animals used in the respective studies.

Beef studies that have included animals repeat measured as young growing animals, and older mature animals have shown the two traits to be highly genetically correlated, with it therefore concluded that it is a repeatable trait across an animals lifetime in cattle (Herd et al., 2003).

Studies including feed efficiency in cattle vary in the range of production traits that have been measured alongside feed efficiency, and hence the range of traits for which the genetic correlation with feed efficiency have been estimated. For studies where comparisons have been included carcass traits, the results have not been consistent as reviewed by Berry and Crowley (2013). However, in more than one study a significant genetic correlation between RFI and carcass composition has been reported, with animals that have improved (negative) RFI having less carcass fat (Crowley et al., 2011b). There are even fewer studies that investigate the genetic correlation between measures of feed efficiency and reproductive and maternal traits, however, for those that have there is a suggestion that animals with improved (negative) RFI attain puberty later, and go on to calve later within calving seasons (Crowley et al., 2011a).

**Feed efficiency and sheep**

What research has been published relating to feed efficiency in sheep is even more sporadic than in cattle, particularly in terms of building a full biological understanding of the genetic relationship between feed efficiency and other production traits. Specifically, there is limited literature investigating the genetic relationship between feed efficiency measured on young growing ewes, and older mature animals and literature investigating the genetic correlation between feed efficiency and maternal traits. Studies by Forgarty et al. (2006; 2009) did investigate variation in feed intake at pasture of Merino derived mature, non-pregnant ewes using chromium sesquioxide marker technology, from this study they demonstrated there to be significant variation in feed intake across progeny groups, with estimated heritabilities from 0.32 to 0.41. Both studies reported no significant genetic correlations with production traits considered (growth, carcass, wool, and reproduction), however, the standard errors associated with the correlation estimates were often larger than the estimates which suggests that the data set was not large enough to estimate the correlations accurately. Published data on sheep through feed-lot type facilities with actual weight of feed consumed is limited to growing animals. Genetic parameter estimates for growing lambs of a terminal composite breed in the USA (Cammack et al., (2005)) ranged from 0.11 to 0.33 depending on the specific feed intake trait assessed. A study is currently underway in Western Australia using Merino genetics that is collecting data on approximately 2000 growing lambs, which as of February 2014 were beginning to be re-measured as adults (Andrew Thompson pers. comm), however, at the time writing there were no publications available from that study.

**The need for feed efficiency data on NZ maternal sheep**

In many cases we successfully assume that data from cattle is pertinent to sheep, but research is required sheep to substantiate this assumption for feed efficiency. As one of the key observations reported in the cattle literature described above that needs to be validated in sheep is that cattle that are genetically superior for RFI have delayed onset of puberty, which manifests itself through delayed date of conception as an adult (Crowley et al., 2011a). Sheep, comparative to cattle are seasonal breeders and it is increasingly expected in the NZ production system that they successfully conceive soon after attaining puberty (as a hogget). If there is any delay in onset of puberty it may impact on the ability of the animal to get in lamb as a hogget, or attain puberty within their first year of life, which has been shown to have impacts on subsequent two tooth and lifetime productivity.

Additionally, cattle nearly exclusively produce one offspring per reproductive cycle, whereas NZ sheep have been genetically selected and managed to maximize multiple births with twins common place, and triplets observed at a high frequency in some flocks. There is no data from cattle then to provide insight in to the genetic relationship between measures of feed efficiency and fertility, a relationship which must be understood in NZ sheep. The literature based on Merino derived sheep (Forgarty et al. (2006); (2009)) does not provide an answer to there is less of an emphasis on early (hogget lambing) and high (multiply births) maternal production in Merino derived sheep compared to NZ maternal breeds.
Overall then, there is a need to establish a comprehensive data set based on NZ sheep genetics that spans the life of animal with feed intake measures recorded on the growing lamb and again as a mature adult to develop a genetic understanding of how differences in feed efficiency impact on economically important traits, specifically reproductive traits.

Establishment of a feed intake research programme for sheep

A new funding cycle for sheep genetics research in NZ commenced in 2014, through an entity called Beef + Lamb NZ Genetics (B+LNZG). Based on the discussion that has been summarized in this paper, one of the priority research programmes in B+LNZG centers around feed efficiency in sheep. A facility is being established which will house up to 200 growing lambs or ewes at one time, with an aim of a throughput of two crops per year, whose feed intake will be monitored and recorded using automated feeders. The facility will be used to collect feed intake data over a number of years, with an initial aim of 1000 ewe lamb progeny from 100 different sires being measured. The ewe lambs will be sourced from already established industry progeny tests including the national across breed genetic evaluation the Central Progeny Test (B+LNZ, (2013a)).

From this resource the between animal variability and the heritability of feed intake (or derived traits) will be able to be estimated for NZ maternal breeds. Longer term, additional data will be collected on the same animals as mature ewes to investigate the genetic correlation between feed efficiency measured in a growing lamb and a mature ewe to consider whether the two traits repeat measures of the same trait. A range of other traits are standardly measured on the progeny test ewe lambs some of which will be measured pre-time in the facility including weaning weight, onset of puberty and others will be measured post-time in the facility including mature weight and reproductive performance. The ram lamb brothers of the ewes will have been grown out and slaughtered as lambs, which will provide carcass breeding values for the sires. There will also be the opportunity to investigate alternate predictor traits reviewed by Berry and Crowley (2013).

The exact protocol for collecting feed intake data is under development at the time of writing, with key considerations including What feed should be supplied, to best match on farm feed? How long will the sheep need to be on the feed before they become accustomed to it, and for actual data collection to ensure accuracy and repeatability? What time of the year the growing measurements should be made, given seasonal physiological variation? and What time of the year the adult measurements should be made, given seasonal physiological variation?

Conclusion

Given the changing dynamics of the NZ sheep industry, there is a need to investigate the genetics of feed efficiency using NZ maternal genetics and its relationship with other economically important traits. A resource is being established with the first hoggets to be measured for feed intake in 2014. The NZ ewe flock has specific drivers for early production and multiple births. Based on literature from cattle studies there is the potential for negative genetic correlations between reproductive traits and feed efficiency. These correlations need to be understood for NZ maternal genetics before any emphasis is placed on selection for increased feed efficiency.

Literature Cited