Small Ruminant Research 137 (2016) 138–150

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Review article

On-farm factors affecting physical quality of Merino wool. 1. Nutrition, reproduction, health and management

B.A. McGregor[a], S.P. de Graaf[b], S. Hatcher[c,*]

[a] Australian Future Fibres Research & Innovation Centre, Institute for Frontier Materials, Deakin University, Geelong 3220, VIC, Australia
[b] Faculty of Veterinary Science, The University of Sydney, 2006 NSW, Australia
[c] NSW Department of Primary Industries, Orange Agricultural Institute, 1447 Forest Road, Orange 2800, NSW, Australia

ARTICLE INFO

Article history:
Received 18 November 2015
Received in revised form 25 January 2016
Accepted 17 March 2016
Available online 19 March 2016

Keywords:
Grazing
Liveweight
Condition scoring
Age
Environmental variables
Allometric

ABSTRACT

The physical quality of Merino wool affects the processing route and efficiencies, the quality and uses of end products and thus the commercial price of both raw wool and wool textiles. The paper is the first of two and is organised into four disciplines relevant to the on-farm sector, being: nutrition, health, reproduction and management. A fifth discipline, breeding and genetics, will be covered in a second paper. Better integration is required of wool quality as part of integrated enterprise management and genetics strategies. There is an essential need to integrate wool quality metrics into pasture improvement activities, particularly on-farm extension activities and enterprise budgeting and modelling. A number of basic areas of wool harvesting and sheep management have been overlooked for decades and need clarification in the face of improved practices in other aspects of wool quality, such as longer staple length as a consequence of improved genetics and/or nutrition requiring increased shearing frequency. The review identifies practices which should be incorporated into all wool production and quality experiments as a consequence of advances in understanding of fibre growth, reduced costs of fibre testing and statistical analyses. The review identifies tools available to aid farmer's adoption of new approaches but there is still a need to develop improved tools to assist wool producers gain the maximum benefits from the current state of knowledge regarding the best management of Merino sheep for wool quality.

1. Introduction

The physical quality of Merino wool affects its processing route and processing efficiencies, the quality and potential uses of end products and thus the commercial price of both raw wool and wool textiles. There are many attributes used for the assessment of wool quality, both subjectively assessed (Mortimer et al., 2009; Australian Wool Exchange, 2011; Anon, 2013) and objectively measured (Anon, 2000). This review focuses on the main attributes affecting processing performance and apparel textile quality of Merino wool, namely fibre diameter, fibre length, staple strength, colour and fibre curvature due to their relative impact on the prices paid for the raw fibre (Nolan, 2014) and their impact on both early (Anon, 2004) and later stage worsted processing (Anon, 1973; Hunter, 1980; CSIRO, 1994). Brief reference is made to other attributes such as vegetable matter contamination and wool fibre surface properties which may have secondary impacts on either processing efficiency or apparel quality.

The review is organised into four disciplines relevant to on-farm control, these being: nutrition, health, reproduction and management. The review aims to provide an overview of advances over the past 20 years in knowledge of how these topics affect Merino wool quality, and to place these into the context of existing knowledge. The review also identifies tools available to aid Merino producers' adoption of new approaches, practices which may improve the conduct and interpretation of wool experiments, and areas for future research into on-farm factors affecting physical qualities of wool. The topics of on-farm control of breeding and genetics are covered by Hatcher et al. (2016).

2. Nutrition

Over the past 70 years nutrition research on wool production primarily focused on wool growth with less attention paid to physical quality traits. This was in part related to the lack of available or affordable testing procedures. In recent decades, while testing has become more affordable, the number of wool nutrition

* Corresponding author.
E-mail address: sue.hatcher@dpi.nsw.gov.au (S. Hatcher).

http://dx.doi.org/10.1016/j.smallrumres.2016.03.019

experiments has declined. Generally for most sheep, as they increase in age, they also increase in liveweight, a process referred to as growth. At any point in time however, liveweight reflects both the long term effects of growth towards mature size, and the effects of short term seasonal changes in nutrition, typified in much of the wool growing regions of Australia by liveweight loss during periods of low pasture digestibility and availability and liveweight gain with the return of pastures with high digestibility. Such changes in liveweight are documented in multi-year studies of grazing sheep (White and McConchie, 1976; Brown, 1977; Black and Reis, 1979; Langlands et al., 1984; Craig, 1992; McGregor, 2010). Thus it is not possible to separate the effects of nutrition on wool growth and quality from the effects of nutrition on the liveweight of sheep.

Body condition scoring (BCS), a technique developed to enable farmers to easily quantify changes in the body energy reserves of sheep in the paddock (Jefferies, 1961; SCA, 1990; van Burgel et al., 2011), has in recent years been evaluated in relation to quantifying the effects of nutrition, as mediated via changes in liveweight, on wool growth and fibre diameter (Thompson et al., 2011). Thus the practical way, and we argue the biological way, to study the effects of nutrition on wool quality will be via changes in the liveweight, or its proxy BCS, of sheep. BCS is not a perfect proxy as the relationship between liveweight and BCS varies between flocks and also varies within flock throughout the year (SCA, 1990; McGregor, 2010; van Burgel et al., 2011). Furthermore, liveweight and BCS comparisons between groups of sheep can be confounded with frame size (SCA, 1990; Brown et al., 2015).

2.1. Fibre diameter

2.1.1. Change with liveweight and animal size

The accepted view for Merino sheep is that as they increase in age fibre diameter (FD) increases and staple length (SL) decreases (Brown et al., 1966; Black and Reis, 1979; Hatcher et al., 2005). Such analyses did not determine if variations in liveweight were more important than age in determining FD as exemplified by the well documented effects of stocking rate on Merino wethers and ewes, where increases in liveweight with age may not occur at higher stocking rates and FD may not change (e.g. White and McConchie, 1976; Brown, 1977; Langlands et al., 1984; Craig, 1992). FD is known to change in response to changes in nutrient availability, as indicated by changes in liveweight (Allden, 1979). Thus any change in the nutritional status of sheep affecting the liveweight will affect FD. Therefore changes in FD should be expected from any seasonal variation in pasture quality, variations in stocking rate and physiological factors such as pregnancy and lactation (Black and Reis, 1979; Morley, 1981) although if maternal liveweight is maintained wool growth is unaffected (Williams and Butt, 1989).

With fibre producing animals, skin follicle initiation is completed by about 4 months of age resulting in increases in liveweight from this age being correlated with reductions in the density of fibre producing follicles and the growth of coarser fibres (Fraser and Short, 1960; Maddocks and Jackson, 1988). It has been accepted that the mechanism for this relationship is that larger animals have larger skin surface area leading to reduced density of skin follicles and less competition between follicles leading to increasing skin follicle bulb dimensions (Hynd, 1994a) and the cross-sectional area of fibres.

The results of recent studies give an alternative explanation, namely that the diameter dimension of fibres is related to the size of the animal through an allometric relationship. To the extent that fibre producing animals of different sizes are morphologically similar (i.e. have the same geometric shape), the skin surface area will be proportional to (animal volume)$^{0.67}$ (Schmidt-Nielsen, 1984) which is the general allometric relationship between surface area and volume of similar three-dimensional objects. In turn, animal volume will be proportional to fleece-free liveweight (FFW). It follows that, the cross sectional area of each fibre will be proportional to (FFW)$^{0.67}$. For Angora goats of the same age and cohort, the FD was proportional to the cube root of animal size indicating that the mean cross-sectional area will be related to the FFW$^{0.67}$ (McGregor et al., 2012). As Angora goats are shorn every 6 months, using FFW to predict FD will be more precise compared with using the same metric for sheep shorn annually. In Saxon Merino sheep FD was allometrically related to the cube root of FFW over 14 periods of liveweight gain and loss (McGregor and Butler, 2016).

The view that FD is related to the size of sheep may provide an explanation for the variability in repeatability estimates for FD as discussed by Hatcher et al. (2016). It may also explain why h^2 estimates of FD become more uniform as animals approach their mature size, i.e. as the size of sheep increases the proportional increase in size decreases and consequently h^2 estimates move closer to their "biological value" at more mature ages. Further work is required to quantify the relationship between FD and liveweight in Merino sheep.

The effects of maternal nutrition on the FD of their progeny are discussed in the reproduction section.

2.1.2. Manipulating nutrient provision

The concept of varying grazing pressure as a means of controlling wool growth rate and reducing variation in FD has been proposed by researchers (Black and Reis, 1979; Birrell, 1981). A key feature of the development of the production system for housed ultrafine Merinos during the 1970s and 1980s was to feed the sheep for the maintenance of a low stable liveweight (Anon, 2005). However, attempts to limit the seasonal increase in FD of grazing sheep during spring in temperate Australia by restricting the food on offer (FOO) have shown the difficulty of the task. This is in considerable part because sheep display compensatory liveweight gain when nutritional conditions become favourable for liveweight gain (Allden, 1968; SCA, 1990). For example, while Thompson et al. (1994) attempted to control FD by grazing to particular FOO levels, particularly green FOO, rather than using stocking rate, it was liveweight change which explained more of the variance in FD during spring than did FOO. Except at the lowest levels of FOO, FD increased significantly during spring. The analysis did not include the mean effect of liveweight in the prediction models. Doyle et al. (1999) used strip grazing between mid-June and late October reducing FOO to as low as 400 kg DM/ha but still reported liveweight gains of 32–50 kg compared with set stocking, which had liveweight gains of 32–67 kg. Consequently FD in all treatments increased, for set stocking from 18.8 to 25.2 μm and for the 400 kg DM/ha strip grazed treatment from 17.5 to 21.2 μm. Similarly Ferguson et al. (2011) found that increasing FOO to pregnant ewes resulted in coarser FD, however they did report that higher liveweight was associated with coarser FD and that losing liveweight during pregnancy resulted in finer wool.

Hynd (2000) reviewed the nutritional biochemistry of wool follicles with a focus on wool growth. The effects on wool growth attributed to Vitamins A and D are likely to be associated with changes in fibre length, FD and cuticle size but have not been quantified.

2.1.3. FD variability

FD variability affects processing performance and staple strength (SS, Section 2.3). Higher FD variability is associated with increased ellipticity of wool (ratio between the major and minor cross sectional diameters). Wool fibres are not circular in cross section but elliptical, with coarser fibres being more elliptical than finer fibres. Other sources of FD variability include differences between skin follicle cross sectional area, and along fibre diameter variation.