Small Ruminant Research 133 (2015) 43–53

Contents lists available at ScienceDirect

Small Ruminant Research

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

Review article

A review of wool fibre variation across the body of sheep and the effects on wool processing

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ARTICLE INFO

Article history:
Received 9 September 2014
Received in revised form 14 October 2015
Accepted 21 October 2015
Available online 26 October 2015

Keywords:
Fibre diameter
Fibre diameter variation
Staple length
Staple strength
Yield
Wool colour
Pigmentation
Medullation

ABSTRACT

Variations in wool characteristics due to location on the body of sheep are reviewed and compared with variation from other sources. The biological basis for variation and the relevance of this source of variation to industry are also discussed. For many traits, variation between sites on the body was trivial in comparison with variation between individual fibres within those sites and variation between sheep. To set the context within which wool variation could have an economic impact, fleece skirting and other wool processing steps that are influenced by fibre variation, or might increase or decrease the impact of variation are initially discussed. Processing intimately blends wool from numerous sources and distributes variation from individual fleeces and positions within fleeces among larger processing batches. Variation within fleeces and flocks is thus of limited concern in breeds with a history of selection for wool for industrially manufactured wool products. Variations in dye uptake caused by highly pigmented or medullated fibres are two exceptions that cannot be effectively hidden by blending. The balance of evidence suggests that reducing the variation in most fibre characteristics across the body of wool-producing breeds is not economically justified for conventional manufacture of apparel, interior textiles or lower value products on an industrial scale, though further research may be justified for high value uses or in breeds not selected for uniform wool production.

1. Introduction

Throughout history, breeders of wool-bearing sheep have sought greater uniformity in the characteristics of the wool carried by their breed of choice. Wool traits are remarkably heritable and obvious morphological differences in the pelage are one of the major features by which sheep breeds are distinguished. For example, the "Breed Description" for the Lincoln breed in the New Zealand Flock Book (2004) has a separate heading on "Fleece" which states: "*Evenness over all the body, belly and points*." Lincoln breeders have followed this breed description for many years. This quote is central to this review because sheep breeders are encouraged to breed sheep with uniform wool across the body.

The mean and standard deviation of fibre diameter, medullation, fibre curvature, fleece discolouration, staple length and staple strength of raw wool are commonly assessed characteristics that influence processing and end products. Average values are subjectively assessed or objectively measured on samples collected from batches of wool. These traits indicate suitability for industrial production of apparel, interior textiles or lower value products. Industrial-scale manufacturing uses large batches of wool blended from many fleeces and many flocks. Sources of variation in the characteristics of the raw wool in each batch are:

- between breeds.
- between flocks.
- between fleeces within flocks.
- between positions within fleeces.
- between staples within positions.
- between fibres within staples.
- along fibres.

Position within the fleece is just one of several sources of fibre variation that might affect manufacturing and end use. The characteristics of harvested fleeces are influenced by many other natural and managed environmental effects. An obvious example of the influence of management is the effect of partial shearing on staple length, where the breech is shorn to remove dags (crutching) between annual shearings, resulting in two lengths of staple in the annual fleece. Degradation of wool on the back from exposure to ultraviolet light, abrasion of wool from the legs or belly

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http://dx.doi.org/10.1016/j.smallrumres.2015.10.025
0921-4488/

due to contact with soil or vegetation are also potential natural sources of variation across a fleece, and greater accumulation of vegetable matter in ventral portions of the fleece has been reported by Thornberry and Atkins (1984). This review does not consider such variations caused by the environment, but is restricted to variation between positions within the fleece due to inherent variation that might be controlled genetically or developmentally. The extensive list of references relevant to this topic have not all been reviewed here. Some areas such as fibre diameter variation have been very widely examined and the trends across the body are similar, while in areas such as variation in medullation references are scant.

The intervening steps between the growth of the fleece and the manufacturer or consumer influence the final degree of variation, and some of these techniques are briefly described to set the scene. The generalised products that may be made from wool are also briefly outlined, to pose the question of whether the inherent level of variation in wool characteristics across the body of a sheep is at all troublesome. A very brief overview of the plethora of processing methods is noted, and the places where fibre variation might influence, or be influenced by, processing are highlighted. Readers should pursue other sources for detailed information about products and processing. The process of fleece skirting and sorting is introduced to question whether this is sufficient to control or exploit variation. In light of the effects of processing and sorting, and the reported range of various wool traits, the developmental processes that create variation across the body are finally reviewed to understand whether these could be controlled and whether sheep breeders and researchers should devote so much resource to studying this phenomenon.

2. Products

Wool can be made into non-woven structures such as insulation through simple processing steps, or through more complicated pathways into woollen, worsted or semi-worsted yarns and then into carpets, knitted apparel, or woven fabrics for furnishings or apparel. Carpet manufacture is relatively tolerant of inter-fibre variation; as long as the fibre will process into a yarn, then it will perform. Variations in wool characteristics are thus low priority considerations for carpets and low cost applications such as fillings and non-woven materials. Although some inefficiency may be associated with high blend variability, the impact on processing efficiency and performance is not really known. Medullated wool may be brittle and easily lost from the carpet pile, while pigmentation is detrimental in pastel carpets but less important in darker shades. Wool bulk, on the other hand, helps the carpet pile recover quickly after crushing and improves long term appearance retention. Apparel products made of fine wool require more exacting wool specifications. For example, any fibres that are greater than 30 μm in diameter can cause prickle sensation in the final product, especially if worn close to the skin (Naylor and Hansford, 1999). These are generally found in wool of mean fibre diameter coarser than 21 μm. Variation within a fleece could therefore have greater significance for apparel products than carpets, and the processing implications may warrant further investigation in fine wool sheep.

3. Processing

The impact of variation in wool, regardless of source, is influenced by processing. Individual farms rarely produce sufficient quantities of wool to process into a parcel suitable for modern manufacturing methods. Wool processors often purchase wool from several sources, which they blend to produce larger parcels of wool with a certain range of characteristics to manufacture industrial-scale products.

Blending is an integral part of processing, which begins during scouring (washing to remove wool grease) and carding (brushing to align wool fibres). Skilful blending can generate reproducible batches, countering seasonal variation in wool characteristics. Blending ensures that fibres with different characteristics are thoroughly dispersed and intermingled in the product and variation is distributed across the blend. It is especially critical to thoroughly blend different coloured fibres to avoid patches that dye to different shades. However, this requires multiple mixing and opening processes, all of which could cause damage that may cause fibre loss, weak points in yarns and thus reduced profitability. When wool is sourced from a single flock, blending is still required to distribute variation within and between fleeces evenly.

The presence of variable fibre characteristics in a wool blend is not always detrimental. During the manufacture of woollen products (e.g. Shetland knitwear, Axminster carpets), manufacturers deliberately ***increase*** variation by blending wool lots that differ in average characteristics to improve processing and end-product performance and increase profitability. Furthermore, radial fibre migration occurs during the spinning process, such that the inner part of yarns become rich in long, fine, straight fibres and the outer yarn becomes rich in coarser, more crimped fibres (Ford, 1958; Hamilton, 1958; Onions et al., 1960; Balasubramanian, 1970). An excellent yarn may therefore be constructed from variable fibres. Nevertheless, processing difficulties may arise if the wool is so varied that it contains fibres which are not compatible in the chosen processing route. An example of this is when coarse wool contains many fine fibres, which can cause "nepping" or tangling of fine fibres during carding (Hunter, 2002). Nepping increases weak points and unevenness in the yarn, and also increases processing costs since machinery requires more frequent cleaning. Highly variable batches also require more processing to ensure thorough blending, are therefore more likely to sustain high levels of fibre breakage and loss, which reduces profitability. Thus manufacturers sometimes place limits on the variability of certain characteristics such as fibre diameter or length. For example, blends destined for apparel must meet critical specifications for yarn uniformity in terms of mass variation and dyeability. Minimising variation within fleeces, between fleeces, between lines or between sources is a possible route to achieving this. Greater uniformity across individual fleeces could therefore make blending more predictable, give better processing performance, and produce better quality products.

4. Fleece skirting and sorting

Prior to the processing steps just described, fibre variation is influenced by fleece skirting and sorting on-farm. During shearing, and following removal of the fleece, wool is separated into different 'lines' with different characteristics. The first blows of the conventional shearing technique remove the wool from the belly, which is cast aside by the shearer and placed in a "belly wool" line by the wool handler. Other portions of fleece are sometimes removed from the fleece and placed in other lines, given names like "eye-clips" from the face, "fribs" from the edges of the inguinal regions or "dags" or "stains" from the breech area. The self-explanatory "bellies out" in the United States means only the belly wool has been removed (Lupton et al., 1992), which in New Zealand for example, would more often be called "unskirted fleece". Wool from the lower leg is sometimes placed in a line called "shanks" while wool from top of the head may be labelled "wigs" or "topknots", depending on country. Portions removed from the edge of the fleece are often pooled into lines called "pieces". The main portion of the fleece will then be placed into one of a few or many fleece lines, based on certain readily visible quality attributes and a hand strength test which aggregates similar fleeces and reduces variation.