Small Ruminant Research 129 (2015) 11–17

Contents lists available at ScienceDirect

Small Ruminant Research

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

Indices for the identification of biologically productive cashmere goats within farms

B.A. McGregor[a,*], K.L. Butler[b]

[a] Australian Future Fibres Research & Innovation Centre, Institute for Frontier Materials, Deakin University, Geelong 3220, VIC, Australia
[b] Biometrics Unit, Agriculture Research, Department of Environment and Primary Industries, Hamilton 3300, VIC, Australia

ARTICLE INFO

Article history:
Received 2 September 2014
Received in revised form 12 May 2015
Accepted 13 May 2015
Available online 27 May 2015

Keywords:
Cashmere
Evaluation
Farm
Fibre diameter
Productivity
Staple length

ABSTRACT

Objectively comparing cashmere goats with different cashmere production, mean fibre diameter (MFD) and staple length (SL) is difficult for farmers. We aimed to develop indices to enable cashmere producers to identify productive goats within their own farms once adjustments had been made for the primary determinants of cashmere production. That is we aimed to develop indices that identify goats and herds that biologically have a high fleece weight in relation to MFD and SL. We used a sample of 1244 commercial cashmere fleeces from goats originating from many Australian farms based in different environmental zones and a previously developed general linear model that related the logarithm of clean cashmere production (CCMwt) and any other potential determinant. In the present study, sub-models were investigated in order to develop new indices for comparing goats in the same farm, based on fleece characteristics and biological efficiency. New Index (MFD), equal to $6.02 \times \text{CCMwt}/1.1531^{\text{MFD}}$, was developed to identify animals of biologically high CCMwt in relation to their MFD. Unlike previously reported results that MFD is not a useful measurement for comparing the biological efficiency of cashmere goats across farms, the New Index (MFD) allows comparison of the biological efficiency of cashmere goats within farms. New Index (SL), equal to $2.70 \times \text{CCMwt}/1.1414^{\text{SL}}$, was developed to identify animals of biologically high CCMwt in relation to their SL. New Index (SL) is very similar to the Clean Cashmere Staple Length Index (CCSLI) that had been previously reported for comparison of cashmere goats across farms, and thus the CCSLI can be usefully used for comparing the biological efficiency of cashmere goats both across and within farms. New $\text{Index}(\text{MFD}, \text{SL}) = 8.90 \times \text{CCMwt}/1.243^{(\text{MFD}+\text{SL})/2}$ was developed to identify animals of biologically high CCMwt in relation to both their MFD and SL within farms, and provides useful information above using either New Index (MFD) or CCSLI. The indices can be presented in the same measurement units as fleece weight, which is a biological concept easily understood by cashmere producers, and enable comparisons to be made between animals using just one attribute, clean cashmere weight.

1. Introduction

The mean fibre diameter (MFD) is the primary determinant of the price of cashmere as it affects the processing route, processing efficiency and the ultimate use and quality attributes of cashmere textiles (Hunter, 1993;

* Corresponding author. Tel.: +61 3 52 273 358.
E-mail address: bruce.mcgregor@deakin.edu.au (B.A. McGregor).

http://dx.doi.org/10.1016/j.smallrumres.2015.05.013
0921-4488/

Schneider, 2014a). Other attributes are also important in affecting the price, processing, softness and quality of cashmere textiles including staple length (SL), fibre curvature (FC) and the colour of the cashmere (Watkins and Buxton, 1992; Dalton and Franck, 2001; McGregor, 2000, 2014; McGregor and Butler, 2008a; McGregor and Postle, 2008, 2009).

The importance of MFD in affecting market demand for cashmere has led to a range of genetic studies on the inheritance of MFD and genetic improvement programs to reduce MFD in cashmere producing goats (Pattie and Restall, 1989; Bigham et al., 1993; Zhou et al., 2002; Tseveenjav et al., 2004; Younesi et al., 2008; Allain and Renieri, 2010; Wang et al., 2013). These developments have also led farmers to use the MFD of their cashmere to compare their goats both within and between farms. In Australia, cashmere farmers have compared the productivity of individual cashmere fleeces and stud breeding using the Patrick Index (Anonymous, 1989, 1990; Graham and Bell, 1990). The Patrick Index ($PI = 4277.335 \times$ [cashmere weight (g)/$(MFD)^{3.3}$]) was designed as a biological index that balanced the amount of fleece with the MFD of fleece. Two fleeces with the same PI should be equally difficult to produce. The PI is standardised to a MFD of 12.6 μm which it means that, at 12.6 μm, the PI equals the weight of clean cashmere.

In Australian, cashmere goats have been farmed in the western, southern and eastern regions of the continent. The determinants of cashmere production of commercially farmed Australian goats have been recently quantified (McGregor and Butler, 2008b,c) and research shows that cashmere production had not increased during the previous 25 years. The lack of improvement may be a consequence of the slow rate of progress predicted from selection studies, the cost of testing cashmere fleeces, or a lack of producer skills in undertaking the genetic evaluation of animals. For example, when the generation interval was fixed at 4 years, Pattie and Restall (1984) predicted responses of 4 g of cashmere per year in the best system using a selection index maintaining MFD, and 12 g per year if MFD was allowed to increase 1.1 μm per generation. In such cases cashmere production should have increased by about 100 g over the intervening 25 years, but such progress was not evident.

McGregor and Butler (2008c) developed a relationship between clean cashmere production and other fleece characteristics using fleeces sourced from 11 Australian farms and showed that cashmere weight is related to a range of fleece measurements and to animal growth measurements. Further, once these fleece and growth measurements are taken into account there are no longer any age or sex cohort effects observable (McGregor and Butler, 2008b) thus indicating fleece characteristics and animal growth are primary determinants of cashmere production. Subsequently it has been shown that cashmere SL is important for comparisons between farms not the MFD of the cashmere. The use of a Clean Cashmere SL Index provided a more robust comparison of cashmere productivity between farms as it is an indirect indicator of desirable skin secondary follicle development (Butler and McGregor, 2014).

Australian cashmere growers have been unable to increase cashmere production when there are a multiple of 'competing' biological attributes to evaluate. How can farmers compare goats within their herds which display large variation in productivity, MFD and SL (e.g. goat producing 130 g of 14 μm versus 250 g of 17.5 μm cashmere)? We aimed to develop indices to enable cashmere producers to identify biologically productive cashmere goats within their own farm herds once adjustments had been made for the primary determinants of cashmere production. The resulting statistical models were used to develop new indices for effective clean cashmere weight, and to compare these indices with PI, and indices that have been developed for comparing cashmere goats between farms (Butler and McGregor, 2014). The use of one term, effective clean cashmere weight, would allow farmers to focus genetic selection upon one parameter, rather than a diversity of parameters such as greasy cashmere weight, cashmere yield, MFD and SL, which may result in less selection differential for each parameter and possibly less improvement in the selection of productive goats (Turner and Young, 1969).

2. Materials and methods

2.1. Data

Fleece and live weight data were analysed from commercially managed cashmere goats from 11 farms in 4 States of Australia (Western Australia, Victoria, New South Wales and Queensland). Full details are provided elsewhere (McGregor and Butler, 2008c). At shearing, greasy fleece weight (g) was measured and fleeces were sampled. Cashmere fibre SL (cm) was measured to the nearest 0.5 cm. Fleece samples were sent to a commercial fibre-testing laboratory and measurements recorded for clean washing yield (CWY; %, w/w), MFD (μm), fibre diameter standard deviation (FDSD; μm), fibre curvature (FC;°/mm) and fibre curvature standard deviation (FCSD;°/mm). Clean cashmere yield (%, w/w) was determined as: clean washing yield × Optical Fibre Diameter Analyser (OFDA100) cashmere yield (determined using fibre diameter profiles (Peterson and Gheradi, 1996)). Clean cashmere production (g) was determined as: CCMwt = greasy fleece weight × clean cashmere yield. Live body weight (LW; kg) was measured and LW change (LWC; kg) was determined as the difference between the Initial LW (taken in January; kg) and the final LW in June.

2.2. Statistical analysis

McGregor and Butler (2008c) developed a general linear model with normal errors to determine the relationship between the logarithm of clean cashmere production and any other potential determinant. The form of this model was:

$$\log_{10}(\text{CCMwt}) = \alpha + \beta_1\text{MFD} + \beta_2\text{FDSD} + \beta_3\text{FC} + \beta_4\text{FCSD} + \beta_5\text{SL} + \beta_6\text{CWY} + \beta_7\text{LWC} + \beta_8\text{InitialLW} + \beta_9(\text{FDSD} \times \text{FC}) \quad (1)$$

where the parameters α, β_1, β_2, β_3, β_4, β_5, β_6 and β_7 differed between farms, the parameters β_8 and β_9 were the same for all farms, and α, β_3, and β_4 also differed for 2-year-old goats on farm 7. According to McGregor and Butler (2008c), this model accounted for 67.6% of the variation of $\log_{10}$(CCMwt). Least squares models that, included α differing with farm, α, β_3 and β_4 differing with 2-year-old goats on farm 7 and either (i) prescribed subsets of the other 'β'parameters in model (1) but not allowing those parameters to differ with farm, or (ii) prescribed subsets of the 'β' parameters in model (1) but allowing those parameters to differ with farm if they differed with farm in model (1) were fitted and compared using percentage variance accounted for (Payne, 2012). Models in option (i) can be described as having an additive effect of farm, while models in option (ii) can be described as having different responses for each farm. All these models are calculated with the separate terms for 2 year old goats from Farm 7 being *a priori* included in the models because they are considered to be an anomalous group of animals ($n = 25$) (McGregor and Butler,