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Prediction of fleece insulation after shearing and its impact on maintenance energy requirements of Romney sheep

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A R T I C L E I N F O

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A B S T R A C T

Calculation of the maintenance metabolisable energy (ME) requirements should include the additional ME required to counteract heat loss in cold conditions if ambient temperatures occur below the lower critical temperature (LCT) of sheep. This correction requires an estimate of the fleece length of sheep during the year. Equations are presented to estimate the monthly fleece length of Romneys assuming different patterns of seasonality of wool growth, month of shearing and total fleece length. These lengths are discussed in the context of predicted levels of fleece insulation, which in turn influence sheep energy requirements under New Zealand climatic conditions. Predicted fleece insulation varied from 1 to 8 °C m^2 d/MJ in different months. The additional maintenance ME requirements of ewes are predicted for each month following shearing for different months of shearing. An example calculation resulted in an estimated additional 30% of ME being required when the average daily ambient temperature in the month of shearing was 5 °C below the LCT.

1. Introduction

Sykes (1982) stated that sheep fed above maintenance with over 2.5 cm wool cover are unlikely to be adversely affected by low environmental temperatures in New Zealand (NZ). However, Nicol and Brookes (2007) noted that the lower critical temperature (LCT) of sheep rises to 20 °C in the month immediately after shearing and the extra heat needed by a 60 kg ewe at 15 °C is equivalent to a 40% increase in metabolisable energy (ME) requirements for maintenance.

Gregory (1995) reviewed the use of shelter belts in NZ and argued that with wet and windy conditions, all sheep, except those fully fleeced, are probably exposed to temperatures below their LCTs. At shorter coat depths, LCTs are over 17 °C for most wind and rain combinations for sheep at maintenance (SCA, 1990; Gregory, 1995). For most grazed areas in NZ the mean monthly temperature is below 17 °C from April to November (NIWA, 2016; Vogeler et al., 2016) and the mean monthly minimum daily temperature is below 15 °C throughout the year with some locations not reaching 17 °C in any month. On average, one-third of days in NZ are wet (> 1 mm rain) and wind speeds can be high (NIWA, 2016). All these climate factors increase LCT and therefore increase the likelihood that additional dietary energy is needed for sheep to maintain their core body temperature. These effects are likely to be exacerbated in lambs because of their smaller body radius (CSIRO, 2007) but we have focussed on adult Romney sheep which make up the majority of the NZ national flock. Cattle have a much larger body mass with higher internal tissue insulation than sheep, so their LCT is much lower (CSIRO, 2007) than ambient temperatures in NZ, so we have focused on sheep.

If cold ambient temperature occurs below the LCT of sheep, calculation of the ME requirements should include the additional ME required to counteract heat loss in the environmental conditions. Month of shearing is expected to have an effect on this as off shears sheep in winter would be expected to be more affected by cold than off shears sheep in summer. An algorithm to calculate the adjustment in ME for cold, wet or windy conditions is available (CSIRO, 2007). However, this algorithm requires an estimate of the fleece length of sheep during the year, which is not published in equation form for any sheep breeds, including seasonal, long wool NZ breeds such as the Romney, which are the main NZ sheep breed. Furthermore, experimental data on the seasonal growth of fleece is scarce. This paper provides such an equation developed from published observations, which then can be used to estimate the coat depth/fleece length of NZ Romney sheep in each month of the year for different levels of seasonality of wool growth, month of shearing and total annual fleece length. This provides a method of estimating the monthly coat depth value (the parameter F in the CSIRO, 2007 algorithm) for any sheep. An improved algorithm to adjust ME requirements would be useful for any sheep nutrition models or software tools that need to predict sheep ME requirements, such as

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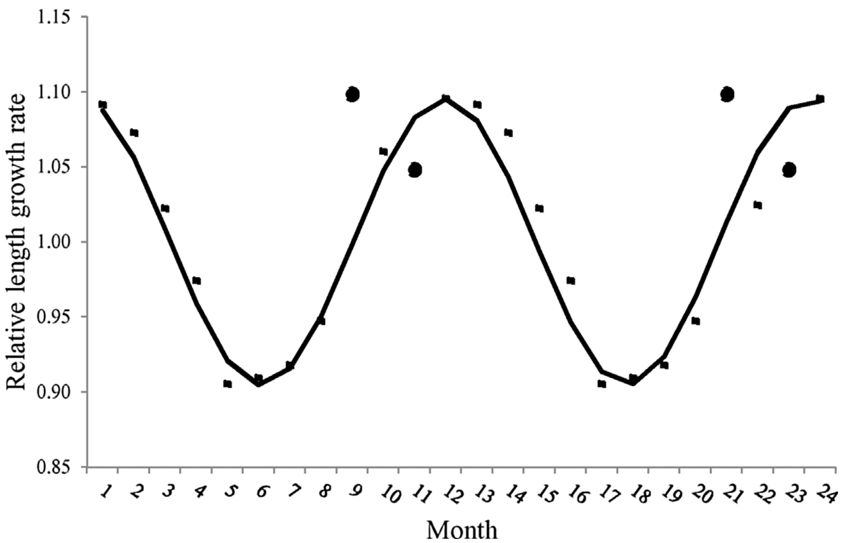

Fig. 1. Romney monthly fibre length growth rate fit to the data of Woods and Orwin (1988). Line is the fitted sinusoidal curve. Month 1/13 = January, Month 12/24 = December (Southern hemisphere). Amplitude is half of the range (maximum minus minimum) of values. The two excluded months from each year are shown as larger dots.

the NZ national inventory for greenhouse gases (Wear, 2013) among others.

2. Materials and methods

2.1. Seasonal fibre growth

Data for the daily fibre length growth rates of Romney sheep in each month (Woods and Orwin, 1988) were converted to the ratio of each month's fleece length growth rate to the yearly average growth rate (Fig. 1). As length growth rate was estimated by Woods and Orwin for every month, unlike seasonal fleece length data from grazing studies in the literature, this allowed monthly, sinusoidal curve parameters to be estimated. The sheep in the Woods and Orwin (1988) study had constant live weights (W) so the amplitude of the estimated sinusoidal curve would be expected to be lower than in grazing sheep, so the amplitude was subsequently adjusted by reference to grazing studies in the literature (see below).

The seasonality of the fleece growth was assumed to follow a sinusoidal curve of the form:

$$y = A*\sin(f.t + \varphi) + d \quad (1)$$

which was fitted to the data (for 2 years) shown in Fig. 1 by least squares (using solver in Excel) to obtain parameter estimates for the amplitude (A), period (f), phase shift (φ) and vertical shift (d) of the relative monthly length growth rate (y) curve. Time (t) was expressed as number of the month in a year, with 1 and 13 being January and 12 and 24 being December. Data for two months of the year with the highest distance from the best fit curve were removed to improve the RMSE ($\sqrt{(\text{observed-predicted})^2/n}$) of the revised equation.

To convert Eq. (1) to a general equation to predict the monthly length growth expected from any assumed yearly fleece length, the vertical shift parameter was multiplied by the ratio of yearly fleece length divided by 12 (i.e. average monthly length): mean annual value, to calculate a revised vertical shift parameter. The revised amplitude parameter was obtained by multiplying the revised vertical shift parameter by the seasonal amplitude expressed as a percentage (or proportion) of the original vertical shift value.

The ratio of fibre length growth between summer and winter (December and June in the Southern Hemisphere, respectively) was 1.19 (i.e. 9.5% amplitude) in the study of Woods and Orwin (1988). Other NZ studies have reported greater summer to winter wool length ratios of around 1.4 (e.g. Montgomery and Hawker, 1987; Hawker, 1985; Hawker and Littlejohn, 1989; Hawker and Thompson, 1987; Sumner and Bigham, 1993) when sheep have been in more typical commercial grazing conditions with fluctuating nutrition and live weights. Therefore the amplitude parameter used to calculate coat length in each month was assumed to be 19% (double that found by Woods and Orwin) to better match the ratios observed from the Hawker et al. studies, using the general equation.

2.2. Shearing month

The effect of shearing month was calculated by assuming that coat depth off shears (Dabiri, 1994; Dabiri et al., 1994, 1995, 2010) was 5 mm (cover combs) or 3 mm (standard combs) at the beginning of the month of shearing. The use of a cover comb, which leaves a greater depth of residual wool after shearing than the standard comb, increases the insulation value of the remaining fleece (Holmes et al., 1992).

Coat length at the beginning of each of the 11 months following shearing was calculated by adding the monthly length growth rate from the predictive sinusoidal equation for each preceding month to the length at the beginning of the preceding month:

$$\text{Length at beginning of month}_{x} = \text{Length at beginning of month}_{x-1} + \text{predicted growth rate in month}_{x-1} \quad (2)$$

The total coat length, when the length grown in the 12th month following shearing was added to the coat length predicted at the beginning of the 11th month post shearing, was set equal to the assumed yearly fleece length. This assumed length was based on an average length of 150 mm of midside wool samples reported by Hight et al. (1976). A survey of staple length in non-second shear, crossbred sale lots from the north island (NZWTA, 2016) however found the average staple length was only 84 mm, so half the Hight et al. (1976) length (i.e. 75 mm) was also used in the modelling.

2.3. Fleece insulation

The effects of month of shearing, assumed yearly fleece length and seasonality of wool growth (i.e. amplitude) were studied by calculating results for fleece length at the beginning of each month using different assumed values in the predictive equation. The impact of coat depth of the animal on their external insulation against heat loss is predicted by CSIRO (2007) as follows:

$$I_e\ (^{\circ}\mathrm{C\,m^2\,d/MJ}) = [r/(r + F)][1/(0.481 + 0.326\ V^{0.5})] + r \ln[(r + F)/r]\ (z\text{-}0.017\ V^{0.5}) \quad (3)$$

Where