Small Ruminant Research 145 (2016) 28–32

Contents lists available at ScienceDirect

Small Ruminant Research

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

Short communication

Allometric relationships determined for skin area and fleece production of Angora goats

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ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form 1 June 2016
Accepted 15 October 2016
Available online 18 October 2016

Keywords:
Scaling
Growth
Fibre quality
Wool
Mohair
Leather

ABSTRACT

This study aimed to determine the relationships between skin surface area, animal size and mohair physical properties using estimates of skin area determined on animals prior to slaughter and to compare these with skin weight and skin area determined after slaughter. Angora kids born in late winter were shorn at 18 weeks of age. Prior to slaughter at 20 weeks of age, 15 kids of each sex were identified to cover the entire range of live weights. Body girth, body length circumference and body condition score were determined. Following slaughter, skins were weighed and skin area determined. Clean fleece weight and mean fibre diameter (MFD) were determined. Parsimonious general linear models were developed to determine the relationships between measured skin area, estimated skin area, live weight and skin weight, clean fleece weight and MFD both with and without $\log_{10}$ transformation. Live weights ranged from 8.3 to 23.1 kg, skin weight from 796 to 2262 g and measured skin area 0.23 to 0.59 m^2. The weight of the skin represented 9.6% of the average live weight of the goats. Predicting measured skin area using body dimensional measurements accounted for 83.7% of the variance in measured skin area. Measured skin area was a constant 0.057 m^2 greater than the estimated skin area. It was more accurate to use live weight to estimate measured skin area as the regression between estimated skin area and live weight accounted for 93.7% of the variance. Measured skin area and clean fleece weight were proportional to live weight $^{0.67}$, which is the general allometric relationship expected between the surface area of a shape and its volume. Both clean fleece weight and MFD were proportional to measured skin area but were better predicted by live weight. Predicting skin surface area using live weight $^{0.67}$ was more reliable than using body dimensional measurements.

1. Introduction

It has been demonstrated that both mohair clean fleece weight and fibre diameter are allometric, in other words they increase proportionally as Angora goats increase in weight (McGregor et al., 2012, 2013). The most likely mechanism for these allometric relationships are that skin follicle density changes proportionally with changes in skin surface area. Studies of Angora goats have shown that primary follicles are initiated from 65 days post conception (PC) until 110 days PC (Margolena, 1974; Wentzel and Vosloo, 1974, 1975). Secondary follicles, the major mohair producing follicles, increase rapidly in number from 90 to 120 days PC and again from 14 days *post partum,* until 4 months *post partum,* when the mature population of mohair follicles is complete. Kids grow rapidly from birth and the increase in size and skin surface area of kids results in a decline in skin follicle density from about 3 months of age as the rate of secondary follicle initiation declines (Wentzel and Vosloo, 1975).

It is necessary to understand the drivers of skin surface area to fully understand the net effect of the increase in animal size upon mohair growth and fibre diameter. With Angora goats and fleece bearing sheep, most of the fibre is produced on the main body of the animal including the upper legs, belly and neck, and almost no mohair or wool is harvested from the head and lower legs. Thus estimates of the area of the skin producing fibre have used body dimensional measurements assuming it is a cylinder (Burns, 1954; Couchman and McGregor, 1983) or taken the general mathematical relationship between the surface and the volume of a geometrical object and its volume e.g. Newton Turner and Young (1969). Measuring body dimensions is a slow and awkward process which may involve unnecessary animal handling and risk of injury to both people and animals. No reports have been located to verify the assumption that body dimensional measurements are a valid method of determining the fleece producing area of Angora goats. Modern body scanning technology may be superior for

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http://dx.doi.org/10.1016/j.smallrumres.2016.10.018
0921-4488/

estimating the surface area of Angora goat skin compared with the use of body dimensional measurements but scanning technology still requires calibration of scans of live goats against direct skin area measurements.

It is well established that animal organs are allometric, i.e. they increase in proportion to changes in size or weight of an animal (Schmidt-Nielsen, 1984) and this is true for Angora goats (McGregor, 1992). It should therefore be relatively simple to relate estimates of skin surface area based on dimensional measurements of goats with other properties such as live weight and skin measurements. It is fortunate that during slaughter of goats in modern abattoirs that the skin is removed in one piece excluding the skin of the head and lower legs. However, recent studies of goat leather and skin production do not report the relationship between skin area and size (live weight) of the goats (e.g. Salehi et al., 2014). Therefore, the aim of this study was to estimate the area of skin of Angora goats based on direct measurements of animals prior to slaughter and compare these with direct measurements of the skin removed at slaughter and with fleece production.

2. Materials and methods

2.1. Animals and measurements

A herd of 200 Angora does (2–6 years of age) were grazed on annual temperate pastures at Werribee (37°54′S., 144°41′E., elevation 46 m), Victoria. They were mated from February and kidded in late July to early August. Kids were dosed with an effective anti-helmintic at 10 weeks of age and vaccinated at 4 and 8 weeks of age. Near 18 weeks of age the kids were shorn. Prior to slaughter at 20 weeks of age, 15 kids of each sex were identified to cover the entire range of live weights. At 20 weeks of age and 2 weeks following shearing, the kids were weighed to the nearest 0.1 kg and various body dimensions measured. Body measurements were three body girth measurements (heart girth, mid-side, hind-quarters in front of the rear legs) and body length circumference (anterior-posterior, around the neck to around the britch; Burns, 1954; Couchman and McGregor, 1983), to the nearest cm using a steel tape measure. Body condition score was determined by palpating the spinous processes of the lumbar vertebrae and assigning a score as follows: 1 (very lean, sharp prominent backbone and spinal processes, little flesh coverage); 2 (lean); 3 (medium, slight rounding of flesh over spine); 4 (fat); 5 (very fat, cannot detect any backbone or spinal processes) with two intermediate scores assigned between each of these main categories i.e. 2.3, 2.7, 3.0, 3.3 (McGregor, 1992, 2011).

Kids were transported to a commercial abattoir 90 km from the Institute five hours prior to slaughter. Skins were collected at slaughter after removal with a hide puller, stored in plastic bags overnight at 4 °C to allow natural relaxation. Within 48 h of slaughter, and after the removal of any other tissue residue such as fatty matter, the skins were weighed to the nearest g. Skin area was determined by carefully flattening out the relaxed wet skin onto a large sheet of strong wrapping paper, ensuring that the skin was smooth not wrinkled and not stretched. Angora goats have few natural wrinkles unlike many types of Merino sheep. The outline of the skin was then marked onto the paper. The paper was oven dried at 30 °C, reconditioned at 20 °C and 65% RH, the outline was carefully cut and the cut out area of paper was weighed (W) to the nearest 0.1 g. The area density of the paper (D, g/m^2) was determined and used to determine the area of the skin (A, m^2) as follows: A = W/D.

At shearing the greasy fleeces were measured to the nearest g and mid-side fleece samples were taken and stored in labeled sealed plastic bags. These samples were tested for clean washing yield (IWTO, 2005a) and mean fibre diameter (MFD, μm; IWTO, 2005b). Clean fleece weight was determined as: greasy fleece weight × clean washing yield.

Table 1
Mean, standard deviation and range in live weight at slaughter, body, skin and mohair fleece measurements of Angora kids slaughtered at 20 weeks of age (n = 30). Note that the mohair fleece was shorn 14 days prior to slaughter.

Attribute	Mean	SD	Minimum	Maximum
Live weight (kg)	14.6	3.81	8.3	23.1
Body condition score	2.5	0.7	1.3	3.3
Average girth (cm)	60.8	5.25	53	72
Body circumference anterior-posterior (cm)	110.9	12.87	80	135
Skin weight (g)	1403	324	796	2262
Skin area measured (m^2)	0.411	0.0837	0.234	0.587
Estimated skin area (m^2)	0.340	0.0663	0.212	0.477
Greasy fleece weight (kg)	0.460	0.107	0.235	0.697
Clean fleece weight (kg)	0.424	0.101	0.213	0.635
Mean fibre diameter (μm)	22.8	2.01	18.8	26.5

2.2. Statistical methods

The body measurements were used to estimate the skin area (m^2) as follows: average girth × (circumference/2)/10000. Mean, range and variance (s.d.) were determined for all measurements. The units for analysis were the individual animal measurements. Parsimonious general linear models with normal errors were developed in a forward stepwise manner using GenStat 15.2 for Windows (Payne, 2013) to determine the relationships between measured skin area, estimated skin area, live weight and skin weight, clean fleece weight and MFD both with and without $\log_{10}$ transformation. Multiple regression models were developed so that the additional significance of any attribute was tested. The best model was developed with terms being added or rejected on the basis of F-tests (P < 0.05). Sex of kid, birth parity, body condition score and the square of any significant term were also tested for significance, but none of these terms were significant (P > 0.1). One skin was broken into pieces and the data have been omitted. Three outliers in measured skin area were identified with residuals greater than + or − 2.5 and these were removed. This procedure was to ensure that outliers did not bias the predictions, which could be affected by both damage to hides caused during hide removal, such as stretching, undetected holes or removal of skin.

Regression constants (±s.e.), precision as represented by residual standard deviation (RSD), correlation coefficient (r) and accuracy as represented by variance accounted for by a model (determined as 100 × r^2) are provided. Predicted responses to significant terms are provided in graphs which also show the raw data (GenStat 15.2; Payne, 2013).

3. Results

The mean, SD and range in animal, skin and fleece measurements are summarised in Table 1. Live weights ranged from 8.3 to 23.1 kg, skin weight from 796 to 2262 g and measured skin area 0.23 to 0.59 m^2. For these Angora goats, the weight of the skin represented 9.6% of the average live weight of the goats (1.40 kg/14.6 kg, Table 1). Body condition scores ranged from 1.3 to 3.3, and as expected were highly correlated with live weight (r = 0.81), increasing by 1.0 score for every 6.5 kg increase in live weight. Clean fleece weight ranged from 0.213 to 0.635 kg and MFD ranged from 18.8 to 26.5 μm.

3.1. Measured skin area, skin weight and live weight

Measured skin area increased at the rate of 0.018 m^2/kg increase in live weight and this regression accounted for 89.6% of the