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Evaluation of mathematical models to describe testicular growth in Blackbelly ram lambs

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Abstract

The primary objective was to compare various mathematical models to describe scrotal circumference (SC) and paired testis volume development in Blackbelly ram lambs. The study was conducted in the state of Querétaro, México (20° 43' N, 100° 15' W). Spring-born Blackbelly ram lambs (n = 41) were housed outdoors and fed alfalfa hay and concentrate. Body weight, SC, and testis length, diameter, and volume were recorded every 2 wk from 24 to 172 d of age (June 18 to November 3). The following mathematical functions were used to model SC-age and testis volume-age relationship: Von Bertalanffy, Brody, Gompertz, Logistic, and Richards. The suitability of the models was evaluated based on parameter values and standard errors, residual mean square, the coefficient of determination (R^2), and the average prediction error (APE). All models, except for Brody's, had good fit to SC ($R^2 > 0.98$) and testis volume ($R^2 > 0.95$), and produced similar growth curves in the range of ages studied. The logistic model predicted SC at maturity quite well, 33.6 ± 0.6 cm as compared with 33.9 ± 0.5 cm observed in adult animals; all models had APE's smaller than ±7% between 56 and 168 d of age. The Bertalanffy model predicted testis volume at maturity quite well, 513 ± 22 cm^3 as compared with 488 ± 20 cm^3 calculated for adult animals. The logistic model had a good fit to testis volume during the period of study, but underestimated the volume at maturity by 28%. All models, except for Brody's, had APE's smaller than ±14% between 98 and 168 d of age. The logistic and Bertalanffy models predicted the inflection point for SC at 83 and 59 d of age, and testis volume at 116 and 109 d of age, respectively. In conclusion, all models, except for Brody's, had good fit to actual SC and testis volume data in the range of age evaluated, whereas the logistic and Bertalanffy's models made the best predictions for adult SC and testis volume, respectively.

Keywords: Hair sheep; Blackbelly rams; Testis development; Scrotal circumference; Male sexual function

1. Introduction

Testis size is indicative of reproductive capacity and fertility in the ram, as the amount of testicular mass is highly correlated with the sperm production capacity and extragonadal sperm reserves [1]. Furthermore, the rate of testis development in the ram lamb may be indicative of their sexual performance, and has been associated with several reproductive characteristics of female siblings and future daughters of the ram, such as age at puberty, fertility, prolificacy, and duration of the breeding season [2–4]. Testicular weight cannot be measured in the living animal, but has been estimated

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in several ways, such as scrotal circumference (SC), testis diameter, length, and volume; of those measurements, SC is the simplest and most accurate method to estimate the amount of testis mass [5,6] and the degree of testis development [7] in the living animal, and it is also highly repeatable within and between operators [6]. Testis size may be useful as a selection criterion for improving reproductive capacity in both sexes, as heritability for SC has been calculated to be medium to high [4,8]; however, the age at which testis size is measured may influence the estimated heritability [4,8,9] and correlated responses that can be expected in female reproductive traits [4].

Most of our current knowledge on testis development in sheep comes from studies on wool breeds, with little information on hair sheep. As testis traits may greatly differ among breeds, it is important to study testis development in various hair breeds, as this would facilitate better use and selection of the young sires from those breeds. In ram lambs differing in body weight (within and between breeds), patterns of testicular growth over time might be more useful to predict the testis size in the adult animal than a single measurement taken at a specific age [10]. Therefore, the objectives of this study were to describe the development of several testicular traits, and compare various mathematical models to describe the development of SC and paired testis volume in Blackbelly ram lambs.

2. Materials and methods

2.1. Animals and testis measurements

All experimental procedures were performed in accordance with the "International Guiding Principles for Biomedical Research Involving Animals" (available at: http://www.cioms.ch/1985_texts_of_guidelines.htm). The study was conducted in the state of Querétaro, México (20° 43' N, 100° 15' W). Forty-one Blackbelly ram lambs were used, which were born between April 17 and May 25 (n = 37) or between March 14 and March 20 of the same year (n = 4). We decided to include this smaller group, as the four lambs were contemporaries of the others; furthermore, the distribution of their observations were within the range of ± 3 SD from the overall mean; therefore, they were not considered as outliers. Ram lambs were always housed in outdoor pens. Before weaning, lambs were creep fed with a diet containing 14% crude protein (78% sorghum, 20% canola meal, and 2% minerals). After weaning (75 d of age as an average) lambs were offered alfalfa hay and a concentrate as described above. Water was consistently available *ad libitum*.

Scrotal circumference was measured as indicated by the Society for Theriogenology [11]. Using the same procedure as for SC, diameter from each testis was measured with calipers at the widest area of the testis, and then adjusted by substracting the thickness of a fold of scrotal skin measured at the same level. Testis length was measured with calipers, without including the tail of the epididymis. A testis conformation factor was calculated as the ratio between testis length and testis diameter. Paired testicular volume was calculated according to the formula of Lunstra and Cundiff [12]. Body weight (BW) and the various traits for testis size were recorded every 2 wk, between June 18th and November 3rd (age range, 24 to 172 d). A total of 374 records were obtained, and each ram lamb was measured from 5 to 11 times. To evaluate the accuracy of prediction by the models at maturity, BW and testis traits were obtained from nine adult rams from the same flock, averaging 28 ± 8.9 m of age (range 11 to 81 m), and 71 ± 3.3 kg BW (range 62 to 90 kg).

2.2. Statistical analysis

The following mathematical functions were used to model SC-age and paired testis volume-age relationship:

Von Bertalanffy: $y = A\,(1-be^{-kt})^3$
Brody: $y = A\,(1-be^{-kt})$
Gompertz: $y = A\,\exp\,(-be^{-kt})$
Logistic: $y = A/(1+be^{-kt})$
Richards: $y = A\,(1+be^{-kt})^m$

where y is the testis size (SC or volume) at t days of age; A is the estimated testis size at maturity; b indicates the proportion of the asymptotic mature testis size to be obtained after birth, established by the initial value of SC or volume and t; k is a maturing index, establishing the earliness with which SC or testis volume approaches A, the asymptote; and m is the shape parameter, allowing a variable inflection point for the Richards function [13–15]. The inflection point for SC and testis volume (i.e. the point at which the rate of change is maximum, and the growth rate changes from an increasing to a decreasing function) estimated by each model, except for Brody's which has no point of inflection, were calculated according to Brown et al [13]. The NLIN procedure of SAS (SAS Inst. Inc., Cary NC, USA), was used to estimate the parameters for each model, using the Newton iterative method. Several characteristics of the curve fitting process were consid-