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Use of nonlinear models for describing scrotal circumference growth in Guzerat bulls raised under grazing conditions

A.M. Loaiza-Echeverri [a], J.A.G. Bergmann [b], F.L.B. Toral [b], J.P. Osorio [a], A.S. Carmo [a], L.F. Mendonça [a], V.S. Moustacas [a], M. Henry [a,*]

[a] Departamento de Clínica e Cirurgia Veterinárias, Escola de Veterinária, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
[b] Departamento de Zootecnia, Escola de Veterinária, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil

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ABSTRACT

The objective was to use various nonlinear models to describe scrotal circumference (SC) growth in Guzerat bulls on three farms in the state of Minas Gerais, Brazil. The nonlinear models were: Brody, Logistic, Gompertz, Richards, Von Bertalanffy, and Tanaka, where parameter A is the estimated testis size at maturity, B is the integration constant, k is a maturating index and, for the Richards and Tanaka models, m determines the inflection point. In Tanaka, A is an indefinite size of the testis, and B and k adjust the shape and inclination of the curve. A total of 7410 SC records were obtained every 3 months from 1034 bulls with ages varying between 2 and 69 months (<240 days of age = 159; 241–365 days = 451; 366–550 days = 1443; 551–730 days = 1705; and >731 days = 3652 SC measurements). Goodness of fit was evaluated by coefficients of determination (R^2), error sum of squares, average prediction error (APE), and mean absolute deviation. The Richards model did not reach the convergence criterion. The R^2 were similar for all models (0.68–0.69). The error sum of squares was lowest for the Tanaka model. All models fit the SC data poorly in the early and late periods. Logistic was the model which best estimated SC in the early phase (based on APE and mean absolute deviation). The Tanaka and Logistic models had the lowest APE between 300 and 1600 days of age. The Logistic model was chosen for analysis of the environmental influence on parameters A and k. Based on absolute growth rate, SC increased from 0.019 cm/d, peaking at 0.025 cm/d between 318 and 435 days of age. Farm, year, and season of birth significantly affected size of adult SC and SC growth rate. An increase in SC adult size (parameter A) was accompanied by decreased SC growth rate (parameter k). In conclusion, SC growth in Guzerat bulls was characterized by an accelerated growth phase, followed by decreased growth; this was best represented by the Logistic model. The inflection point occurred at approximately 376 days of age (mean SC of 17.9 cm). We inferred that early selection of testicular size might result in smaller testes at maturity.

1. Introduction

Scrotal circumference (SC) is frequently used in breeding programs, because of its easy measurement, high repeatability, and moderate to high heritability [1–4]. In addition, SC is favorably associated with physical semen characteristics, age at puberty, sexual precocity, and weight gain [5–8]. Furthermore, based on the genetic correlation between SC and reproductive characteristics in females, e.g., age at puberty, days to calving, and age at first calving, selection for SC had a positive influence on female reproductive performance [8–11].

Zebu cattle are older at puberty and have delayed first calving (30–46 months) [12,13]; these are attributed to genetic and environmental factors [14]. Bulls selected on

* Corresponding author. Tel.: +55 31 3409 2239; fax: +55 31 3409 2249.
E-mail address: henrym@ufmg.br (M. Henry).

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the basis of larger SC and early puberty usually produce daughters reaching puberty at significantly earlier ages and greater percentages of heifers cycling early in the breeding season, even when used in crossbreeding [8,10]. This is very important for cattle breeding in tropical countries, where delayed puberty and poor reproductive efficiency are major constraints limiting the cattle industry [15].

The SC at puberty is relatively constant among breeds and across bulls varying widely in age and weight at puberty; therefore, SC might be more useful than other characteristics for predicting age at puberty [1,16,17]. Scrotal circumference is more easily obtained than sperm production or behavioral measurements and should be useful in the selection of beef bulls for early sexual maturity [1].

Selection of bulls at the earliest possible age will not only improve reproduction, but also provide economic advantages by decreasing feeding and management costs and improve economic returns to producers [18]. However, Lunstra et al. [1] reported that male offspring of diverse heat-adapted sire breeds had lower postweaning testicular growth rates and were slower to reach puberty than offspring of European sire breeds. Therefore, there is a need for characterization of reproductive traits in bulls representing diverse beef breeds.

Furthermore, nutrition, breed, and environmental factors influence reproductive development and testicular size [19,20]. Therefore, to achieve higher accuracy in assessing the reproductive capacity of bulls based on testicular measurements, comparisons should be made within the same age group, breed, bull stud, and year-season [21].

One way to describe testicular growth is using nonlinear regression models. The advantage of nonlinear models is that they can accommodate a large number of measurements in some parameters and, thus, permit appropriate biological interpretation. The benefit of these models in animal breeding is using these parameters to identify animals more suited for specific purposes [22]. Furthermore, a growth trait can be improved by using growth curves and their properties. In that regard, Kratochvílová, et al. [23] identified early and late maturing heifers during early phases of growth (6–9 months) using growth curve parameters of nonlinear models.

Given the growing interest in Zebu cattle because of their better adaptation than *Bos taurus* breeds to tropical conditions, and the need for producers to emphasize growth rate and early pubertal development in genetic improvement programs [17], the objective of this study was to evaluate six nonlinear models to describe SC development in Guzerat bulls and to evaluate environmental effects on growth curve parameters.

2. Materials and methods

2.1. Bulls and scrotal circumference measurement

All procedures were approved by the ethics committee of Universidade Federal de Minas Gerais. This study was conducted on three farms located in Brasilândia de Minas (17°00′36″ South and 46°00′32″ West), Carlos Chagas (17°41′30″ South and 40°45′15″ West), and Unaí (16°21′43″ South and 46°54′09″ West), in the state of Minas Gerais, Brazil. The climate classification in this regions is Aw (tropical rainy climate, Köppen classification), with average temperature of 18° in the coldest month. The dry season coincides with fall and winter, principally, and these seasons go from April to September. Spring and summer go from October to March. November, December, January, and February had the most rainfall, approximately 60% of the annual total [24].

During the nursing period and after weaning (approximately 7 months old), all Guzerat males were raised under grazing conditions on palisade grass (*Brachiaria brizantha* Stapf) and bluestem (*Andropogon gayanus* Kunth) in the savannah region, with water and mineral salt available *ad libitum*. During the dry season, the cattle were supplemented with salt-type protein or roughage.

Scrotal circumference was measured in the region of the greatest diameter of the testes and included both testes positioned symmetrically side by side, leaving the skin of the scrotum distended. Measurements were performed every 3 months, most of them beginning at approximately 240 days of age (SC measurements: <240 days = 159; 241–365 days = 451; 366–550 days = 1443; 551–730 days = 1705; and >731 days = 3652), and continuing throughout the period the bull remained on the farm.

Before analysis, the initial database was edited to enable the environmental factor study on the three farms. Therefore, a final database of 7410 SC measurements of 1034 males, born between 2001 and 2007, aged between 2 and 69 months, with SC from 11 to 44 cm were used in the two stages of this work.

2.2. Statistical analyses

2.2.1. Nonlinear models

Estimates of SC growth curves were obtained based on all SC-age data, using five nonlinear asymptotic models and one nonlinear indeterminate model (Table 1). The asymptotic models describe a growth that never exceeds a horizontal asymptote to infinity (SC (t) = ∞ SC), whereas the Tanaka model allows indeterminate growth without an asymptote [25].

In the nonlinear models used to model SC–age relationship, SC_t is the scrotal circumference (SC) to t days of age, A is the estimated SC at maturity, B indicates the proportion of the asymptotic mature testis size to be obtained after birth (established by the initial value of SC

Table 1
Nonlinear models evaluated in this study to describe scrotal circumference (SC) growth in Guzerat bulls.

Model	Equation
Brody	$SC_t = A\,[1 - B \exp(-kt)]$
Logistic	$SC_t = A/[1 + B \exp(-kt)]$
Gompertz	$SC_t = A \exp[-B \exp(-kt)]$
Richards	$SC_t = A\,[1 + B \exp(-kt)^m]$
Von Bertalanffy	$SC_t = A\,[1 - B \exp(-kt)]^3$
Tanaka	$SC_t = (1/\sqrt{B})\ln\lvert 2B(t-m) + 2\sqrt{B2(t-m)2 + AB}\rvert + k$

Abbreviations: A, scrotal circumference at maturity; B, proportion of the asymptotic mature testis size to be obtained after birth; exp, exponent; k, maturing index; m, inflection point; SC_t, scrotal circumference to t days of age.