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Original

Growth and reproductive performance in females of Romosinuano cattle

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ABSTRACT

Objective. To characterize growth curves and reproductive performance of Romosinuano cows in Mexico. **Materials and methods.** Weight and age records (928) of females (117) for growth traits and calving records (459) of cows (113) for reproductive traits were analyzed. Four non-linear mixed models were adjusted to describe the growth curves. Indicators of age at 50% of maturity (A50M), and percentage of maturity at 18 months of age (PM18) were estimated. The reproductive performance was evaluated through the age at first calving (AFC), the calving interval (CI), and calving rate (CR). **Results.** The Brody model showed the best adjustment to the growth curve. The *A* parameter, which estimates maturity weight, fluctuated within 430.2 and 466.2 kg; the *b* parameter within 0.94 and 5.45; and the *k* parameter within 0.001 and 0.002; depending on the used model. The A50M varied from 20 to 21 months, and the PM18 from 44.5 to 45.5%. The means for AFC, CI, and CR at 550 d were 1059±282 d, 553±68 d, and 74±19%; those indicators improved ($p<0.05$) when cows have a higher percentage of their maturity weight, depending on calving season. **Conclusions.** The estimates of maturity weight indicate that Romosinuano cattle could be considered as a breed of small or medium size, with an acceptable reproductive ability. The females with small estimated maturity size aged at first calving earlier than cows with high weights.

Keywords: Age at first calving; calving interval; genetic resources; growth models; liveweight (*Source: CAB*).

RESUMEN

Objetivo. Caracterizar las curvas de crecimiento y el comportamiento reproductivo de vacas Romosinuano en México. **Materiales y métodos.** Se analizaron 928 registros de peso y edad de 127 hembras para características de crecimiento, y 459 registros de partos de 113 vacas para características reproductivas. Se ajustaron cuatro modelos no lineales mixtos para describir la curva de crecimiento, y se estimaron los indicadores de edad al 50% de madurez (E50M) y porcentaje de

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madurez a los 18 meses de edad (PM18). Para evaluar el comportamiento reproductivo se estimó la edad al primer parto (EPP), intervalo entre partos (IEP), y tasa de pariciones (TP). **Resultados.** El modelo de Brody fue el que mejor ajustó la curva de crecimiento. El parámetro *A,* que estima el peso maduro, osciló entre 430.2 y 466.2 kg; el *b* entre 0.94 y 5.45; y el *k* entre 0.001 y 0.002; dependiendo del modelo utilizado. La E50M varió entre 20 y 21 meses, y el PM18 entre 44.5 y 45.5%. Las medias de EPP, IEP, y TP a los 550 d fueron 1059±282 d, 553±68 d, y 74±19%, y mejorando ($p<0.05$) cuando las hembras presentan mayor porcentaje de su peso maduro, dependiendo de la época de parto. **Conclusiones.** El peso maduro estimado indica que el ganado Romosinuano puede considerarse como una raza de tamaño pequeño o mediano, con aceptable aptitud reproductiva. Las hembras con menor tamaño maduro estimado presentaron edades al primer parto más temprano que vacas más pesadas.

Palabras clave: Edad al primer parto; intervalo entre partos; modelos de crecimiento; peso vivo; recursos genéticos (*Fuente: CAB*).

INTRODUCTION

Cattle production systems in warm tropical regions have a low technical level of management and are traditional systems based on low-quality grasslands, little use of technology, and limited animal genetic resources adapted to tropical conditions (1). Bovine production in tropical areas is affected by several factors, of which the most important one is animal growth (2). Creole cattle have been developing from isolation and adaptation since the first bovines were brought to the American continent, originating from different breeds developed in America's harsh environment (3). Romosinuano cattle are creole animals adapted to adverse tropical conditions, which suggests that their growth and reproductive performance are acceptable under such conditions.

Assessing animal growth is an important practice for evaluating profitability and efficiency in meat production. Body growth has been represented by nonlinear models that describe growth over time, based on a reduced number of parameters (4). On the other hand, a factor restricting the productivity of tropical livestock is low reproductive efficiency. Ossa et al. (5) mention that an outstanding characteristic of Romosinuano cattle is their adaptation to tropical conditions, which is reflected in excellent fertility rates.

In the last two decades, Mexican farmers have established herds of Romosinuano cattle (3), whose population has been increasing (6), facilitating the productive and reproductive evaluation of this genetic resource. The objective of this study was to characterize the growth and reproductive performance of Romosinuano females in Mexico.

MATERIALS AND METHODS

Data origin. The data were obtained from the Asociación Mexicana de Criadores de Ganado Romosinuano y Lechero Tropical, particularly from a production unit placed in the municipality of Tihuatlán, Veracruz. The ranch is located in a tropical area of Mexico (northeastern part of the country), where the animals were fed on pasture, mainly *Brachiaria brizantha* and *Cynodon plectostachyus*. The site has a warm sub-humid climate with summer rains, an annual average temperature between 24 and 26°C, and a precipitation range of 1100 to 1300 mm (7).

The growth curves of Romosinuano females were estimated using information of 127 animals born between 2001 and 2018, considering a total of 928 records of live weight and age. Live weight and age records were obtained throughout the life of the animals: at the time of calf birth and weaning (approximately eight months of age) (8) and during palpations to verify gestation after breeding and before birth. The females had an average of 7.3 records per animal, with a minimum of three records.

Information for the reproductive analyses was obtained from 113 cows with calving records between 2004 and 2019, considering 459 records. The reproductive variables considered were age at first calving (AFC), calving interval (CI), and calving rate (CR), and in the final analyses, only animal records within ± 3σ of the mean were considered. For the analysis of the AFC, records of 113 cows were used, grouped into 31 contemporary groups (year-season calving). Two calving seasons were defined, namely rainy (June to November) and dry (December to May). For CI and CR analyses, 346 calving records from 81 cows were used, grouped into 28 contemporary groups (year-season calving), with an average of 4.3 calvings per cow. Numbers of records to calculate calving intervals were 74 from first to second, 70 from second to third, 53 from third to fourth, 48 from fourth to fifth, and 101 from cows of the fifth calving or more.

Growth analysis. Statistical analyses to fit growth curves were performed using the following mixed nonlinear models:

Brody: $y_{ij}=f(t_{ij};\varphi_i)+\varepsilon_{ij}=A_i(1-be^{-k_it})+\varepsilon_{ij}$
Logistic: $y_{ij}=f(t_{ij};\varphi_i)+\varepsilon_{ij}=A_i/(1+be^{-k_it})+\varepsilon_{ij}$
Von Bertalanffy: $y_{ij}=f(t_{ij};\varphi_i)+\varepsilon_{ij}=A_i(1-be^{-k_it})^3+\varepsilon_{ij}$
Gompertz: $y_{ij}=f(t_{ij};\varphi_i)+\varepsilon_{ij}=A_i(e^{-be^{-k_it}})+\varepsilon_{ij}$

The assumptions in the models were as follows: $\varphi_i=\varphi_p+\eta_i$, $\eta_i\sim N(0,\Omega)$, $\varepsilon_{ij}\sim N(0,\sigma_\varepsilon^2)$ where *y* is the live body weight in kilograms, *t* is the age of the animal in days, *e* is the base of the natural logarithm, *A* is the mature or asymptotic weight in kilograms, *b* is an integration constant, *k* is the animal's maturity rate, φ_p and η_i are the respective fixed and random effect vectors in parameters *A* and *k*, Ω is the matrix of (co) variances of the random effects, ε_{ij} is the residual, and σ_ε^2 is the variance of the residual.

Goodness-of-fit tests were performed to determine which growth model should be used in the calculation of growth indicators, using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the maximum likelihood logarithm (logL), choosing the best model as the one with the lowest AIC and BIC values, and the highest logL value. In the four growth models compared in this study, the parameters related to the asymptotic weight (*A*) and the maturity rate (*k*) were adjusted as random effects, given the consideration of the fixed plus the random parts. The estimates of parameters and (co)variance components were estimated by maximum likelihood, using the nlme procedure (9) in the R software (10). With the estimated parameters of the best model, the growth indicators of age (AIP) and weight (WIP) at the inflection point (except for the Brody model), age at 50% maturity (A50M), and percentage of maturity at 18 months of age (PM18) were calculated (Table 1).

Reproductive analysis. Age at first calving (AFC), calving interval (CI), and calving rate (CR) were evaluated as reproductive traits of the cows. For the AFC analysis, the contemporary group effects (classes formed with the year and season of calving) and the covariate of the estimated weight at calving (generated from the Brody model) were considered. For CI analysis, the effects included in the AFC were also considered, plus calving number as a covariate, and the random effects of sire and cow. For both response variables, the significance of fixed effects considered in the models ($p<0.05$) was evaluated, with the primary purpose of adjusting them for these environmental effects. The models were adjusted by maximum restricted likelihood, using the R lme4 package (11).

A variable with binary distribution was generated to estimate CR, coding as 1 when the female gave birth, given that the cow had been in breeding, and as 0 otherwise, to estimate the probability that a cow calved on a particular day after birth. For the above mentioned, a multiple logistic regression model was used with the following function:

$$E(y)=1/(1+\exp\{\beta_0 - x_1\beta_1 - x_2\beta_2 - x_3\beta_3\})$$

where β_0 is the regression intercept, β_1 is the parameter related to the calving season (rainy and dry), β_2 is the parameter related to the calving number (first, second, third, fourth, and fifth+ calving), and β_3 is the parameter related to the covariate of the day after calving. The parameters were estimated with the maximum likelihood methodology, using the glm2 package (12) of the R software (10).

Table 1. Growth indicators from the nonlinear models evaluated for the growth of cows of the Romosinuano breed.

Model[a]	AIP[b]	WIP[c]	A50M[d]	PM18[e]
Brody	-	-	$\ln(0.5/b)/-k$	$1-be^{-k(547)}$
Logistic	$(\ln b)/k$	$A/2$	$\ln(1/b)/-k$	$1/(1+be^{-k(547)})$
Von Bertalanffy	$(\ln 3b)/k$	$28A/27$	$\ln((\sqrt[3]{0.5}-1)/-b)/-k$	$(1-be^{-k(547)})^3$
Gompertz	$(\ln b)/k$	Ae^{-1}	$\ln(\ln(0.5)/-b)/-k$	$e^{-b(e^{-k(547)})}$

[a]*A* = mature weight of the animal; *b* = constant of integration; *k* = maturity rate of the animal. [b]AIP = age at inflection point. [c]WIP = weight at inflection point. [d]A50M = age at 50% maturity. [e]PM18 = percentage of maturity at 18 months.

To have points of comparison between different times of the year and calving numbers of the cows, and for comparison with similar studies, complementary reproductive indicators were generated, establishing cut-off points set at specific times. Considering that the most extended period of an animal in this herd to reach the first calving was approximately two years and the expression of reproductive indicators used for other studies, the indicators were established (using the probabilities of cows calved at 550 days and the number of days elapsed until 50% of calving occurred in the herd) as follows: calving rate at 550 days (CR550), and days at 50% of calving (D50C).

RESULTS

Growth analysis. Table 2 presents the estimates of the parameters and components of (co) variance for the growth analysis in the four nonlinear mixed models studied. Based on the estimates of the growth parameters and the random (co)variance components, the models were adjusted to predict and describe the weight of the animals over time for each of the models evaluated (Figure 1). In general, the four models appropriately described the growth performance curves over time.

Table 2. Estimated parameters[a] (Param) for the nonlinear models evaluated in Romosinuano cattle.

Param	Brody	Logistic	Gompertz	Von Bertalanffy
A	466.16 ±6.48	430.17 ±5.75	441.46 ±5.73	447.15 ±5.80
b	0.94 ±0.006	5.45 ±0.200	2.14 ±0.420	0.53 ±0.008
K	0.001 ±0.00	0.002 ±0.00	0.001 ±0.00	0.001 ±0.00
σ_A^2	4.81	4.90	4.66	4.62
σ_k^2	0.0002	0.0005	0.0003	0.0003
σ_ε^2	2.92	3.09	2.96	2.92

[a]A = mature weight of the animal (kg); b = constant of integration; k = maturity rate of the animal; σ_A^2 = variance of the asymptotic (mature) weight of the animal; σ_k^2 = variance of the maturity rate of the animal; σ_ε^2 = residual variance.

Table 3 describes the results for goodness-of-fit indicators used in selecting the best model. Based on the values of information criteria of Akaike and Bayesian (lower values indicate better choice) and the maximum likelihood logarithm (higher values indicate better choice), the function that presented the best fit was the Brody model, followed by the Logistic and Gompertz models and, finally, the Von Bertalanffy model.

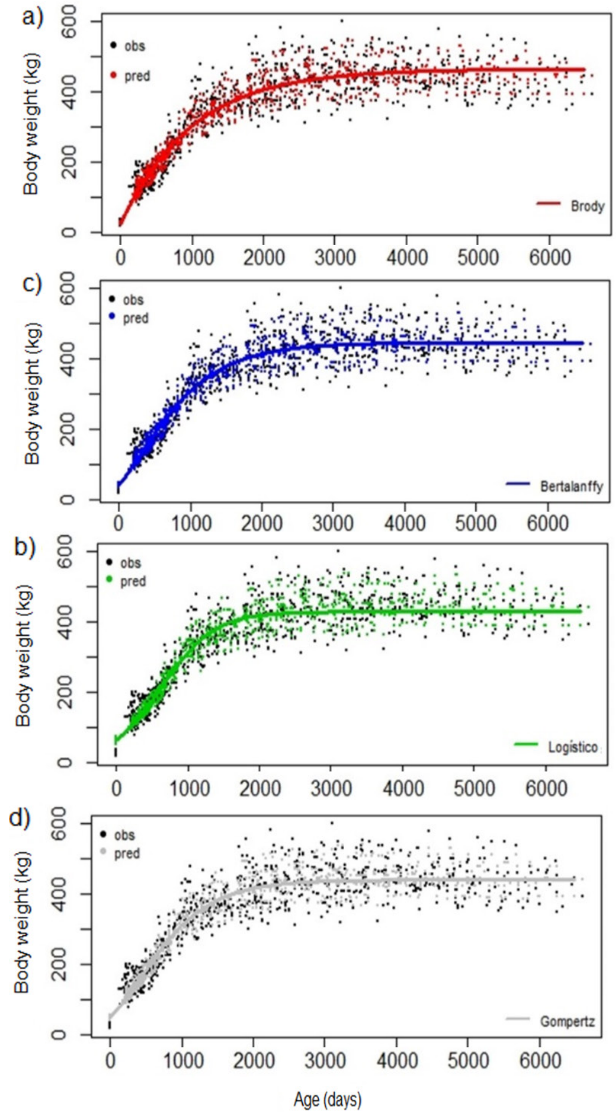

Figure 1. The fit of different nonlinear models for growth curves in Romosinuano cattle (a) Brody, b) Logistic, c) Gompertz, and d) Von Bertalanffy).

Table 3. Fit tests for the selected models of growth curves in Romosinuano females.

Model	AIC[a]	BIC[b]	logL[c]
Brody	9,233.71	9,267.54	-4,609.85
Von Bertalanffy	9,350.88	9,384.71	-4,668.44
Logistic	9,239.51	9,273.34	-4,612.75
Gompertz	9,265.53	9,299.36	-4,625.76

[a]AIC = Akaike Information Criterion. [b]BIC = Bayesian Information Criterion. [c]logL = Maximum Likelihood Logarithm.

The estimated parameters were used to calculate indicators such as AIP and WIP of the function, which were 628 d and 215 kg, 309 d and 132 kg, and 418 d and 162 kg for the Logistic, Von Bertalanffy and Gompertz models, respectively. The estimated A50M and PM18 values for the Romosinuano females were similar in the models studied, with values of 634 d and 45.42%, 628 d and 44.54%, 619 d and 45.54%, and 620 d and 45.31% for the models of Brody, Logistic, Von Bertalanffy, and Gompertz, respectively.

Reproductive analysis. The means of AFC and CI were 1,059 (±282) and 553 (±68) days. As expected, contemporary groups and calving weight of the cow affected both AFC and CI ($p<0.05$). Cows with lower mature weight were earlier (1.8 d/kg) and had earlier AFC. For CI, a higher calving number meant lower values for this variable (-1.23 d for each calving), while a lower estimated calving weight meant a higher CI (-0.10 d/kg).

The parameter estimates for the multiple logistic regression in the calving rate were significant ($p<0.01$), and the values are presented in table 4. The reproductive indicators CR550 and D50C were divided for groups of the rainy and dry seasons and for groups of calving number (table 5). In general, when calving occurred in the rainy season, the females showed a 5.5 to 12.3% higher reproductive performance in the variable CR550, depending on the calving number of the female. The variable D50C was reduced by 34 days for each increase in the female's calving number and by 32 days if the previous calving had occurred in the rainy season.

Table 4. Estimated parameters for multiple logistic regression in the calving rate of Romosinuano females.

Parameter	Estimation	p-value
Intercept	-8.3920 ± 0.038	<0.001
Day	0.0014 ± 0.000	<0.001
Season	0.0498 ± 0.014	<0.001
Calving number	0.4773 ± 0.005	<0.001

Table 5. Calving rate at 550 days (CR550) and number of days at 50% of calvings (D50C) in Romosinuano females.

Calving number	CR550 (%)		D50C (d)	
	Rainy	Dry	Rainy	Dry
1	45.1	33.3	563	597
2	57.0	44.6	531	565
3	68.1	56.5	499	533
4	77.5	67.7	467	501
5+	84.8	77.1	435	469

The mean value of CR at 550 d was 74 ± 19%. The CR was affected ($p<0.05$) by the previous calving season (Figure 2), with higher CR values when the previous calving had occurred in the rainy season. The differences in CR between different calving numbers are shown in Figure 3, with the CR being higher with increasing calving number ($p<0.05$).

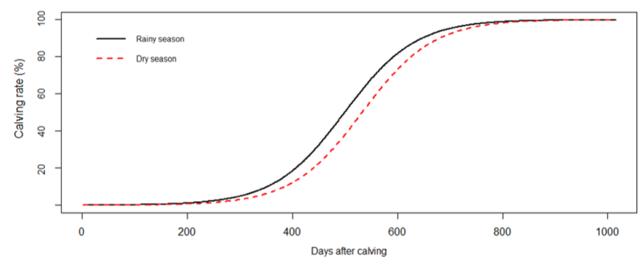

Figure 2. Calving rate of Romosinuano females with calving at a different season.

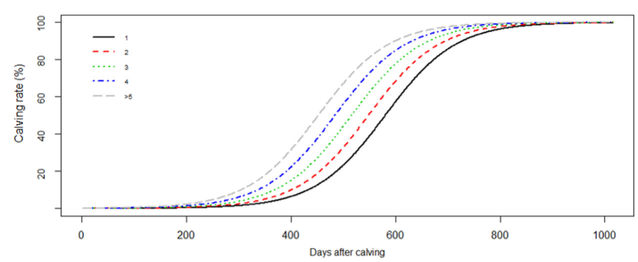

Figure 3. Calving rate in Romosinuano females with a different calving number.

DISCUSSION

Growth curve characterization of Romosinuano females, using nonlinear models, presented a better fit when the random effects of mature weight and maturity rate were included in the model. Other studies related to the fitting of nonlinear models in animal production have also presented better fit when random effects were included in the model, for both growth curve (13) and lactation models (14). This indicates the importance of the animals' individual effect in the expression of their production potential.

Based on the goodness-of-fit test' results, the best model to describe the growth curve in Romosinuano females was the Brody model. In other studies describing cattle growth, the Brody model has also been the most appropriate one to fit their growth pattern (15,16,17). Brody's model is the model most frequently used to characterize the growth of cattle, partly because it allows a biological interpretation of its parameters, facilitating the description of animal growth.

Direct comparison of the values in the growth parameters obtained with the different fitted models is not possible since they measure slightly different aspects. However, parameter *A*, which estimates the mature weight in all models, has a similar biological interpretation. Despite the high variability between the estimates of AIP and WIP in the models fitted, the estimates of mature weight varied only slightly between the models (430 to 466 kg), which indicates some consistency in proximity to the estimated value with the actual value, independent of the model used. The relatively small estimated value of *A* suggests that these are early maturing females. The values estimated in the present study for mature weight were similar to those reported by Ramírez et al. (18) for six groups of crossbred bovine females (including F1 Romosinuano-Zebu) in tropical conditions. Estimated mature weight values are consistent with the description of Romosinuano as a small to medium-size breed. This trait in Criollo and native breeds indicates that they are animals with lower nutritional requirements than breeds of larger sizes, which could also represent advantages in reproductive traits for production systems with food restrictions (19,20). In this study, the components of variance for mature weight ranged from 61.2 to 62.2% of the total variance, being larger for the Brody model. The variance of the maturity rate did not exceed 0.06% of the total variance in all models.

The Brody model, which produced the best fit among the models studied, does not estimate AIP and WIP because it does not have an inflection point. The high variability in estimates of these indicators, depending on the fitted model, shows the need to use the parameters of the model with best-fit. In the three models where the AIP can be calculated, higher ages than the age at conventional weaning of the breed in Mexico (240 d) were obtained (8), unlike those observed in the Tropicarne breed and Zebu cattle (16,21). This leads us to infer that weaning in Romosinuano animals does not significantly stop growth acceleration around this age. The estimated A50M between 20 and 21 months of age and the PM18, about 45%, place this genetic resource late to reach maturity compared to other tropical genetic resources. Domínguez-Viveros et al. (16) estimated A50M and PM18 of Tropicarne cattle in Mexico at approximately 1 year of age and 65%. In general, these relatively low values indicate that cattle in the tropics have low maturity rates.

The estimated mean for AFC in this study (35.3 months) was lower by 3 months than the reported estimates (22,23) for Romosinuano in Colombia and higher by 3 months than that reported for this breed in Mexico (24). However, contrasting with other breeds in Mexico, it was similar to that reported for the Tropicarne breed (25) and 1 to 3 months shorter than those reported by other authors for tropical livestock (26,27). Vera (28) mentions that heifers should keep low live weight gains to reduce the age at first calving. On the other hand, Núñez-Domínguez et al. (25) found that medium-sized cows in the Tropicarne achieved sexual maturity earlier than those of small or large size.

The estimated CI in this study (18.4 months) was between 4 and 5 months higher than those published for Romosinuano cattle from Colombia and Mexico (23,24,29) and that published for other tropical cattle breeds in Mexico (26,30,31). For this variable, it is possible that Romosinuano cows in this study were unable to satisfy their nutritional requirements in the early postpartum period, causing delays in the restart of postpartum ovarian activity, consequently generating increases in CI. For CI and CR, the performance of Romosinuano cows was affected by the calving number of the cow and the calving season. The higher CI values in the first calving of the cows could have occurred because, at these ages, the cows had not reached their maturity in weight (i.e., only 67.3% of the female's mature weight was obtained at first calving). Ossa et al. (22,29) estimated a tendency to decrease CI when the calving number of Romosinuano cows in Colombia increased. Likewise, in Mexico's tropical conditions, Mejía-Baustista et al. (26) reported lower CI values as the number of calving increased in *Bos taurus*, *Bos indicus,* and their crosses.

In conclusion, the fitted mixed nonlinear models allowed us to adequately describe the growth pattern of the Romosinuano females in the tropics, with feeding based on grazing; the Brody model was the most appropriate one of the compared models. In the environmental conditions of the studied production unit, this population of Romosinuano females presented a slow growth rate and can therefore be considered a small or medium mature-size cattle breed. The population breed had an acceptable reproductive efficiency, considering the environmental restrictions and genotypes available in tropical areas. Reproductive activity is better when females have achieved a higher percentage of mature weight at calving and calved down during the rainy season. Romosinuano females with smaller mature size were younger at first calving than heavier cows.

In general, the characterization of the growth pattern and reproductive performance of Romosinuano females under tropical conditions in the herd study gives an idea of the situation that occurs in other similar herds that use this breed in the country. Also, our results are complementary to the estimates made with the Romosinuano breed in other countries. However, a complete collection of productive information on the breed would allow a more accurate and representative characterization of the productive potential of Romosinuano herds in Mexico.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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