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DESCRIPTION AND COMPARISON OF GROWTH PARAMETERS IN CHIANINA AND NELORE CATTLE BREEDS*

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ABSTRACT

Weight data from birth to 18 months of age of Nelore and Chianina, both meat-producing cattle breeds, were analyzed. Data were corrected for significant effects of environment and utilized to estimate genetic parameters through the non-linear von Bertalanffy model. Average values found for growth parameters in Nelore were: mature weight (A), 312.87 kg; integration constant (B), 0.49; maturity rate (k), 0.13; age at inflection point ($T_{(I)}$), 3.29 months; weight at inflection point ($P_{(I)}$), 92.70 kg, and maturity interval (1/k), 8.04 months. For the Chianina animals, the values were 751.38 kg, 0.59, 0.10, 6.64 months, 222.63 kg, and 10.98 months, respectively. Nelore animals exhibited higher maturity rate, smaller maturity intervals, reaching mature weights younger than Chianina animals, although lighter than these at maturity. Heritability estimates presented low values, mainly for mature weight (0.093 and 0.212), age at inflection point (0.062 and 0.202), weight at inflection point (0.093 and 0.212) and maturity interval (0.057 and 0.309) (for Nelore and Chianina, respectively). The parameters mature weight and weight at inflection point presented positive genetic correlations with weights at different ages and with similar trends, increasing as age increased, in both breeds. Considering the development period analyzed, from birth to 18 months of age, the parameter maturity rate and the weights at different ages showed genetic correlations which increased until the weight at 150 and 205 days in Nelore and Chianina, respectively, and decreased from these ages on, and the genetic correlations among the parameter maturity interval and the weights at different ages were negative. They decreased until the weights at 150 and 205 days, respectively, in Nelore and Chianina, and increased from these ages on.

INTRODUCTION

Rapid growth until slaughter weight is an important goal for increased meat production. Curves that relate weight or size with age have been used to describe growth. Growth parameters such as mature weight and general maturity rate, estimated from weights taken periodically during the life of the animal, can be used to evaluate development of animals (Brody, 1945).

Growth equations are important in estimating parameters that are biologically uninterpretable, such as age at point of inflection of the growth curve, mature weight and maturity rate (Richards, 1959). These estimates should be used under the hypothesis that they simulate the true biological model (Brown *et al.*, 1972).

The growth functions of Richards, Logística, von Bertalanffy, Gompertz and Brody have been used to describe the Nelore growth (Duarte, 1975). Results suggested the function of von Bertalanffy was the most reasonable in describing the rapid growth and regular development of Nelore cattle. These growth functions have also been used by others (Wada *et al.*, 1983) to describe bovine growth and, according to the authors, of all the growth models compared, the von Bertalanffy model was the easiest from a computational point of view.

The curves derived from polynomial and von Bertalanffy models have been used to describe bovine growth (Vaccaro and Rivero, 1985). The authors verified that the von Bertalanffy model resulted in a curve that agreed better with conventional standards of biological growth. The von Bertalanffy function was selected as the most appropriate to evaluate development of beef cattle (López De Torre *et al.*, 1992). The criteria used by the authors to compare the functions of von Bertalanffy, Brody and Richards were computational difficulty, goodness of fit and absence of weight bias at maturity.

From the point of view of bovine development measured in terms of body weight at different ages, growth is a combination of hereditary and environmental effects. High heritability values for mature weight have been found by Northcutt and Wilson (1993) and Bullock *et al.* (1993). According to the authors, selection based on this characteristic should be effective, and the parameter mature weight can be genetically altered through selection. Adjustment of non-linear models algebraic functions to bovine weights could help detect genetic variability, a fundamentally important factor for genetic selection in breeding programs.

From a genetic aspect, relationships that may eventually exist between the different non-linear growth parameters could provide alternatives for genetic selection programs. Genetic antagonism has been found between mature weight and maturity rate (Taylor and Fitzhugh Jr., 1971; Brown *et al.*, 1972; Nelsen *et al.*, 1982; Perotto, 1992; Bullock *et al.*, 1993), indicating that selection for

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higher maturity rates could lead to lighter weights at maturity. On the other hand, positive and high genetic correlations were found between mature weight and birth weight, as well as between mature weight and yearling weight (Bullock *et al.*, 1993) and, according to Northcutt and Wilson (1993), heifer weight taken before maturity could be used in genetic evaluations of mature weight.

The purpose of the present study was to analyze growth of Nelore (*Bos taurus indicus*) and Chianina (*Bos taurus taurus*) animals. The non-linear growth model proposed by von Bertalanffy (1938) was used and the growth parameters were estimated to describe and to compare the development of these two meat-producing bovine breeds.

MATERIAL AND METHODS

Nelore breed animals

Nelore animals came from a herd of the Bonsucesso farm, Guararapes, State of São Paulo. They were kept in colonião grass pasture (*Panicum maximum*), with mineral salt and bone meal supplements available *ad libitum*. Mating took place in the field, year round; consequently, calves were born during all months of the year. Animals were weighed successively and monthly from birth to 18 months. Only healthy and pasture-fed pure animals (males and females) with a sufficient number of weights were included in the analyses. The sample was composed of 1358 animals, including monthly weight data from 1972 to 1978 and 1980 to 1982. Data were standardized for birth weight, 90, 150, 205, 365, 455 and 550 days.

Chianina breed animals

Data referring to the Chianina breed came from six herds from the States of São Paulo and Rio de Janeiro, and one herd from the State of Goiás. Animals were raised under a pasture regime. The reproduction system was by natural service; therefore, calves were born throughout the year. Weights were measured trimesterly from birth until 18 months with a tolerance of 15 days, limiting variation (in days) for age groups. Only healthy and pure animals (males and females) with all consecutive weights until 18 months of age were used. The 257-animal sample included data from 1973 to 1978 and 1980 to 1982. Trimester weights were standardized for birth weight, 90, 150, 205, 365, 455 and 550 days.

Obtaining growth parameters

The form of the model used in this study was a function of von Bertalanffy, given by the equation: $Yt = A(1-Be^{-kt})^3$, where Yt is weight at time t; t is the time (age of animal since birth); A is the asymptotic weight, final weight, or mature weight; B is the integration constant, and k is the maturity rate or measurement of the exponential function variation.

Model parameters can be interpreted biologically:

1. **Asymptotic weight or mature weight** is represented by the letter A in the equation. It is the weight achieved by organisms in growth, which is not surpassed by the elapsing exponential decline in the maturity rate.
2. **Inflection point** occurs when the estimated maturity rate passes from a growing function to a declining function. In other words, the rate of change in weight is at its maximum and an exponential decline begins with an increasing reduction in the maturity rate.
3. **Slope** is represented by the letter k. The estimate of the slope of a non-linear equation is the measurement of the rate of approximation to its asymptotic value. It is referred to as growth rate or maturity rate in relation to mature weight. The value k^{-1} is the interval of time spent to attain maturity and serves to measure changes in the degree of maturity (Taylor, 1965).
4. **Y-intercept** is related to the initial weight of the animal. It represents weight t, when time equals zero and estimates birth weight. In the model, it is assigned the letter B and has no biological interpretation. It can be called the integration constant (Richards, 1959; Fitzhugh Jr., 1976).

The von Bertalanffy function parameters were adjusted according to the methodology presented by Draper and Smith (1966).

Standardizing weight

Monthly weights were standardized for birth weight, 90, 150, 205, 365, 455 and 550 days, using the following methodology (Warwick and Legates, 1979):

$$P_i = Pnear_i + ADG\ (i - \text{age } Pnear_i)$$

where P_i is the standardized weight at standard age i, $Pnear_i$ is the weight nearest to standard age i, ADG is average daily gain considered among the weights after standard age i and before standard age i, i is age to which weight is standardized, and age $Pnear_i$, age to weight nearest to standard age i considering

$$ADG = \frac{PP_i - PA_i}{\Delta days}$$

where ADG is the average daily gain of the time interval in days relative to PA_i (weight before standard age i) and PP_i (weight after standard age i) and Δdays the interval in days among the weights considered.

Correcting data for environmental effects

Corrections for environmental effects were made using the program "Mixed Model Least Squares and Maximum Likelihood Computer Program" (Harvey, 1987).

For Nelore breed animals,

$$Y_{ijk} = \mu + a_i + F_j + e_{ijk}$$

where Y_{ijk} is the dependent variable; μ is the general average; a_i is a group of random effects (in this case the effect of the bull); F_j is the group of fixed effects (month and year of birth, age of mother and sex), and e_{ijk} is the experimental error.

For Chianina animals,

$$Y_{ijkl} = \mu + a_i + b_{ij} + F_k + e_{ijkl}$$

where Y_{ijkl} is the dependent variable; μ is the general average, a_i is the group of random effects (representing herds); b_{ij} is a hierarchical random effect (bull within the herd); F_k is other group of fixed effects (year and month of birth, age of mother and sex), and e_{ijkl} is the experimental error.

Estimates of heritability and genetic, phenotypic and environmental correlations

Estimates of heritability and genetic, phenotypic and environmental correlations were obtained through the methodology described in specialized literature. Heritability estimates were based on interclass correlations between paternal half brothers. Genetic, phenotypic and environmental correlations among growth parameters were based on variance and covariance components between and among sires and error, respectively.

RESULTS AND DISCUSSION

Environmental variation factors of growth parameters

For weights observed in Nelore animals, analysis of variance (Table I) showed that effects of the bull, year and month of birth, age of mother and sex were significant for all parameters. These results agreed with those obtained by other authors. Growth parameters have been influenced by effect of the age of the mother (Quaas, 1983; Wada and Nishida, 1987; Northcutt *et al.*, 1994). The effect of the season was significant for the maturity rate (Nuru *et al.*, 1981), as well as for mature weight and maturity rate (McLaren *et al.*, 1982). The year of birth proved to be significant for the growth parameters and the effect of the bull's lineage for mature weight (DeNise, 1982; Quaas, 1983). The effects of the bull, month and year of birth and sex have been significant for the parameters mature weight and integration constant, while the maturity rate had been influenced by the effect of the bull (Bianchini Sobrinho and Duarte, 1991; Souza and Bianchini Sobrinho, 1994).

Table I
Analysis of variance for estimated growth parameters by von Bertalanffly's model, obtained from Nelore weight data.

Sources of variation	Degrees of freedom	Mean squares					
		A	B	k	$T_{(I)}$	$P_{(I)}$	1/k
Bull	23	14039.887*	0.003*	0.003*	8.529*	1232.582*	22.703*
Year of birth	9	92342.452*	0.012*	0.022*	24.476*	8106.882*	82.630*
Month of birth	11	56258.279*	0.004*	0.013*	20.766*	4938.998*	79.305*
Age of mother	8	18109.216*	0.004*	0.004*	16.966*	1589.834*	42.034*
Sex	1	1446898.060*	0.065*	0.082*	121.331*	127025.338*	247.554*
Residual	1305	6984.821	0.001	0.001	4.815	613.207	12.597

* Significant, $P < 0.10$.

Table II
Analysis of variance for estimated growth parameters by von Bertalanffy's model, obtained from Chianina weight data.

Sources of variation	Degrees of freedom	Mean squares					
		A	B	k	$T_{(I)}$	$P_{(I)}$	1/k
Herd	6	169880.408	0.005	0.003	23.205	14914.054	45.243
[#]Bull/Herd	25	134701.277*	0.004*	0.002*	23.434*	11825.626*	39.384*
Year of birth	8	45379.905	0.001	0.001	9.283	3983.968	19.894
Month of birth	11	43891.854	0.002	0.001	11.356	3853.330	19.998
Age of mother	7	103592.265	0.004*	0.002	22.005*	9094.521	31.497
Sex	1	4668169.632*	0.107*	0.005*	118.692*	409825.577*	69.342*
Residual	198	67443.577	0.002	0.001	12.086	5920.972	19.597

* Significant, $P < 0.10$.

Table III
Estimates of heritability of growth parameters estimated by the model of von Bertalanffy in Nelore animals.

Parameters	Heritabilities	Standard error
A	0.093	0.047
B	0.236	0.084
k	0.129	0.057
$T_{(I)}$	0.062	0.038
$P_{(I)}$	0.093	0.047
1/k	0.057	0.037

Table IV
Estimates of heritability of growth parameters estimated by the model of von Bertalanffy in Chianina animals.

Parameters	Heritabilities	Standard error
A	0.212	0.176
B	0.542	0.228
k	0.330	0.196
$T_{(I)}$	0.202	0.174
$P_{(I)}$	0.212	0.176
1/k	0.309	0.192

Statistical analysis applied to growth parameter values obtained from Chianina animal weights (Table II) showed that the effect of the bull within the herd and sex were significant for all parameters, and the effect of age of the mother proved to be significant for the parameters integration constant and age at inflection point.

Heritability estimates for growth parameters

The heritability estimates found for Nelore animals were low (Table III). For the Chianina, heritability estimates were also low (Table IV), mainly for mature weight, age at inflection point, weight at inflection point and maturity interval. Such results suggest that selection for growth, based solely on curve parameters, may not lead to a satisfactory response. These results agreed with those obtained in the literature (Bianchini Sobrinho and Duarte, 1991; Souza and Bianchini Sobrinho, 1994). However, high heritabilities for the growth parameters were found (Wada and Nishida, 1987). High heritabilities for the parameter mature weight were observed by others (Northcutt and Wilson, 1993; Bullock *et al.*, 1993), suggesting that this parameter could be genetically altered by selection.

Table V
Average values of growth parameters estimated by the model of von Bertalanffy obtained from growth data adjusted for significant environmental effects in Nelore animals.

		Parameters					
Bull´s number	**Son No.**	$A_{(kg)}$	B	k	$T_{(I)\,(months)}$	$P_{(I)\,(kg)}$	$1/k_{(months)}$
41	144	321.27	0.492	0.127	3.359	95.191	8.442
43	38	321.92	0.515	0.134	3.435	95.385	7.812
44	33	334.94	0.514	0.137	4.327	99.243	8.919
45	98	310.70	0.493	0.142	3.255	92.060	7.895
46	74	322.13	0.485	0.137	2.961	95.446	7.794
48	14	332.25	0.505	0.138	3.297	98.446	7.722
51	33	328.58	0.497	0.127	3.320	97.357	8.226
54	70	298.11	0.484	0.145	2.785	88.328	7.284
57	16	323.27	0.506	0.136	3.232	95.784	7.772
58	15	365.51	0.497	0.112	4.724	108.30	10.953
59	63	312.41	0.496	0.135	3.389	92.565	8.176
61	55	280.80	0.496	0.144	2.939	83.199	7.285
64	44	282.24	0.492	0.157	2.916	83.627	7.177
66	34	311.76	0.497	0.132	3.257	92.372	7.969
68	19	303.06	0.501	0.138	3.085	89.796	7.551
69	22	271.35	0.486	0.162	2.439	80.399	6.376
89	59	331.85	0.504	0.124	3.761	98.327	8.841
299	49	320.48	0.499	0.143	3.048	94.957	7.484
473	59	297.90	0.480	0.160	2.666	88.267	7.079
494	94	311.64	0.501	0.134	3.310	92.337	7.958
605	127	326.93	0.493	0.129	3.896	96.868	9.334
739	65	310.49	0.495	0.134	3.144	91.997	7.949
800	42	298.85	0.506	0.123	3.596	88.548	8.527
806	91	298.50	0.503	0.141	3.131	88.445	7.475
Total number of animals	1358						
General average of growth parameters		312.87	0.496	0.137	3.297	92.702	8.048

Table VI
Average values of growth parameters estimated by the model of von Bertalanffy obtained from growth data adjusted for significant environmental effects in Chianina animals.

		Parameters					
		$A_{(kg)}$	B	k	$T_{(I)(months)}$	$P_{(I)(kg)}$	1/k $_{(months)}$
Bull´s number	**Son No.**						
89	15	806.43	0.610	0.096	6.745	238.94	11.000
91	18	719.17	0.599	0.108	5.702	213.09	9.602
110	3	1025.40	0.606	0.092	6.495	303.83	10.829
134	4	849.98	0.569	0.093	11.621	251.85	18.246
177	4	606.34	0.590	0.110	5.766	179.66	9.955
234	4	739.87	0.567	0.126	4.343	219.22	8.113
328	3	930.25	0.616	0.072	8.925	275.63	14.468
335	12	640.37	0.585	0.101	6.217	189.74	10.717
439	7	703.84	0.579	0.127	4.818	208.54	8.492
459	9	756.62	0.598	0.130	4.963	224.18	8.288
462	3	512.86	0.542	0.140	3.479	151.96	7.119
544	5	649.93	0.570	0.081	9.446	192.57	15.923
548	4	602.00	0.572	0.084	6.614	178.37	12.122
551	10	896.20	0.617	0.075	8.864	265.54	14.225
608	4	645.83	0.568	0.106	5.387	191.36	9.893
645	6	674.96	0.570	0.104	5.455	199.99	10.060
651	11	719.01	0.594	0.112	6.464	213.04	10.601
711	5	777.38	0.621	0.074	8.518	230.34	13.596
714	3	623.45	0.591	0.117	6.297	184.73	10.446
901	6	872.67	0.597	0.117	6.197	258.57	10.194
908	13	792.51	0.597	0.112	5.450	234.82	9.240
1151	6	893.44	0.616	0.090	8.052	264.72	12.677
1188	18	727.94	0.628	0.103	6.946	215.68	10.742
1229	7	554.78	0.542	0.132	4.670	164.38	9.094
1386	3	435.39	0.529	0.138	3.332	129.01	7.228
1569	10	935.93	0.628	0.076	9.020	277.31	13.966
1570	11	741.56	0.602	0.103	6.421	219.72	10.664
1700	12	748.61	0.611	0.095	6.990	221.81	11.293
1701	12	888.38	0.626	0.098	7.684	263.23	11.777
1702	17	716.08	0.588	0.109	6.143	212.17	10.456
1906	6	880.84	0.620	0.087	8.874	260.99	13.679
2440	6	620.25	0.595	0.094	6.374	183.78	10.888
Total number of animals	257						
General average of growth parameters		751.38	0.598	0.103	6.640	222.63	10.989

Growth parameter values obtained with the von Bertalanffy model

In addition to the basic growth parameters, such as mature weight (A), maturity rate (k) and integration constant (B), the model can generate diverse growth measurements that permit the study of variations among the developmental standards that may not be reflected in the basic parameters. Among these are age at inflection point of the growth curve ($T_{(I)}$), weight at inflection point of the growth curve ($P_{(I)}$) and average maturity interval (1/k). This additional information allows more precise comparisons among the developmental standards. These statistics proved to be useful information regarding bovine growth (Duarte, 1975).

Average values were obtained for growth parameters of Nelore (Table V) and Chianina (Table VI) breed animals. Note that average mature weight (A) estimated for the Chianina breed (751.38 kg) is more than twice the value estimated for the Nelore breed (312.87 kg). Although presenting heavier average mature weights, Chianina exhibited maturity rates (k) inferior to those of Nelore by approximately 25%, which is deemed relevant considering the magnitude of this parameter.

Parameters A and k showed a pronounced inverse relationship in both breeds. Animals with heavier average A values presented the slowest average k values. On the other hand, those that grew with fast maturity rates were lighter at maturity. An inverse relationship between mature weight and maturity rate was also observed in the literature (Taylor and Fitzhugh Jr., 1971; Brown *et al.*, 1972; Duarte, 1975; Nelsen *et al.*, 1982; Perotto, 1992; Bullock *et al.*, 1993; Perotto *et al.*, 1994).

An inverse relationship between parameters k and 1/k was observed in both breeds. These observations agree

Table VII

Estimates of genetic, phenotypic and environmental correlations between growth parameters estimated by the model of von Bertalanffy for Nelore animals.

Parameters		Correlations			
		Genetic	Standard error	Phenotypic	Environmental
A -	B	0.463	0.236	0.718	0.780
	k	-0.728	0.364	-0.700	-0.698
	$T_{(I)}$	0.501	0.278	0.845	0.874
	$P_{(I)}$	1.000	0.000	1.000	1.000
	1/k	0.500	0.287	0.791	0.816
B -	k	-0.599	0.268	-0.529	-0.521
	$T_{(I)}$	0.810	0.147	0.715	0.730
	$P_{(I)}$	0.463	0.236	0.718	0.780
	1/k	0.440	0.284	0.552	0.591
k -	$T_{(I)}$	-0.795	0.441	-0.724	-0.723
	$P_{(I)}$	-0.728	0.364	-0.700	-0.698
	1/k	-0.838	0.480	-0.819	-0.824
$T_{(I)}$ -	$P_{(I)}$	0.501	0.278	0.845	0.874
	1/k	0.873	0.093	0.957	0.962
$P_{(I)}$-	1/k	0.500	0.287	0.791	0.816

with other authors' results (Brown *et al.*, 1976; López De Torre and Rankin, 1978; Perotto *et al.*, 1994). Note that the Chianina breed had slower maturity rates, and consequently, their maturity intervals were longer than Nelore.

Average values for parameters $T_{(I)}$, $P_{(I)}$ and 1/k were respectively: 3.297 months, 92.702 kg and 8.048 months for Nelore animals and 6.640 months, 222.63 kg and 10.989 months for Chianina animals. Observe that Nelore breed animals were younger and lighter at inflection point and at maturity than Chianina breed.

Estimates of correlation

1) Nelore breed

Correlations among growth parameters

Correlations among growth parameters of Nelore animals were estimated (Table VII). Observe that parameter k exhibited a negative genetic correlation coefficient with A, indicating that selection for faster maturity rates could result in a reduction in mature weights. Negative genetic correlation coefficients between maturity rate and mature weight were also found in the literature (Taylor and Fitzhugh Jr., 1971; Brown *et al.*, 1972; Calo *et al.*, 1973; Duarte, 1975; López De Torre and Rankin, 1978; Nelsen *et al.*, 1982; Perotto, 1992).

The parameter k was negatively correlated genetically with 1/k, agreeing with results found in the literature (Brown *et al.*, 1976; López De Torre and Rankin, 1978; Perotto *et al.*, 1994). This result indicates that selection for faster maturity rates could result in individuals that reach maturity much more quickly. The parameter k was negatively correlated genetically with B, $P_{(I)}$ and $T_{(I)}$, meaning that selection for faster maturity rates could result in lower birth weights and weight at inflection point, and therefore, could reduce the age at inflection point.

Parameter A showed positive genetic correlation with 1/k, agreeing with Duarte (1975) and Bullock *et al.* (1993). The genetic correlation among A and $T_{(I)}$ was also positive, and there was an equal genetic correlation of +1.0 between parameters A and $P_{(I)}$, suggesting that selection for heavier weights at the inflection could increase mature weight; however, animals would also be older at maturity.

The parameter 1/k had positive genetic correlations with B, $T_{(I)}$ and $P_{(I)}$. Genetic correlations were positive between B and $T_{(I)}$, B and $P_{(I)}$, as well as between $T_{(I)}$ and $P_{(I)}$, meaning that selection for heavier birth weights could result in older and heavier animals at inflection point, and selection for younger animals at inflection point could reduce weight at inflection point.

Correlations among different parameters and weights at diverse ages

The correlations among different parameters and weights at diverse ages of Nelore animals were obtained (Table VIII). Examine that mature weight had positive genetic correlation with birth weight. This result was also verified by Northcutt *et al.* (1994). This value tended to increase as age increased, agreeing with Bullock *et al.* (1993). For maturity rate, agreeing with results in the literature which indicate negative genetic correlation between parameters A and k, one would expect that genetic correlation between k and weight at different ages would tend to decrease as age increased. However, in this study such correlations tended to grow until 150 days of age, after which values tended to decrease.

For the period studied, from birth to 18 months, the results indicate that selection could be made at 150 days, choosing animals with faster maturity rates without reducing mature weight. Selection after or before 150 days for heavier weights could result in choosing animals with slower maturity rates that reach mature weight older.

Genetic correlation for the parameter 1/k tended to decrease until 150 days of age, after which it tended to increase with age even though values were negative. Considering the time interval studied, selection performed at 150 days, aiming to decrease the maturity interval, could result in heavier and younger animals at maturity. Selection for shorter maturity intervals before or after 150 days could result in animals that reach mature weight younger, and are therefore, lighter at maturity.

Among $P_{(I)}$ and weight at different ages, the genetic correlations were positive and tended to increase with age, suggesting that selection for heavier weights at in-

Table VIII
Estimates of genetic, phenotypic and environmental correlations between growth parameters estimated by the model of von Bertalanffy and weight at different ages for Nelore animals.

Parameters	Weight at different ages	Correlations			
		Genetic	Standard error	Phenotypic	Environmental
A -	BW*	0.217	0.278	0.169	0.195
	P 090	0.463	0.260	0.032	-0.067
	P 150	0.438	0.271	-0.014	-0.110
	P 205	0.467	0.266	0.001	-0.096
	P 365	0.721	0.189	0.288	0.210
	P 455	0.785	0.157	0.441	0.389
	P 550	0.835	0.130	0.544	0.505
B -	BW	-0.728	0.158	-0.352	-0.142
	P 090	-0.402	0.235	-0.336	-0.313
	P 150	-0.346	0.244	-0.250	-0.217
	P 205	-0.312	0.246	-0.138	-0.076
	P 365	0.078	0.260	0.252	0.315
	P 455	0.252	0.246	0.362	0.399
	P 550	0.092	0.262	0.339	0.422
k -	BW	0.190	0.265	0.019	-0.056
	P 090	0.177	0.271	0.372	0.444
	P 150	0.203	0.271	0.438	0.510
	P 205	0.171	0.275	0.431	0.508
	P 365	-0.130	0.282	0.115	0.179
	P 455	-0.279	0.277	-0.093	-0.051
	P 550	-0.326	0.278	-0.221	-0.201
$T_{(I)}$ -	BW	-0.622	0.267	-0.100	0.031
	P 090	-0.507	0.324	-0.394	-0.410
	P 150	-0.532	0.337	-0.469	-0.489
	P 205	-0.510	0.339	-0.462	-0.484
	P 365	-0.193	0.339	-0.194	-0.207
	P 455	-0.047	0.342	-0.044	-0.046
	P 550	-0.045	0.342	0.042	0.058
$P_{(I)}$ -	BW	0.217	0.278	0.169	0.195
	P 090	0.463	0.260	0.032	-0.067
	P 150	0.438	0.271	-0.014	-0.110
	P 205	0.467	0.266	0.001	-0.096
	P 365	0.721	0.189	0.288	0.210
	P 455	0.785	0.157	0.441	0.389
	P 550	0.835	0.130	0.544	0.505
1/k -	BW	-0.268	0.317	-0.003	0.074
	P 090	-0.389	0.344	-0.403	-0.444
	P 150	-0.468	0.357	-0.514	-0.557
	P 205	-0.446	0.361	-0.535	-0.586
	P 365	-0.249	0.351	-0.304	-0.333
	P 455	-0.150	0.350	-0.134	-0.139
	P 550	-0.024	0.350	-0.010	-0.008

*BW- Birth weight.

flection point could result in heavier mature weights, which agrees with Duarte (1975).

Parameter B had low genetic correlation coefficients with weight at different ages, which although negative until the weight at 205 days, tended to increase with age. Genetic correlations between $T_{(I)}$ and weight at different ages tended to increase with age, even though values were negative.

For the period analyzed, the practice of selection for heavier weights at 150 days could lead to obtainment of animals that grow with faster maturity rates, and are heavier and younger at inflection point and maturity.

2) Chianina breed

Correlations among growth parameters

Correlation coefficients among growth parameters of Chianina animals were estimated (Table IX). The genetic correlation between A and k was negative, agreeing with results found in literature (Talyor and Fitzhugh Jr., 1971; Brown *et al.*, 1972; Calo *et al.*, 1973; Duarte, 1975; López De Torre and Rankin, 1978; Nelsen *et al.*, 1982; Perotto, 1992). The genetic correlation between k and $P_{(I)}$

was also negative. Such results indicate that selection to faster maturity rates could lead to lighter weights at inflection point and maturity. The parameters A and $P_{(I)}$ had equal genetic correlation +1.0. These results indicate that selection for heavier weights at inflection point could lead to heavier mature weights.

Parameter A presented negative genetic correlation with $T_{(I)}$. Genetic correlation between $P_{(I)}$ and $T_{(I)}$ was also negative, meaning that selection for younger animals at inflection point could increase weight at inflection point and mature weight. These results did not agree with those found in literature.

Between 1/k and k the genetic correlation was negative, indicating that with faster maturity rates, maturity is reached at a shorter interval of time. These results were also observed by Brown *et al.* (1976), López De Torre and Rankin (1978) and Perotto *et al.* (1994). The parameter 1/k was negatively correlated genetically with parameters A, B and $P_{(I)}$, suggesting that selection for shorter maturity intervals could increase birth weight and weight at inflection point. These results do not agree with those found in literature. However, high standard errors were found suggesting that interpretations should be made cautiously. One of the factors that could explain this finding could be related to the small number of observations in the sample.

The parameter 1/k was positively correlated genetically with $T_{(I)}$, meaning that selection for shorter maturity intervals could reduce age at inflection point. Parameters B and $P_{(I)}$ had positive genetic correlations with A, indicating that selection for heavier birth weights could result in heavier weights at inflection point and heavier mature weights.

Table IX

Estimates of genetic, phenotypic and environmental correlations between growth parameters estimated by the model of von Bertalanffy for Chianina animals.

Parameters		Correlations			
		Genetic	Standard error	Phenotypic	Environmental
A -	B	0.618	0.243	0.827	1.029
	k	-0.245	0.669	-0.711	-0.890
	$T_{(I)}$	-0.040	0.711	0.864	1.100
	$P_{(I)}$	1.000	0.000	1.000	1.000
	1/k	-0.138	0.544	0.815	1.153
B -	k	-0.415	0.499	-0.732	-1.006
	$T_{(I)}$	0.217	0.423	0.761	1.140
	$P_{(I)}$	0.618	0.243	0.827	1.029
	1/k	-0.023	0.415	0.680	1.225
k -	$T_{(I)}$	-1.015	0.969	-0.793	-0.726
	$P_{(I)}$	-0.245	0.669	-0.711	-0.890
	1/k	-0.930	0.763	-0.816	-0.763
$T_{(I)}$ -	$P_{(I)}$	-0.040	0.711	0.864	1.100
	1/k	0.973	0.026	0.988	1.003
$P_{(I)}$ -	1/k	-0.138	0.544	0.815	1.153

Correlations among different parameters and weight at different ages

Correlation coefficients between different parameters and weight at different ages of Chianina animals were obtained (Table X). Note that standard error values varied between ±0.25 and ±0.50, which can be considered high. The small sample size of Chianina could have resulted in these values. Genetic correlations between A and weight at different ages tended to increase with age. This result agreed with those of Bullock *et al.* (1993). Therefore, selection for heavier weights at any age could lead to heavier mature weights.

The parameter k and weight at different ages presented genetic correlations which increased until 205 days of age; afterwards, it decreased. For this group of animals and the interval of ages analyzed, results suggested that selection for heavier weights at 205 days could lead to faster maturity rates without reducing mature weight. Selection for heavier weights, before or after this age, could result in animals with slower maturity rates and lighter mature weights.

The parameters A and $P_{(I)}$ showed genetic correlations with weight at different ages which were equal and tended to increase as age increased, inferring that evaluation of genetic potential for weight at maturity could be made early, reducing the interval between generations and, consequently, leading to better genetic gains per unit of time.

For parameter 1/k and weight at different ages, genetic correlations tended to decrease as age increased, until 205 days of age, after which it increased as age increased, although with negative values. Considering the developmental period analyzed, it is suggested that selection at 205 days for shorter maturity intervals could lead to faster maturity rates and heavier mature weights. From this age on, or before it, selection for shorter maturity intervals could result in lighter animals at maturity. The integration constant (B) had low genetic correlations that grew with age, although they were negative until 205 days of age.

CONCLUSIONS

Low heritabilities found for both breeds, mainly for mature weight, age at inflection point of growth curve, weight at inflection point of growth curve and maturity interval, suggest that selection for growth based solely on phenotypic values of curve parameters may not lead to a satisfactory response.

Nelore animals grow faster with shorter maturity intervals, and reach mature weight younger than Chianina. Despite its slow maturity rates and longer maturity intervals, Chianina exhibited mature weights superior to those of Nelore.

Table X
Estimates of genetic, phenotypic and environmental correlations between growth parameters estimated by the model of von Bertalanffy and weight at different ages for Chianina animals.

Parameters	Weight at different ages	Correlations			
		Genetic	Standard error	Phenotypic	Environmental
A -	BW*	-0.123	0.505	0.180	0.315
	P 090	0.026	0.412	0.099	0.219
	P 150	0.039	0.390	0.098	-0.998
	P 205	0.042	0.387	0.138	-0.593
	P 365	0.232	0.376	0.393	0.834
	P 455	0.316	0.367	0.539	0.856
	P 550	0.424	0.332	0.645	0.933
B -	BW	-0.323	0.479	-0.198	-0.124
	P 090	-0.184	0.376	-0.230	-0.350
	P 150	-0.160	0.351	-0.163	0.879
	P 205	-0.100	0.343	-0.044	-0.117
	P 365	0.114	0.352	0.366	0.977
	P 455	0.190	0.354	0.503	0.943
	P 550	0.258	0.344	0.550	0.920
k -	BW	0.073	0.409	0.023	-0.019
	P 090	0.441	0.277	0.287	-0.025
	P 150	0.445	0.260	0.324	0.224
	P 205	0.476	0.253	0.306	0.421
	P 365	0.301	0.310	0.028	-0.701
	P 455	0.186	0.342	-0.154	-0.753
	P 550	0.082	0.352	-0.291	-0.889
$T_{(I)}$ -	BW	-0.278	0.416	-0.033	0.155
	P 090	-0.575	0.334	-0.255	0.358
	P 150	-0.550	0.317	-0.291	-1.781
	P 205	-0.539	0.312	-0.268	-0.854
	P 365	-0.357	0.316	-0.019	0.809
	P 455	-0.259	0.328	0.144	0.798
	P 550	-0.155	0.339	0.260	0.875
$P_{(I)}$ -	BW	-0.123	0.505	0.180	0.315
	P 090	0.026	0.412	0.099	0.219
	P 150	0.039	0.390	0.098	-0.998
	P 205	0.042	0.387	0.138	-0.593
	P 365	0.232	0.376	0.393	0.834
	P 455	0.316	0.367	0.539	0.856
	P 550	0.424	0.332	0.645	0.933
1/k -	BW	-0.261	0.401	0.011	0.245
	P 090	-0.641	0.316	-0.252	0.598
	P 150	-0.615	0.304	-0.316	-2.645
	P 205	-0.618	0.301	-0.325	-1.085
	P 365	-0.452	0.311	-0.140	0.693
	P 455	-0.351	0.319	0.022	0.693
	P 550	-0.244	0.325	0.153	0.804

*BW- Birth weight.

Selection for heavier weights at inflection point of growth curve leads to increased mature weight, in both breeds, allowing for early estimates of the genetic potential of the animals, contributing to increased genetic gains per unit of time.

Considering the developmental period studied, from birth to 18 months, the results suggested that the practice of genetic selection for heavier weights at 150 and 205 days of age for Nelore and Chianina animals, respectively, leads to animals that grow with faster maturity rates and reach the maturity younger and heavier.

Nelore animals reach the age considered ideal for selection for growth characters younger than Chianina animals, implicating on reduction of the interval between generations on Nelore breed animals, allowing for greater annual genetic gains on that breed.

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RESUMO

Foram analisados dados de pesagens do nascimento aos dezoito meses de idade de bovinos de corte das raças Nelore e Chianina. Os dados foram corrigidos para os efeitos significativos de meio ambiente e utilizados para estimar parâmetros de crescimento através do modelo não linear de von Bertalanffy. Os valores médios encontrados para os parâmetros de crescimento em Nelore foram: peso à maturidade (A), 312,87 kg; constante de integração (B), 0,49; taxa de maturidade (k), 0,13; idade ao ponto de inflexão ($T_{(I)}$), 3,29 meses; peso ao ponto de inflexão ($P_{(I)}$), 92,70 kg, e intervalo de maturidade (1/k), 8,04 meses. Para os animais Chianina os valores foram 751,38 kg, 0,59, 0,10, 6,64 meses, 222,63 kg e 10,98 meses, respectivamente. Animais Nelore exibiram maiores taxas de maturidade, menores intervalos de maturidade, atingindo pesos à maturidade em idades mais jovens do que animais da raça Chianina, apesar de mais leves do que estes à maturidade. As estimativas de herdabilidade apresentaram valores baixos, principalmente para os parâmetros peso à maturidade (0,093 e 0,212), idade ao ponto de inflexão (0,062 e 0,202), peso ao ponto de inflexão (0,093 e 0,212) e intervalo de maturidade (0,057 e 0,309) (para Nelore e Chianina, respectivamente). Os parâmetros peso à maturidade e peso ao ponto de inflexão mostraram correlações genéticas positivas com os pesos em diferentes idades e com tendências similares, sendo estas crescentes conforme aumentou-se a idade, em ambas as raças. Considerando o período de crescimento analisado, ou seja, do nascimento aos 18 meses de idade, o parâmetro taxa de maturidade e os pesos em diferentes idades mostraram correlações genéticas crescentes até os pesos às idades de 150 e 205 dias em Nelore e Chianina, respectivamente, decrescendo a partir destas idades e os valores das correlações genéticas entre o parâmetro intervalo de maturidade e os pesos em diversas idades apresentaram-se negativos, decrescentes até os pesos às idades de 150 e 205 dias, respectivamente, em Nelore e Chianina, e crescentes a partir destas idades.

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