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Original Article

Index proposal for Nelore bulls classification using traits groups of weight, carcass and reproductive

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Genetic breeding programs generally evaluate animals considering the same objectives, but the indices used in the selection criteria can vary. This can give rise to distinct bull rankings in each program. Thus, we aimed to create alternatives for the referral of bulls for mating through multivariate analyses. We used information from the summaries of two genetic evaluation programs (1 and 2) with Nellore bulls. Characteristics were separated into groups: weight, carcass and reproduction. Groups were formed using the mean Euclidean distance and the Tocher optimization method. The means of each trait among the animals allocated to the same group were used to compose the following subindexes: weight gain (siWG), carcass (siCG) and reproduction (siRG). Based on the mean of the group subindex classification, we calculated the average index of group classification (iAGc). When classifying the best groups by characteristics, we observed an increase (superiority of some bulls) in the estimated breeding values (EBVs) by comparison with the total number of bulls evaluated by the programs, selected animals and best 10 final indexes of the programs. There was a change in bull classification when using the iAGc in relation to the classification using the final indexes of the programs. The coefficient of simple coincidence showed that there was a change in bull classification between programs, both between deciles of the final indexes and groups of characteristics. The subindexes siWG, siCG and siRG are important for correcting specific problems in herds. The iAGc should be used instead of the final index of the programs, providing more options for the selection of bulls for mating.

INTRODUCTION

In breeding programs, bulls are usually evaluated according to common selection objectives, with variations in the criteria for characteristics and indexes used in the selection of breeding animals. Weight and weight gain are traditionally used as selection criteria in beef cattle. Previous studies have recommended counting the number of days necessary for the animals to gain weight as a selection criterion, as it can help

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distinguish precocious animals without increases in their adult size (MUNIZ et al., 2005; MALHADO et al., 2008).

Reproduction traits are also fundamental in a selection program. Herds with high sexual precocity and fertility have greater availability of individuals for selection or sale, providing greater selection intensity, genetic progress and profitability (GUIMARÃES et al., 2011). According to Brumatti et al. (2011), reproduction traits are about 13 times more important than growth traits in determining the economic weights applicable to genetic evaluations.

Also, visual scores and carcass characteristics are also interesting to analyzed for animal selection in breeding programs, and should respond rapidly to mass selection (YOKOO et al., 2009). The carcass has great relevance to slaughterhouses to evaluate the value of the purchased product (RESTLE; VAZ; QUADROS, 1999), and the ribeye area correlates with carcass weight and the yield obtained with commercial cuts on the animal's back (SUGUISAEA et al, 2003).

The multivariate analysis procedures, by summarizing the post-genetic evaluation information, can contribute to animal selection and help in the definition of mating, forming balanced groups of females and males and correcting deficiencies of characteristics within a group (VAL et al. 2008). Therefore, our objective was to create an index based on the similarity of the bulls by groups of characteristics (weight, carcass and reproduction) as alternatives to the final indexes of the bulls' summaries, using multivariate analysis techniques.

MATERIALS AND METHODS

Summary information from two Nellore bull genetic evaluation programs were used. In programs 1 and 2, 73 and 356 bulls had EBVs for all characteristics evaluated, respectively. Among these bulls, 50 bulls were chosen for the first analysis, consisting of the top ten animals classified using the final index of each program and 40 bulls with the best accuracy. For the second analysis, 16 bulls with complete data, common to the two programs, were chosen.

All the EBVs of the characteristics were standardized with mean zero and standard deviation 1 and for the characteristics of birth weight (BW), gestation period (GP), age at first birth (AFB), the signal of the EBVs was inverted by converting them into larger values the better the genetic value for the characteristic.

For the analysis of the 50 bulls, the groups of characteristics of weight gain (WG), carcass (CG) and reproduction (RG), were analyzed to evaluate the differences among the bulls in each group of characteristics. The principal components analysis was performed and the clustering analysis was performed using the mean Euclidean distance and the Tocher optimization method.

After Tocher grouping analysis, the mean of the EBVs of each characteristic of the bulls allocated in the same group was calculated. These averages were used to compose the subindexes of group means (siX), calculated by the following formula:

$$siX = \left(\sum_{i=1,\, j=1}^{i,\, j} Eij \right) / \, mn$$

Where:

siX = subindice of the X group of characteristics; E= EBV of the characteristic j of the bull i in the group formed by the group of characteristics; m = number of bulls of the group formed; n = number of characteristics of the group.

In order to classify the bulls, including the three groups of characteristics, the average index of rating of groups (iAGc) was created. This index was calculated by the average of the rating of the groups of subindexes (rsiX), within the group that the animal is part of. As this is a classification index, the lower its value the better the bull was ranked. To better understand this analysis, an example for 6 bulls is presented in Table 1.

Table 1 – Average index of group classification (iAGc) with respective ranking positions and subindexes of groups of 6 bulls taken at random.

Bull	siW	siC	siR	csiP	csiC	sciR	IMcG
A	1,45	0,86	-0,20	1	2	6	3,00
B	0,76	0,86	0,55	3	2	2	2,33
C	0,76	0,28	-0,88	3	3	8	4,67
D	0,59	-0,15	0,55	6	6	2	4,67
E	0,76	0,28	0,13	3	3	4	3,33
F	-2,20	-1,97	0,73	15	9	1	8,33

SiW, siC, siR = subindex of weight, carcass and reproduction groups; rsiW, rsiC and rsiR = rating of the subindexes of weight, carcass and reproduction groups; iAGc = average index of group classification

To compare the ratings of the 16 bulls using the final indexes of breeding programs 1 and 2, the subindex of group (siX) and average index of group classification (iAGc), we used the simple coincidence coefficient (SCC) calculated with GENES (CRUZ; GENES, 2013).

RESULTS AND DISCUSSION

For the group of characteristics of weight gain (WG) in program 1, 15 groups were formed, demonstrating greater heterogeneity within this program compared to that of program 2, in which nine groups were formed (Table 2).

Table 2 – Groups formed by the Tocher method for weight (WG), carcass (CG) and reproduction (RG) characteristics in both programs.

	Program 1		Program 2	
	NG	NB	NG	NB
WG	15	17, 10, 4, 3, 3, 2 ,2 ,2 ,1 ,1 ,1 ,1 ,1 ,1 ,1	9	23, 8, 5, 5, 4, 2, 1, 1, 1
CG	9	28, 8, 6, 2, 2, 1, 1, 1, 1	5	43, 2, 2, 2, 1
RG	9	20, 11, 6, 5, 3, 2, 1, 1, 1	6	44, 2, 1, 1, 1, 1

NG = Number of groups formed; NB = Number of bulls per group.

When comparing the means of the EBVs for the characteristics, we observed an increase in the best-rated group (BG) in relation to all the animals evaluated for almost all the characteristics in the two programs (Tables 3 and 4). It is important to note that some gains were above 300% for GWY (923%); D240 (902%); D400 (787%); BYG (686%); BWG (479%); D160 (447%); PA (353%); Mwean (1729%); Pwean (970%); Myear (912%); Cwean (729%); Pyear (427%) and Cyear (317%); SCAW (7080%); ASC (2471%) and GP (1657%). Exceptions were observed for MATA (-674%) and AFB (-709%) in program 1 and GP (-463%) and AFB (-348%) in Program 2. The increment verified for most of the characteristics shows that the selection criterion would be the best option when one wants to fix specific problems in the herd.

Table 3 – Mean of the EBVs and percentage of increment (Inc.) in relation to the average of all bulls evaluated (all), the 50 chosen (C50), the 10 best final indexes of the program (B10) and the best group (BG) of Program 1.

Characteristic	All		C50		B10		BG	
	N	Mean	Mean	Inc.	Mean	Inc.	Mean	Inc.
BWG	829	1,01	2,57	155%	4,68	366%	5,82	479%
GWY	828	0,85	2,27	167%	5,13	504%	8,70	923%
BYG	828	1,85	4,84	162%	9,81	431%	14,52	686%
MATA	470	0,19	0,67	249%	0,22	14%	-1,11	-674%
PA	121	2,69	3,42	27%	8,45	214%	12,19	353%
D160	829	2,41	5,87	143%	10,37	330%	13,21	447%
D240	828	6,97	19,80	184%	41,47	495%	69,84	902%
D400	828	9,37	25,67	174%	51,84	453%	83,06	787%
Cwean	829	0,04	0,11	191%	0,23	507%	0,31	729%
Pwean	829	0,03	0,17	451%	0,22	626%	0,33	970%
Mwean	829	0,03	0,16	446%	0,20	618%	0,52	1729%
Cyear	826	0,05	0,15	214%	0,33	577%	0,20	317%
Pyear	828	0,04	0,21	458%	0,30	691%	0,20	427%
Myear	825	0,04	0,21	462%	0,31	736%	0,38	912%
GP	423	-0,06	0,24	479%	0,85	1474%	0,97	1657%
BW	726	0,14	-0,10	-172%	-0,37	-359%	0,56	290%
AFB	141	-0,79	-1,74	-119%	-3,18	-302%	-6,40	-709%
ASC	828	0,05	0,38	637%	0,80	1437%	1,33	2471%
SCAW	828	-0,02	0,20	1143%	0,43	2412%	1,31	7080%

BWG = birth weight gain at weaning; WYG = weight gain post-weaning to the yearling age; BYG = weight gain from birth to the yearling age; MATA = maternal ability for BWG; LW = adult live weight; D160 = days to reach 160Kg; D240 = days to reach 240Kg; D400 = days to reach 400Kg; Cwean = conformation at weaning (Cw); Pwean = precocious at weaning; Mwean = muscle at weaning; Cyear = conformation to the yearling ; Pyear = precocity to the yearling; Myear = muscularity to the yearling; BW = birth weight; gestation period (GP); AFB = age at first birth; ASC = age-adjusted scrotal circumference; SCAW = scrotal circumference adjusted for age and weight.

Table 4 – Mean of the EBVs and percentage of increment (Inc.) in relation to the average of all bulls evaluated (all), the 50 chosen (C50), the 10 best final indexes of the program (B10) and the best group (BG) of Program 2.

	General		M50		M10		MG	
Characteristics	N	Mean	Mean	Inc.	Mean	Inc.	Mean	Inc.
W120	813	4,83	5,51	14%	6,29	30%	10,26	112%
MA120	813	2,05	1,77	-13%	3,02	48%	3,52	72%
TMW120	813	4,47	4,53	1%	6,17	38%	8,65	94%
W210	813	7,23	8,67	20%	10,64	47%	15,58	115%
MW210	813	2,48	2,01	-19%	3,44	38%	2,39	-4%
TMW210	813	6,10	6,34	4%	8,76	44%	10,18	67%
W365	813	13,49	13,75	2%	17,41	29%	24,19	79%
W450	813	14,81	14,93	1%	19,73	33%	25,49	72%
Cwean	370	59,08	60,92	3%	60,04	2%	63,22	7%
Pwean	370	53,58	55,80	4%	63,83	19%	57,71	8%
Mwean	370	56,07	58,85	5%	64,97	16%	60,96	9%
Cyear	370	56,77	57,56	1%	58,30	3%	59,61	5%
Pyear	370	54,44	56,70	4%	60,28	11%	58.03	7%
Myear	370	60,69	62,87	4%	63,66	5%	63,91	5%
Fcar	813	-0,01	-0,01	42%	0,22	2182%	-0,04	287%
LEA	811	0,52	0,65	26%	1,85	257%	0,58	12%
LW	813	22,72	26,14	15%	19,89	-12%	26,59	17%
GP	813	0,70	-0,43	-162%	-0,23	-133%	-2,52	-463%
BW	813	0,98	-1,23	-225%	-1,10	-212%	-0,78	-179%
AFP	813	-0,66	0,58	-189%	0,98	-249%	1,63	-348%
SC365	813	0,48	0,43	-11%	0,15	-69%	1,06	119%
SC450	813	0,59	0,60	1%	1,43	142%	1,41	139%
D3P	813	49,84	50,10	1%	53,12	7%	65,40	31%

W120 = weight at 120 days; MA120 = maternal ability; TMW120 = total maternal weight at 120 days; W210 = weight at 210 days; MW210 = maternal weight at 210 days; TMW210 = total maternal weight at 210 days; W365 = weight at 365 days; W450 = weight at 450 days; LW = adult live weight; Cwean = weaning conformation; Pwean = precocious at weaning; Mwean = muscle at weaning; Cyear = conformation to the yearling; Pyear = precocity to the yearling; Myear = muscularity to the yearling; Fcar = carcass finishing; LEA = loin-eye area; BW = birth weight; GP = period of gestation; AFB = age at first birth; SC365 = scrotal circumference adjusted at 365 days; SC450 = scrotal circumference at 450 days; D3P = probability of early delivery.

We also found higher correlations between the final indexes of the programs (P1 = 0.75, P2 = 0.73) with the subindexes of the weight characteristics group (SiW), indicating that the weight gain characteristics have a higher value in the formation of the selection index in both programs. There were lower correlations for the reproduction characteristics group (csiR) (P1 = 0.14; P2 = 0.28). According to Lira, Rosa and Garnero (2008), growth and reproduction precocities are mediators of greater annual economic gain.

Growth precocity is an important selection objective, aiming at increasing the efficiency for weight gain, reducing the time spent by the animals in the pasture and the quantity of supplements, besides obtaining a more efficient feed conversion, minimizing the financial expenses and the time for slaughter (MARQUES; MAGNABOSCO; LOPES, 2012). With reproduction precocity, the generation gap can be shortened, increasing the replacement rate, profitability and the economic value of the breeding stock. Thus, it is relevant to seek selection criteria for precocity of growth and sexuality.

In Program 1, a higher correlation (0.72) was found with the visual characteristics of carcass (csiC), showing a greater concern in the selection for these characteristics in relation to Program 2 (0.06). The body shape scores are used as a selection criterion to infer the quality of the carcass (SHIOTSUKI et al., 2009) and, in this way, can meet market requirements (FARIA et al., 2009).

Regarding the average index of group classification (iAGc), changes in bull classification were observed in relation to the classification proposed by the programs, through their final index (Table 5). Alternatively to bulls A, B, C and D, which would be used in the hypothesis for selecting the four best final indexes of Program 1, bulls E and G can also be used by the iAGc subindex, increasing the options from four to six possible bulls. Likewise in Program 2, in the hypothesis of selection of the three best evaluated, with the bulls K, L, M, by the final index of the program, the best three bulls can be added by the subscript iAGc subindex (P, Q and S). Using the current study proposal, to improve weight gain characteristics, one could use the two best bulls for csiW (A and I) of Program 1 or the bulls K, L and S of Program 2.

Table 5 – Classification of bulls by final index, by groups of characteristics and iAGc of some bulls evaluated in the Programs.

Bull	cF	csiP	csiC	csiR	iAGc
Program 1					
A	1	1	2	6	3,0
B	2	3	3	2	2,7
C	3	3	3	2	2,7
D	4	9	3	1	4,3
E	6	3	2	2	2,3
F	8	3	3	6	4,0
G	17	3	3	4	3,3
H	20	3	3	6	4,0
I	37	2	4	5	3,7
J	49	15	9	1	8,3
Program 2					
K	1	1	1	5	2,3
L	2	1	1	5	2,3
M	3	6	1	5	4,0
N	6	3	1	5	3,0
O	7	3	1	5	3,0
P	8	3	2	2	2,3
Q	9	5	1	1	2,3
R	12	3	1	5	3,0
S	13	2	1	5	2,7
T	16	3	1	5	3,0
U	24	8	4	1	4,3

CF, csiP, csiC, csiR = position in the classification for the final index of the program, subindexes of weight, carcass and reproduction characteristics, respectively; iAGc = average index of rating of groups.

In relation to the carcass characteristics, the selection for precocious visual scores and muscularity of the loin-eye area and subcutaneous fat thickness will cause genetic changes (YOKOO et al., 2009). According to Dibiasi et al. (2010), the direct selection for muscularity will have a correlated and favorable response in the loin eye-area.

Therefore, to correct problems of the carcass group (CsiC), the bulls A and E of Program 1 or the bulls K, L, M, N, O, P, Q, R, S, T of Program 2 are recommended. On the other hand, for the improvement in reproduction characteristics, bulls B, C, D and E of Program 1 or P and Q of Program 2 are indicated. J and U bulls are the best classified for reproduction traits, however, with low performance in the carcass and weight gain groups. Therefore, they can be chosen in situations where the improvement of the reproduction characteristics is advantageous in relation to the characteristics of weights and carcasses.

Thus, it is provided more options in the selection of bulls for mating, being able to produce gains due to the genetic variability, besides preserving this genetic variability of the population when using crosses involving the progenies of more divergent bulls, as suggested by Ferraz Filho et al. (2008).

Regarding some alterations in relation to the final index, the bull A remained in the csiR in sixth place, leaving first in the final index of program 1 for iAGc 3.0, lower than the bulls B, C and E that obtained iAGc 2, 7; 2.7 and 2.3, respectively. The reverse occurred with the bull E which, having the most balanced groups of characteristics, changed his position from sixth place in the final index to first in the iAGc. The group index is useful for fixing specific problems and the average index of groups seeks more balanced animals.

Although the general objectives of selection were to increase weight, improve visual characteristics of carcass and reproduction efficiency, the coincidence between the classification of bulls in groups of programs 1 and 2 was low. This can be explained by the fact that bulls are evaluated in different herds and different selection criteria were used. This may be related to genotype-environment interaction, since such interaction has not been considered in the current genetic evaluations in Brazil (AMBROSINI et al., 2012). Carvalho et al. (2013) found divergences when considering genotype-environment interaction in the Nellore weight gain assessment and attributed these divergences to the number of animals evaluated and the management methods to which the animals were submitted, since the data belong to different programs of breeding.

When analyzing the 16 bulls for the WG, CG and RG characteristics groups, there was a total coincidence only in the WG for the bull P, who composed a single group in the two programs (Table 6). The same happened for the groups composed by G for the CG group and (D) and (G) for the RG group. It was observed changes on bulls' classification for the final indexes of the programs, with a simple coincidence coefficient (SCC) equal to 31.3% (Table 7). It should be noted that bull I is decile 4 and 1; the bull L is decile 5 and 2; the bull M is decile 6 and 1; the bulls N and O are decile 6 and 3; the bull P is decile 8 and 3 in programs 1 and 2, respectively.

Table 6 – Bull groupings (A to P) by the Tocher optimization method between characteristics groups in the two Programs.

Program 1	Program 2
Group by weight characteristic (GW)	
D, G, H, J, L, M, O (4)	F, H, K, L, M, N, O (3)
A (1)	A, B, G (2)
B, C, I (2)	C, E, I (1)
N (6)	D (4)
P (5)	P (5)
E, F, K (3)	J (6)
Group by carcass characteristic (GC)	
I, J, L, O (7)	A, B, C, D, E, F, H, J, K, L, M, N, O (1)
F, N (5)	
C, D, H (4)	
M, P (8)	I, P (4)
A, B (2)	J (3)
E (1)	
K (6)	
G (3)	G (2)
Group by reproduction characteristic (GR)	
A, C, E, H, I, J, L, M, N, P (4)	C, H, I, J, L, M, N, O, P (5)
K, O (5)	K (6)
B, F (2)	A, E, F (2)
G (3)	G (3)
D (1)	D (1)
	B (4)

Values within parentheses refer to the group classification.

Regarding the classifications in the characteristics groups, the SCC between programs 1 and 2 were 31.3%; 6.3% and 25.0% for csiW, csiC and csiR, respectively. The major differences were for csiC and csiR. These alterations may be related to variations in the selection criteria and in the evaluation particularities of each program, such as progeny testing in different herds (environmental and genetic effects of matrices). As an example, for the weight characteristics Program 1 uses days to reach a certain weight, while Program 2 uses weight at certain ages. For carcass characteristics, Program 2, in addition to the visual carcass characteristics, common to both programs, adds loin-eye area and carcass finishing. For reproduction characteristics, Program 2 includes the probability of early delivery.

Different from dF, csiW, csiC and csiR, iAGc showed a high correlation (0.81; $p < 0.05$) between the classification of the indexes formed in Programs 1 and 2, indicating that the proposed index (iAGc) recognizes bull with similar classifications in the programs, providing alternatives to the current indexes, allowing to refine the selection of bulls for farm mating, widening the possibilities of choice and thus promoting greater variability within the population.

Table 7 – Comparison of the classifications of the 16 bulls for the final index of the program, classifications in the subindexes of weight, carcass, and reproduction groups and average index of rating of groups between breeding programs 1 (P1) and 2 (P2).

Bull	dF		csiW		csiC		csiR		ciAGc	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
			SCC = 31,3%		SCC = 6,3%		SCC = 25,0%		R = 80,9%	
A	1	1	1	2	2	1	4	2	2,3	1,7
B	1	1	2	2	2	1	2	4	2,0	2,3
C	1	1	2	1	4	1	4	5	3,3	2,3
D	2	1	4	4	4	1	1	1	3,0	2,0
E	2	1	3	1	1	1	4	2	2,7	1,3
F	3	1	3	3	5	1	2	2	3,3	2,0
G	3	1	4	2	3	2	3	3	3,3	2,3
H	3	3	4	3	4	1	4	5	4,0	3,0
I	4	1	2	1	7	4	4	5	4,3	3,3
J	5	5	4	6	7	3	4	5	5,0	4,7
K	5	4	3	3	6	1	5	6	4,7	3,3
L	5	2	4	3	7	1	4	5	5,0	3,0
M	6	1	4	3	8	1	4	5	5,3	3,0
N	6	3	6	3	5	1	4	5	4,7	3,0
O	6	3	4	3	7	1	5	5	5,3	3,0
P	8	3	5	5	8	4	4	5	5,7	4,7

dF = deciles of the final indexes in the programs; csiW, csiC, csiR = classification for the final index, subindexes of weight, carcass, reproduction characteristics groups, respectively; ciAGc = average group classification index; SCC = simple coincidence coefficient; R = Sperman correlation.

Finally, the need for caution in the indication of bulls for herds presenting specific problems (productive, reproduction and carcass) is suggested. The use of group subscripts (siW, siC and siR) as a complementary tool to current program indexes may be useful to fix specific problems in herds, which require targeted mating, otherwise the progenies will be unbalanced. In addition to fine adjustments in the herds, it allows the use of a larger number of breeding herds in mating programs, allowing a better orientation of mating in order to reduce inbreeding, increasing the greater gains with the maintenance of genetic variability.

CONCLUSIONS

The subindexes by characteristic groups (siWG, siCG and siRG) are important to correct specific problems in herds, complementing the final indexes of the programs. The iAGc should be used as an alternative to the use of final index of the bull mating programs.

REFERENCES

AMBROSINI, D. P. et al. Interação genótipo ambiente para peso ao ano em bovinos Nelore no Nordeste do Brasil. **Pesquisa Agropecuária Brasileira**, v. 47, n. 10, p. 1489-1495, 2012.

BRUMATTI, R. C. et al. Desenvolvimento de índice de seleção em gado corte sob o enfoque de um modelo bioeconômico. **Archivos de Zootecnia**, v. 60, n. 230, p. 205-213, 2011.

CARVALHO, C. V. D. et al. Interação genótipo-ambiente sobre os pesos aos 205 e 365 dias de idade em bovinos da raça Nelore em diferentes regiões do Brasil. **Revista Brasileira de Saúde e Produção Animal**, v. 14, n. 1, p. 10-20, 2013.

CRUZ, C. D. GENES - a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum. Agronomy**, v. 35, p. 271-276, 2013.

DIBIASI, N. F. et al. Proposta de metodologia para a conversão de escore de avaliação visual de conformação em escore de estrutura, em bovinos de corte. **ARS Veterinária**, v. 26, n. 2, p. 82-87, 2010.

FARIA, C. U. et al. Análise genética de escores de avaliação visual de bovinos com modelos bayesianos de limiar e linear. **Pesquisa Agropecuária Brasileira**, v. 43, n. 7, p. 835-841, 2009.

FERRAZ FILHO, P. B. et al. Divergência genética de touros Nelores com sêmen Disponível em Centrais de Inseminação no Brasil. **Archivos Latinoamericanos de Producción Animal**, v. 16, n. 1, p. 25-31, 2008.

GUIMARÃES, J. D. et al. Seleção e manejo reprodutivo de touros zebu. **Revista Brasileira de Zootecnia**, v. 40, n. 1, p. 379-388, 2011.

LIRA, T.; ROSA, E. M.; GARNERO, A. V. Parâmetros genéticos de características produtivas e reprodutivas em zebuínos de corte (revisão). **Ciência Animal Brasileira**, v.9, n. 1, p. 1-22, 2008.

MALHADO, C. H. M. et al. Parâmetros e tendência genética da taxa de maturação e peso assintótico de bovinos da raça Nelore no estado da Bahia. **Revista Brasileira de Saúde e Produção Animal**, v. 10, n. 2, p. 245-255, 2009.

MARQUES, E. G.; MAGNABOSCO, C. U.; LOPES, F. B. Índices de seleção para bovinos da raça Nelore participantes de provas de ganho em peso em confinamento. **Revista Brasileira de Saúde e Produção Animal**, v. 13, n. 3, p. 669-681, 2012.

MUNIZ, C. A. S. D. et al. Dois Critérios de Seleção na Pré-Desmama em Bovinos da Raça Gir. 1. Estimativas de Parâmetros Genéticos. **Revista Brasileira de Zootecnia**, v. 34, n. 3, p. 807-815, 2005.

SHIOTSUKI, L. et al. Genetic associations of sexual precocity with growth traits and visual scores of conformation, finishing, and muscling in Nellore cattle. **Journal of Animal Science**, v. 87, n. 5, p. 1591-1597. 2009.

RESTLE, J.; VAZ, F. N.; QUADROS, A. R. B. Características de carcaça e de carne de novilhos de diferentes genótipos de Hereford x Nelore. **Revista Brasileira de Zootecnia**, v. 28, n. 6, p. 1245-1251, 1999.

SUGUISAWA, L. et al. Ultrasonography as a predicting tool for carcass traits of young bulls. **Scientia Agrícola**, v. 60, n. 4, p. 779-784, 2003.

VAL, J. E. et al. Alternativas para seleção de touros da raça Nelore considerando características múltiplas de importância econômica. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 60, n. 3, p. 705-712, 2008.

YOKOO, M. J. I. et al. Correlações genéticas entre escores visuais e características de carcaça medidas por ultrassom em bovinos de corte. **Pesquisa Agropecuária Brasileira**, v. 44, n. 2, p. 197-202, 2009.