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Body condition score of Nellore beef cows: a heritable measure to improve the selection of reproductive and maternal traits

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Despite the economic importance of beef cattle production in Brazil, female reproductive performance, which is strongly associated with production efficiency, is not included in the selection index of most breeding programmes due to low heritability and difficulty in measure. The body condition score (BCS) could be used as an indicator of these traits. However, so far little is known about the feasibility of using BCS as a selection tool for reproductive performance in beef cattle. In this study, we investigated the sources of variation in the BCS of Nellore beef cows, quantified its association with reproductive and maternal traits and estimated its heritability. BCS was analysed using a logistic model that included the following effects: contemporary group at weaning, cow weight and hip height, calving order, reconception together with the weight and scores of conformation and early finishing assigned to calves at weaning. In the genetic analysis, variance components of BCS were estimated through Bayesian inference by fitting an animal model that also included the aforementioned effects. The results showed that BCS was significantly associated with all of the reproductive and maternal variables analysed. The estimated posterior mean of heritability of BCS was 0.24 (highest posterior density interval at 95%: 0.093 to 0.385), indicating an involvement of additive gene action in its determination. The present findings show that BCS can be used as a selection criterion for Nellore females.

Keywords: heritability, ordinal logistic regression, score trait, selection criterion, Nellore cattle

Implications

In the beef production system, cows should have a high reproductive performance and maternal ability. These are traits of economical importance. However, due to their low heritability (about 0.10 for reproductive performance and 0.20 for maternal ability), they are rarely included as selection criteria in breeding programmes. The body condition score (BCS) can be used as an indicator of reproductive performances of cows and their calves. In addition, the measurement of BCS is easy, fast, inexpensive and non-invasive. If BCS presents enough additive genetic variability, then it could be used to identify the most efficient females. The results obtained in this study support this hypothesis.

Introduction

Brazil has the second largest effective cattle herd in the world and has been one of the world's largest beef exporters since 2004. Among the specialised cattle breeds for meat production, Nellore cattle accounts for 80% of the beef cattle population. Despite the importance of female reproductive performance for the efficiency of beef production systems, this trait is generally not included as a criterion for animal selection. Instead, beef cattle producers in Brazil select animals based primarily on growth-related traits.

Therefore, beef production could be further optimized by improving the reproductive efficiency and maternal ability of cows. However, these traits are difficult to measure directly and have low heritability; thus, selection for these traits is expected to produce a weak response ($h^2 = 0.03 \pm 0.001$ and 0.18 ± 0.002 for reproductive performance published by Barrozo *et al.*, 2011 and Buzanskas *et al.*, 2012, respectively; and $h^2 = 0.07 \pm 0.006$ and 0.08 ± 0.005 for maternal traits published by Lopes et al., 2013). One alternative measure that could be used as an indicator of reproductive and maternal performance is the body condition score (BCS) (Pryce *et al.*, 2001).

BCS has been used routinely in dairy cows to improve the distribution of food resources for the different categories of females and to help with the disposal of cows due to reproductive failures (Montiel and Ahuja, 2004). BCS measurement

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is easy, fast, inexpensive and non-invasive (Machado *et al.*, 2008) and due to these useful characteristics has been developed as an indirect measure of the body reserves of an animal, and consequently of its reproductive potential. Nevertheless, the existing evidence on the connection between BCS and pregnancy rate is controversial. Lake *et al.* (2005) conducted a study with crossbred cattle and reported increased pregnancy rate in cows with high BCS, whereas Mulliniks *et al.* (2012) found that BCS had no effect on the pregnancy rate. Furthermore, little is known about the variability of BCS in beef cows and whether such differences are heritable. Another important question related to BCS is the number of classes used to assign BCS. The topic has been discussed in the literature in a debating way with the proposed number of BCS classes ranging from three (Taiwo *et al.*, 2010) up to nine (Looper *et al.*, 2010).

The objective of the present study was to investigate the potential of using BCS as an indicator trait of female reproduction performance in beef production and assess its usefulness as a selection tool in breeding programmes. More specific, (i) the effect of different traits associated with cow and calf performance on the variation of BCS was investigated by using an ordinal logistic regression model and (ii) the heritability of BCS was determined.

Material and methods

Beef cattle herd

In this study, a data file of animals from 10 Nellore cattle herds participating in the DeltaGen breeding programme was used. The DeltaGen is a beef cattle breeding programme managed by a cattle raising association whose herds are spread throughout ten Brazilian states. Data from 9035 cows born between 1988 and 2007 were used, and all of the cows had been maintained in tropical pasture systems and received mineral salt. Mating occurred in the rainy season, usually between November and January, by means of controlled natural breeding, or artificial insemination. The mean age at first calving of females was 33.8 ± 3.6 months. Although cows that did not conceive (3019) during the breeding season were removed from the herd, their records were included in the present analyses. The weaning of calves occurred at approximately seven months of age, during the dry season (June to August).

Data set

The data file contained genealogical and zootechnical information for the females as well as data describing the performance of their offspring. Only one BCS measurement was made per cow, during the weaning period of one offspring. The oldest and the youngest cows were 17 and 4 years old, respectively. BCS scores were assigned empirically to cows considering five phenotypic classes (Supplementary Figure S1), according to: 1 (cachectic): full visibility of ribs, exposed iliac and ischial bones and pronounced muscle atrophy ('skin and bones' appearance); 2 (thin): very prominent bones and visibility of the dorsal, iliac and ischial processes; 3 (optimal): slight muscle coverage and no fat layers; 4 (fat): good muscle coverage and some fat deposition in the tail insertion; 5 (obese): all body angles covered, including the protruding parts of the skeleton, and a round appearance of the animal. This grade criterion was described by Machado *et al.* (2008). The reproductive and maternal ability traits of the cow (Table 1) were distributed into phenotypic classes so that both dependent and independent variables were discrete variables. The means and respective standard deviations of BW, cow hip height and calf weaning weight were 408.8 ± 48.04 kg, 140.6 ± 4.63 cm and 180.0 ± 24.02 kg, respectively.

The reproductive status of the female was evaluated upon the diagnosis of pregnancy. For reconception, non-pregnant cows received a score of 1, and pregnant cows received a score of 2. The age of the female was analysed by calving order: primiparous, secundiparous and multiparous females received scores of 1, 2 and 3, respectively. Cow weight and height were categorised into eight and six classes, respectively, based on Sturges' formula (Sturges, 1926), which optimizes the number of classes of these effects (Table 1).

With regard to the calf performance traits, weight, conformation and early finishing at weaning were considered (Table 1). Cows that weaned calves were divided into three classes: lightweight-calf cows with calves up to 144 kg (score of 1), those with calves of moderate weight ranging between 145 and 215 kg (score of 2) and heavy-calf cows with calves weighing over 215 kg (score of 3). Sturges' formula was again used to define the calf weaning weight classes. Visual scores of calf conformation and early finishing at weaning were divided into five phenotypic classes, according to the methodology described by Queiroz *et al.* (2011). A score of 1 was assigned to the worst performing animal, and a score of 5 was assigned to the calf with the best conformation or finishing (Table 1). Contemporary group (CG) was assembled in order to control the unpredictable environmental effects. The CG for the cows was established at calf weaning as a concatenation of the following variables: farm, calving year and season, sex of calf and management group from birth to weaning. For genetic analyses, groups formed by offspring of a single bull, groups with less than two offspring per bull and groups consisting of only one animal were excluded from the database. The initial data set had 9660 animals and 617 CG. After data editing remained 9035 cows and 152 CG.

Non genetic factors affecting BCS were identified using Spearman's correlation. Due to the ordinal nature of BCS, significant effects identified in the previous analyses were included as fixed effects in an ordinal logistic regression model, fitted using the LOGISTIC procedure of SAS (SAS Institute Inc., version 9.0). The logistic model can be represented by the following equation:

$$\log\left(\frac{Pr(\mathrm{BCS} \leq i \mid x)}{Pr(\mathrm{BCS} > i \mid x)}\right) = \boldsymbol{\alpha}_i + \boldsymbol{X\beta},\ i = 1,\dots,4 \qquad (1)$$

where the dependent variable is log-odds of BCS falling within or below the *i*th category *v.* falling above it (for all values of *i*), $\boldsymbol{\alpha}_i$ is the intercept parameter, $\boldsymbol{\beta}$ the vector of

Table 1 *Frequency (*n*) and percentage values (%) for the categorical variables of cows and calves*

		Trait of cow				Trait of calf			
Category		BW	HH	BCS	CO	RE	WW	C	EF
1	Δ	300 to 329	126 to 133				<145		
	n	348	492	161	3373	2601	532	700	700
	%	4.1	5.86	1.9	39.74	30.64	6.27	8.25	8.25
2	Δ	330 to 359	134 to 137				145 to 215		
	n	1020	1613	1599	1667	5887	7370	2028	724
	%	12.02	19.21	18.84	19.64	69.36	86.83	23.91	8.53
3	Δ	360 to 389	138 to 141				>215		
	n	1723	2942	4709	3448		586	2890	1658
	%	20.30	35.03	55.48	40.62		6.90	34.07	19.54
4	Δ	390 to 419	142 to 145						
	n	2116	2129	1775				2004	2713
	%	24.93	25.35	20.91				23.62	31.98
5	Δ	420 to 449	146 to 149						
	n	1702	1072	244				861	2174
	%	20.05	12.76	2.87				10.15	25.63
6	Δ	450 to 479	>149						
	n	970	150						
	%	11.43	1.79						
7	Δ	480 to 509							
	n	440							
	%	5.18							
8	Δ	>509							
	n	169							
	%	1.99							

Δ = range (kg); HH = hip height (cm) of cow; BCS = body condition score; CO = calving order; RE = reconception; WW = weaning weight of calf (kg); C = visual score of conformation of calf at weaning and EF = visual score of early finishing of calf at weaning.

fixed effects (CG at weaning (379 classes), mature weight of cow (8), hip height of cow (6), weaning weight of calf (3), calving order (3), reconception (2), conformation visual score of calf (5), early finishing visual score of calf (5)) and $\boldsymbol{X}$ the incidence matrix relating elements in $\boldsymbol{\beta}$ to the dependent variable. Notice that this model assumes that, for a given independent variable *x*, the effect $\boldsymbol{\beta}$ is constant for all of the cumulative probabilities (proportional odds assumption), whereas a different intercept ($\boldsymbol{\alpha}_i$) is estimated for each cumulative probability. The results regarding to the estimated effects of the independent variables in this model are presented in terms of the odds of falling into a higher BCS category.

In the LOGISTIC procedure of SAS, a stepwise variable selection method was applied, using a significance level of 95% for the inclusion and removal of variables from the model. The significance of the effects included in the model was tested using the χ^2 test. To assess the changes in goodness of fit provided by the inclusion/removal of variables in the model, the Akaike's information criterion (AIC) and the Schwarz's Bayesian information criterion (BIC) were used. AIC minimizes the information loss between the true distribution and the estimate from a candidate model, whereas BIC maximizes the posterior model probability. For both criteria, a smaller value should be preferred or considered as a best model (Burnham and Anderson, 2004; Yang, 2005).

Furthermore, we performed additional logistic regression analyses to verify the effect of BCS on female reproductive and calf performance traits. For this, a series of logistic regression models were fitted, including each trait as the response variable (female reproductive or calf performance) as well as BCS and CG as independent variables. The results regarding to the estimated effects of BCS in each of these models will be presented in terms of the odds of falling into a higher category of each response variable related to female reproduction or calf performance.

Genetic analysis

Using the methodology described by Gianola (1979), variance components for BCS were estimated by fitting a single-trait threshold animal model. It was assumed that an underlying continuous random variable γ could represent the liability for BCS. Because BCS was defined by records falling into five mutually exclusive ordered categories (Table 1), a set of four thresholds (t_1 to t_4) was used to correspond to the discontinuities in the observed scale (y) (under the assumption that $t_0 = -\infty$ and $t_5 = +\infty$), such that: if $\gamma < t_1$, $y = 1$; if $t_1 < \gamma < t_2$, $y = 2$; if $t_2 < \gamma < t_3$, $y = 3$; if $t_3 < \gamma < t_4$, $y = 4$; and if $t_4 < \gamma$, $y = 5$.

In this way, the liability γ was modelled as follows:

$$\gamma = \boldsymbol{X\beta} + \boldsymbol{Zu} + \boldsymbol{\varepsilon} \qquad (2)$$

Table 2 *Sources of variation of the body condition score (BCS) of Nellore beef cattle assessed using logistic regression and the stepwise procedure*

Step	Source of variation	d.f.	χ^2	AIC	BIC
1	Body weight (Cw)	7	1066.2567	18 075.30	18 152.69
2	CG (Cw)	151	2287.3096	15 610.28	16 749.97
3	Hip height (Cw)	5	452.6642	15 148.40	16 323.27
4	Calf conformation (Cf)	4	243.6331	14 902.10	16 105.11
5	Calf early finishing (Cf)	4	38.1914	14 871.96	16 103.11
6	Reconception (Rp)	1	27.5060	14 846.21	16 084.40
7	Calf weaning weight (Rp)	2	21.2490	14 831.53	16 090.83*
8	Calving order (Rp)	2	8.7777	14 826.78*	16 100.15

Cw = cow trait; Cf = calf trait; Rp = reproductive trait; AIC = Akaike information criterion; BIC = Bayesian information criterion of Schwarz; CG = contemporary group.
Asterisks indicate the best model according to each criterion.

where $\boldsymbol{\gamma}$ is the vector with underlying liabilities for BCS and $\boldsymbol{\beta}$ and $\boldsymbol{u}$ the vectors of fixed effects (the same as described in model (1)) and genetic additive random effects of the animal, respectively. $\boldsymbol{X}$ and $\boldsymbol{Z}$ the incidence matrices relating elements in $\boldsymbol{\beta}$ and $\boldsymbol{u}$ to $\boldsymbol{\gamma}$, respectively. The following relationships were assumed: $E[\boldsymbol{\gamma}] = \boldsymbol{X\beta}$; $\boldsymbol{u} \sim N(0, \boldsymbol{A}\sigma^2_u)$; and $\boldsymbol{\varepsilon} \sim N(0, \boldsymbol{I}\sigma^2_\varepsilon)$, where $\boldsymbol{A}$ is the additive genetic relationship matrix and $\boldsymbol{I}$ the identity matrix of order equal to the number of observations.

The THRGIBBSF90 program was used (Misztal, 2002) to fit the model in (2). Three chains with a length of 1 000 000 cycles that had been initiated from different initial values were generated. Flat priors were used for all effects. The samples were stored every 50 cycles. The convergence of the chains generated by the Gibbs sampler was monitored by graphical analysis and diagnosis based on Gelman and Rubin (1992), using the R software 'coda' package (R Development Core Team, 2012).

Results

BCS is associated with the reproductive and maternal traits of Nellore cows

In the studied population, most cows had a BCS of 3 (55%), followed by BCS values of 4 (21%), 2 (19%), 5 (3%) and 1 (2%). All of the reproductive and maternal traits analysed were associated with BCS, as indicated by a significant ($P < 0.001$) correlation between all of the variables and BCS. As expected, the strongest correlation was verified between BCS and BW (0.34, $P < 0.001$), confirming the expectation that BW is the most important component of this score. However, hip height and reconception were only weakly correlated with BCS (0.10 and 0.14, respectively). BCS was negatively and weakly correlated with calving order (−0.05), weaning weight (−0.08), conformation (−0.10) and early finishing (−0.03).

Because all of the variables were associated with BCS, all of them were included in the model for determining the relative contribution of each factor to the observed variability in BCS (Table 2). The logistic regression analysis results showed that all of the factors were significantly associated with BCS variation, although most of the variation was explained by BW and CG (Table 2). Conformation was the most important calf trait identified by the model, whereas reconception was the reproductive character with the greatest impact (Table 2). The best model according to AIC and BIC differed. For AIC, all of the variables were included in the model. In contrast, calving order was excluded for BIC. This is due to the stronger penalization of model complexity in BIC compared with the AIC criterion.

Table 3 illustrates the use of BCS as independent variable and its effect on the traits related to female reproduction and calf performance. Except for reconception, the results are expressed in terms of the odds of each BCS category presenting response in a higher level of the response when compared with the baseline category (BCS = 5). In the case of reconception, results are expressed as the odds of each BCS category achieving success in reconception compared with the baseline category (BCS = 5). For mature weight and hip height, the logistic regression revealed odds ratios (OR) <1; which indicates that, animals with BCS ranging from 1 to 4 have lower chances to be classified into the higher weight and hip height classes when compared with animals with BCS 5. Similar trend is observed for reconception, for which the first classes of BCS (1 to 3) were associated to smaller chances of success in reconception, when compared with BCS = 5. However, there was no difference in the odds of reconception between BCS classes 4 and 5 (confidence interval crosses 1). The OR values suggested that females with intermediate (BCS 3) and heavy (BCS 4 and 5) conditions are more likely to be pregnant when compared with those in the classes of BCS 1 and 2.

For the traits measured in the calf (conformation, early finishing at weaning and weaning weight), cows with BCS ranging from 1 to 4 had a higher probability of weaning heavier calves with better conformation and earlier finishing compared with cows with a BCS of 5 (OR >1). Additionally, the odds ratios were higher for the intermediate BCS classes (Table 3), indicating a higher probability of calves with better performance from mothers in these classes.

BCS is heritable in Nellore cows

As shown in Table 4, estimated posterior mean for the heritability of BCS was moderate, being that the posterior mean

Table 3 *Odds ratios obtained after fitting BCS as an independent variable to model variations in body weight, hip height, reconception, calf conformation, calf early finishing and calf weaning weight*

	Odds ratio (95% CI)			
Traits	1 *v.* 5	2 *v.* 5	3 *v.* 5	4 *v.* 5
BW	0.002 (0.001 to 0.003)	0.008 (0.006 to 0.010)	0.036 (0.028 to 0.046)	0.175 (0.136 to 0.226)
HH	0.489 (0.335 to 0.716)	0.655 (0.507 to 0.845)	0.688 (0.540 to 0.877)	0.734 (0.571 to 0.944)
RE	0.184 (0.110 to 0.306)	0.355 (0.245 to 0.516)	0.612 (0.427 to 0.877)	0.875 (0.603 to 1.269)*
C	4.524 (3.105 to 6.593)	6.279 (4.851 to 8.128)	5.811 (4.542 to 7.434)	3.411 (2.649 to 4.392)
EF	2.859 (1.971 to 4.148)	3.430 (2.664 to 4.416)	3.849 (3.024 to 4.899)	2.632 (2.054 to 3.374)
WW	8.634 (4.506 to 16.543)	12.437 (8.354 to 18.515)	10.740 (7.411 to 15.564)	5.185 (3.546 to 7.583)

HH = hip height; RE = reconception; C = calf conformation; EF = calf early finishing; WW = calf weaning weight.
*Non-significant as 1 is included in the 95% confidence interval.

Table 4 *Summary statistics for the marginal posterior distribution of variance components and the heritability (h^2) of body condition score in Nellore cows*

Estimates	Mean	s.d.	TS-s.e.	HPD lower	HPD upper	Effective sample size
σ^2_a	0.014	0.003	0.00009	0.008	0.019	1002
σ^2_e	0.053	0.043	0.00013	0.021	0.151	1002
h^2	0.242	0.073	0.00023	0.093	0.385	1002

TS-s.e. = time-series standard error (for adjusting the 'naïve' standard error for autocorrelation); HPD = highest posterior density (lower and upper limits for the interval at 95%); σ^2_a = additive variance; σ^2_e = residual variance.
Effective sample size relates to the correlation between samples, measure mixing of the Markov chain.

(highest posterior density interval at 95%) was 0.242 (0.093, 0.385). Graphical inspection of variance components and heritability estimates also showed that the posterior marginal distributions approached to a normal distribution (Supplementary Figure S2). The chains were long enough to obtain more than 1000 effective samples for the marginal posterior distribution of BCS heritability.

Discussion

The present findings indicate that the BCS of Nellore cows is affected by reproductive and maternal traits. As expected, BW and hip height both influenced BCS, as the animal silhouette is the main variable detected by the human eye for BCS determination. However, the raw correlations of BCS to BW and hip height were of low magnitude, indicating that the visual evaluation of BCS does not strongly rely on the subjective assessment of BW and height. Thus, other variables that are difficult to quantify, such as muscle mass and fat distribution in strategic parts of the body of the cow, could have greater relevance in the determination of BCS. In the present study, better BCS cows (from 3 to 5) were more likely to exhibit higher hip height and mature weight, demonstrating that animals with such phenotypes are capable of acquiring the nutrients required for good body conditions from pasture (Table 2).

The finding that cows with higher BCS (from 3 to 5) had a higher probability of reconception indicates that the likelihood of pregnancy in Nellore cows is improved by the presence of body reserves. These results are consistent with the observation that insufficient body reserves can be detrimental to oestrous occurrence (Roche *et al.*, 2007) or the maintenance of pregnancy, as thin cows have a lower percentage of net energy for the development of maternal tissues (Lalman *et al.*, 2000). Additionally, reproduction can be compromised by a negative energy balance (NEB), with the probability of a successful pregnancy decreasing with an increase on NEB (Roche *et al.*, 2007).

Calving order was found to affect the BCS of cows (Table 2) in the present study. Cows in the second calving represented the smallest percentage of total assessed females (19%), and 61% of these animals had BCS values of 3. Cows with three or more births (41%) had the highest frequency of thin scores (1 and 2), while first calving cows (39%) had the highest percentage of scores 3, 4 and 5 (data not shown). Cows with two or more calvings likely experienced increased physiological wear due to successive pregnancies and lactations, resulting in a loss of body reserves. First-calf heifers, despite having to mobilize nutrients and body reserves for pregnancy, lactation and growth, generally exhibited better body conditions than other females during the breeding season, permitting them to progress through the reproductive stages without losing as much weight. It is also possible that milk production in primiparous females is lower, resulting in lower consumption of body reserves; however, Freneau *et al.* (2008) previously observed that the BCS of growing females was similar to that of mature cows.

In terms of calf performance, the values observed in this study suggest that cows with intermediate BCS score (2 and 3) wean heavier calves with better conformation and earlier finishing (Table 3). Accordingly, the body reserves of the cows are consumed as more nutrients are used for the production of calves. These results suggest some degree of variation among females in terms of nutrient mobilisation for calves. Whereas some animals mobilize body reserves for milk production, others store reserves in the adipose tissue. Hence, cows that produced less milk and weaned lighter calves with poor conformation and later finishing accumulated greater body reserves and, consequently, exhibited better body conditions (Vieira *et al.,* 2005). In a dairy cattle study, Loker *et al.* (2012) found an unfavourable genetic correlation between BCS and milk production that increased as the lactation period progressed: the higher the milk production, the worse the body condition of the cow. Conversely, Lake *et al.* (2005) found no significant effect of cow BCS on the calf weaning weight.

The estimated value of BCS heritability (0.24) obtained in this study indicates additive gene action and the possibility of using BCS as a criterion for the selection of Nellore cows. However, the inclusion of fixed effects in the model (i.e. cow weight, calf weight and calf conformation, among others) influenced by genetic factors also associated with BCS may have contributed to the reduction of BCS additive variance estimates. Genetic parameter estimates for BCS in beef cattle have been reported in a few studies. Johnston *et al.* (1996) reported BCS heritability estimates between 0.14 and 0.21 for Angus, Hereford and Polled Hereford cows. In a more recent study, Arango *et al.* (2002) estimated BCS heritability values of 0.22 and 0.51 for beef cows of different breeds at 2 and 8 years of age, respectively.

In this study, five BCS classes were used to represent the existing variability of this trait in Nellore. The high variability in the number of BCS classes used (from three to nine classes in Blank and Agabriel, 2008; Ayres *et al.*, 2009; Looper *et al.*, 2010; Taiwo *et al.*, 2010; Mulliniks *et al.*, 2012) complicates comparisons among studies, and we therefore propose the standardization of this number. A smaller number of classes can make phenotypic discrimination difficult, while a larger number of phenotypic classes hampers the training of evaluators for the collection of field data, increases the required observation time in the cowshed and may result in increased costs. Additionally, with few animals assigned extreme scores, several classes may need to be grouped for data analysis (Looper *et al.*, 2010; Mulliniks *et al.*, 2012).

An intermediate scale of phenotypic classes would therefore ensure a better distribution of animals across all scores. Additionally, an intermediate scale and an even number of classes, for example, 1 to 4 or 1 to 6, may permit improved phenotypic discrimination among individuals and thereby circumvent the problem of a large concentration of animals with intermediate scores. The advantage of standardising the number of BCS phenotypic classes is therefore two-fold: it would facilitate the decision-making process and allow comparisons to be made among different studies.

The variability obtained for BCS and the significant association of this score with all of the reproductive and maternal ability traits assessed support the inclusion of this criterion in the index for female selection, with cows exhibiting BCS scores of 3 and 4 as the most ideal for maintaining the breeding stock. BCS is easily measured and has a low implementation cost as the only requirement is good training of the personnel in charge of herd management. The routine use of BCS in farms would facilitate breeding herd management and reduce the amount of time animals need to remain in the cowshed. BCS could be used as a replacement for the weighing of cows at farms where this management procedure has not been incorporated into the working routine. An advantage of using BCS in addition to BW is that BCS is informative about the cow silhouette.

The time period used for BCS measurement must be well evaluated and standardized. BCS measurements at the start of the breeding season may be useful for the identification of females with low nutritional reserves and the formation of lots for supplementation for increasing pregnancy rates. BCS measurements at the point when pregnancy is diagnosed would be useful for identifying and supplementing females with great body wear from pregnancy and lactation. Finally, BCS measurements during weaning would help identify and enrich the diets of cows with the worst scores at the end of pregnancy to allow them to recover for the next calving, lactation and conception events. Future studies with BCS measurements repeated at each stage of the same production cycle of beef cows will help to elucidate how body reserves are mobilized. Furthermore, the genetic and phenotypic correlations of BCS with other breeding programme selection criteria must also be estimated for the effective inclusion of BCS as selection criterion for Nellore cows.

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Supplementary material

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