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Genetic analysis of average annual productivity of Nellore breeding cows (COWPROD)

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ABSTRACT. With the aim of estimating the coefficient of heritability of average annual productivity of Nellore cows (COWPROD), a data set from 24,855 animals with known pedigree was analyzed. COWPROD is defined as the amount (in kilograms) of weaned calves produced yearly by one cow during her remaining time in herd ignoring a fixed period of 365 days. COWPROD was calculated regarding three standards: a) based on the post-weaning weight from the calves ignoring any kind of adjustment (COWPROD_NAJ), b) adjusted weight for the fixed effects (COWPROD_AJFIX) and c) adjusted weight for the fixed effects and for the genetic merit of the sire (COWPROD_AJFIN). The obtained heritabilities were 0.15, 0.15 and 0.16 for COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN, respectively. A complete set composed of 105,158 COWPROD records on 130,740 animals in pedigree was also analyzed for predicting the genetic merit of all animals in the data set and for the calculation of the genetic, phenotypic and residual trends. Ranking correlation was high for the adjusted and non-adjusted data, yet, for some of the animals, the difference among the genetic values was large. This would be an indication that it would be better to work always with the adjusted weaning weights. The genetic trend was positive, but was of small magnitude (0.26% of the trait average) and the residual trend was negative as a consequence of the large intensification of the production system, which has been occurring in the last years in the farms studied. The phenotypic trend was also negative and intermediate between the genetic and the residual ones.

Key words: Beef cattle; Productive efficiency; Heritability; Selection; Genetic trend

INTRODUCTION

In any beef cattle production system, the search is for profitable economic performance or, in other words, productive efficiency. Reproduction is one of the important components for productive efficiency, but the number of kilograms of weaned calves is the main factor of concern.

In Nellore breeding, the reproductive processes are deeply related to the heifer sexual precocity and to the fertility of the adult female. Some studies have shown that the sexual precocity of the Nellore breed can be genetically improved by selecting sires based on their genetic merit regarding scrotal circumference (Brinks et al., 1978; Smith et al., 1989; Eler et al., 1996) and in a more efficient way, by the genetic merit of sires regarding the probability of pregnancy of the young female (Eler et al., 2002, 2004; Silva et al., 2005). The age of first calving as a selection criterion, however, depends significantly on the age that those females are first exposed to the reproductive process (Pereira et al., 2001a,b, 2002, 2006). Using survival analysis, Pereira et al. (2006) obtained a high heritability estimate for age of first conception for heifers that have been exposed to reproductive processes aged around 14 months. The stayability in the livestock for at least 6 years (Silva et al., 2003, 2006; Van Melis et al., 2007) has been reported as a feature related to the fertility of the adult female. In general, the reproductive management of beef cattle is based on the culling of females which do not calve in the breeding season or of those that wean a very light calf. Thus, this trait is related to sexual precocity, fertility and calf post-weaning weight gain. The weaning weight in turn is directly affected by the calf's genotype and indirectly by that of the dam. The dams' mothers show a genetic variability for milk production and maternal ability, which results in differentiated maternal environments for the calves aside from their direct additive genetic contribution. Lôbo (1996) proposed the use of an index called accumulated productivity (PAC) for evaluating herd productivity. This index takes into account the total amount of weaned calves (in kg) and the total length of time for its production. For evaluating productive efficiency, PAC could be a more adequate index than stayability in the livestock, as it allows the inclusion of the young females that have only one calf, enabling the prediction of the genetic merit for younger bulls. Schwengber et al. (2001) report a heritability estimate of 0.15 for that trait. Heritability could be of a sufficient magnitude for the use of PAC as criterion for bull selection, regarding reproductive efficiency, replacing in this case stayability.

In the model proposed by Lôbo (1996), the equation for the calculation of cow productivity has considered, as its target, first calving at 30 months of age. In the population analyzed in this study, the exposure of heifers to bulls at 14 months of age has been taking place since 1995, and this allows the choice of the goal for first calving at the age of 24 months. The designation of this trait has also been chosen as "average annual productivity (COWPROD)", taking into account that the cow phenotype is considered as a yearly average of calf production instead of being just a sum of the weights.

The objectives of the present study were: a) to propose a change in the denominator of the equation for assessing COWPROD, considering that what had been assessed before is being assessed at this moment through the use of a new equation yielding the average annual production of each cow instead of its accumulated production, and b) to estimate heritability of the average annual production and to calculate the genetic, phenotypic and residual trends for this trait in a large population of Nellore cattle.

MATERIAL AND METHODS

The data used in this research came from the files of Agro-Pecuária CFM Ltda., cattle breed-

ing company located in Southeastern and Central-Western Brazil. Calves had been raised on pastures, receiving mineral supplementation throughout the year. From 1984, that is, the start of data recording, until 1995, the heifers were first exposed to breeding at the age of approximately 24 months. From 1995/1996, the heifers started to be first exposed to reproduction at the age of 14 months. The heifers that did not conceive at this first exposure were given another chance at the age of 24 months. A short breeding season of 60 days for cows and 90 days for heifers has always been adopted.

The initial data set included 460,873 calves with post-weaning weights and born between 1984 and 2005 in the States of São Paulo, Mato Grosso do Sul and Goiás. The calves, 392,085 Nellore and 68,788 crossbred, were from 175,514 Nellore cows born between 1980 and 2003. From the total number, 299,517 calves had unknown sires or they were born from multiple sire groups which were also studied as coming from unknown sires, and 161,356 were generated by 1377 bulls. The calves were distributed into 9499 contemporary groups. Initially, an attempt was made to derive the adjusted weight directly from a GLM analysis using the Proc Mixed of SAS (1995), in a model that included the contemporary group, age at weaning, Julian date of birth, age of dam, and percentage of Nellore breed as fixed effects and sire of calf as random effect. However, this analysis could not be done because of excessive RAM demand. In this case, a BLUP analysis was adopted to predict breeding value for using an animal model that included the above mentioned fixed effects, the additive direct and maternal genetic effects, besides the permanent environment of the cow and residual effects as random. The Animal Breeders Tool Kit (Golden et al., 1995) software was used for processing the data which provided both the prediction of the expected progeny difference (EPD) and the solutions for the fixed effects. The post-weaning weight of the calves was adjusted for the fixed effects and for their sires' EPD, using previously obtained solutions.

A file for the cows was created that included, for each cow, the COWPROD, calculated based on the average of post-weaning weights of calves. In creating this file, only the cows that had first calved by the age of 42 months were included, which means the ones that had had their calving record controlled since the start of their reproductive lives. For this analysis, three different productivities were studied: a) COWPROD_NAJ which was assessed based on the weaning weight without any adjustment; COWPROD_ AJFIX which was assessed based on the weaning weight adjusted to the fixed effects (contemporary group, age of the calf at weaning, Julian date of birth, age class of dam, and Nellore percentage), and COWPROD_AJFIN, assessed based on the weaning weight adjusted to the fixed effects mentioned above and also for the sire's EPD. COWPROD was calculated by the equation:

$$\mathbf{COWPROD_i} = \frac{\sum_{j=1}^{n} \mathbf{WW_{ij}} \times \mathbf{365}}{\mathbf{AC_n} \quad \mathbf{365}}$$

where $COWPROD_i$ = average annual productivity for the i^{th} cow; $\sum_{j=1}^{n} WW_{ij}$ = sum of the weaning weight of all the calves from each cow. For assessing the COWPROD_NAJ, WW_{ij} is the non-adjusted weaning weight of the j^{th} calf from the i^{th} cow. For assessing the COWPROD_ AJFIX or the COWPROD_AJFIN, WW_{ij} corresponds to the adjusted weaning weight; AC_n = age of the cow at its last calving. The 365 value in the numerator of the equation refers to an annual production base and the 365 one in the denominator refers to the calving goal at 24 months and starts in reproduction aged 12 months. Using the above equation, COWPROD can be defined as the amount, in kilograms, of weaned calves produced yearly by a cow during its remaining time in the

herd, ignoring a fixed period of 365 days. This period is in regard to the minimum age for a heifer to start its reproductive life.

After discarding the observations in the contemporary groups consisting of less than five cows, the composed file count of 105,158 cows were distributed into 273 contemporary groups which were formed by the concatenation of farm + birth year of the cow. Of the total number of the cows, 80,289 of them originated from multiple sires or from really unknown sires, and 24,868 originated from 788 bulls. There were 57,367 dams of cows. For the estimation of genetic parameters, a file of known sires was used, which, after eliminating the animals in contemporary groups with less than five individuals, counts of 24,855 cows were distributed into 107 contemporary groups. These cows originated from 787 bulls and 17,741 cows. The pedigree included all the known ancestors and totaled 48,668 animals. The genetic and residual variance components were estimated by restricted maximum likelihood through the use of the MTDFREML software (Boldman et al., 1995), according to an animal model which included the contemporary group as a fixed effect besides the direct genetic and residual effects as random.

For genetic prediction, the model described above was also adopted, yet the genetic values concerned up to 130,740 animals. These refer to the pedigree from the whole file, counting 105,158 observations. The genetic merit of the animals for COWPROD was also expressed as EPD, corresponding to half of the predicted genetic value.

Genetic trends were calculated by the regression of the genetic values of the animals on their birth year. The phenotypic trend tendency was assessed by the regression of the phenotypic values (COWPROD) on the birth year. The environmental (residual) trend was calculated by the regression of the solutions for the contemporary groups weighted by the number of observations in each group on the birth year of the individuals. In this study, of the group of cows born in 2003, only those that had precociously calved (less than 30 months old) were analyzed. For the remaining cows, we did not yet have their calf's weaning weight (calves to be born in 2006). The cows born in the year 2003 were a selected group and consequently showed a high value of COWPROD, and thus their average does not rightly represent the year 2003. That is why these cows were dropped from the figures and the trends calculated up to the year 2002.

RESULTS AND DISCUSSION

The means and standard deviations of the average annual productivity were 107.6 ± 30.0, 102.9 ± 26.6 and 101.3 ± 32.0 kg of weaned calves per cow per year for the COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN, respectively. The averages in this study were lower than those of Rosa (1999) who reported averages of 144 kg and those of Schwengber et al. (2001) who reported a mean of 135 kg. However, the change in the denominator of the equation is emphasized in this study. Performing the calculation of the COWPROD based on Lôbo's equation (1996), used by Schwengber et al. (2001), the average would be 129.5 ± 34.2, 124.3 ± 29.4 and 122.4 ± 29.0 kg, for COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN, respectively.

Considering only the cows with known sires, the means and their standard deviations obtained in this study were 115.0 ± 26.9, 107.0 ± 26.3 and 104.2 ± 32.2 kg of weaned calves per cow per year for the COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN, respectively. The variance components and heritability estimation for the average annual productivity are shown in Table 1.

Table 1. Estimation of the additive genetic (σ^2_a), residual (σ^2_e) and phenotypic (σ^2_p) variances and estimation of heritability (h^2) of average annual productivity (COWPROD) in Nellore cattle.

Trait	σ^2_a	σ^2_e	σ^2_p	h^2
COWPROD _NAJ	127.65	727.53	855.18	0.15
COWPROD _AJFIX	98.40	527.38	625.78	0.15
COWPROD _AJFIN	93.47	504.55	598.02	0.16

For other abbreviations, see legend to Figure 1.

Besides being very close to each other (0.15, 0.15 and 0.16 for the COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN), the heritability estimates also agreed with the results published by Rosa (1999) and by Schwengber et al. (2001) who reported values of 0.19 and 0.15, respectively. Baldi et al. (2008) have also reported a heritability value of 0.15 for the amount, in kg, of weaned calves per year of stayability of the cow in the herd. The average annual productivity shown by the amount (in kg) of weaned calves per year of stayability in the herd (COWPROD) is a function of the weight of the weaned calves and of the total number of calves produced during the permanence of a cow in the population. Thus, the sexual precocity and the length of the life of a cow are determinant factors for the increase in COWPROD.

The values in Table 1 indicate that the response to the direct selection for this trait will be small. Nevertheless, these values of heritability allow the differentiation of bulls that produce daughters with a high or a low COWPROD; in other words, it would be possible to obtain considerable genetic gain from bull selection. The highest value for estimates of heritability for COWPROD_AJFIN indicates that the use of adjusted weights when calculating COWPROD should be indicated for sire selection.

On the other hand, even though heritability values for COWPROD are not high, they are similar to those obtained for stayability in the same population (Van Melis et al., 2007). COWPROD can, however, be better than the stayability as a selection criterion for reproductive efficiency, because it allows the prediction of the genetic merit for the young cows and consequently the identification of the best young sires.

The maximal and minimum values for the EPD of average annual production of cows and the rank correlation values are shown in Tables 2 and 3, respectively.

Table 2. Minimum and maximal value for the expected progeny difference of average annual productivity (COWPROD).

Trait	Minimum	Maximal
COWPROD_NAJ	-13.4	15.9
COWPROD_AJFIX	-11.5	13.0
COWPROD_AJFIN	-11.3	12.9

For other abbreviations, see legend to Figure 1.

Table 3. Rank correlation among the traits COWPROD_NAJ, COWPROD_AJFIX and COWPROD_AJFIN in Nellore cattle, assessed for all the animals and for only the bulls.

Trait	All animals		Bulls	
	COWPROD_AJFIX	COWPROD_AJFIN	COWPROD_AJFIX	COWPROD_AJFIN
COWPROD_NAJ	0.965	0.963	0.976	0.973
COWPROD_AJFIX	1.00	0.999	1.00	0.997

For other abbreviations, see legend to Figure 1.

The high values for the correlations allow the conclusion that the COWPROD could be calculated based on the weaning weights of the calves without any adjustment, which would make the processing of the genetic evaluation easier. However, some differences of up to 5 kg between the adjusted and non-adjusted EPD were observed, corresponding to more than 30% of the maximal value for the trait. The larger differences were related to the cows with just few calves and, mainly, when the differences between the COWPROD values assessed based on the adjusted and non-adjusted weight occur in the opposite direction of the average differences in the contemporary group. Regarding the bulls, the ranking changes are really small. As for the cows, more important changes can be observed. These results indicate the direction that the assessment of the COWPROD should be done based on adjusted weights.

The genetic, phenotypic and residual trends can be viewed in Figures 1, 2 and 3. The genetic trend regarding the population of this study was low yet positive (around 0.26% of the average of the trait) from the year 1993 to 2002 (Figure 1). The values were similar for the adjusted and non-adjusted COWPROD ones. PODVAC is a complex trait which actually involves a set of other traits such as sexual precocity, fertility, longevity, and growth. There had not been for this population any direct selection for COWPROD, yet a selection for precocity and for pre-weaning performance is taking place, as shown by the selection index used (CFM, 2006, pg. 4), which was not totally reflected in the genetic improvements for the average annual production.

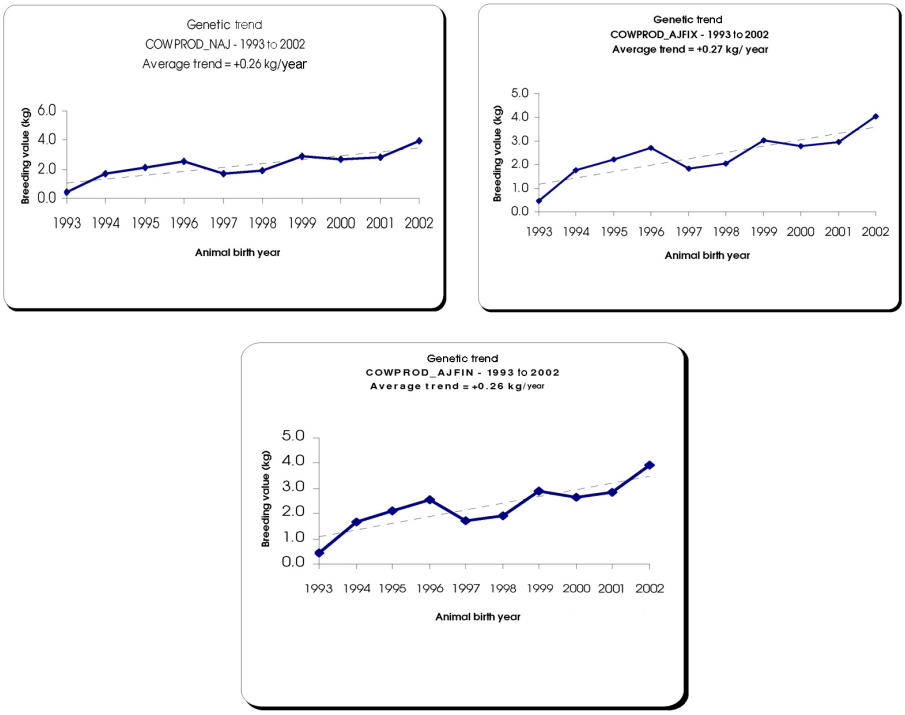

Figure 1. Observed genetic trend for the average annual productivity (COWPROD) calculated based on the non-adjusted weaning weight of the calves (COWPROD_NAJ), adjusted for the fixed effects (COWPROD_AJFIX) and adjusted for the fixed effects and for the sire's genetic merit (COWPROD_AJFIN).

The environmental trend (Figure 2) was negative and of large magnitude (around 2.9% of the average). With a fast reading, these effects could be confounded by the degradation of the pastures and some other restrictive factors in the production system. A more cautious analysis, however, points to the intensification of the system which has proved to be happening in the last few years, mainly from the year 2000.

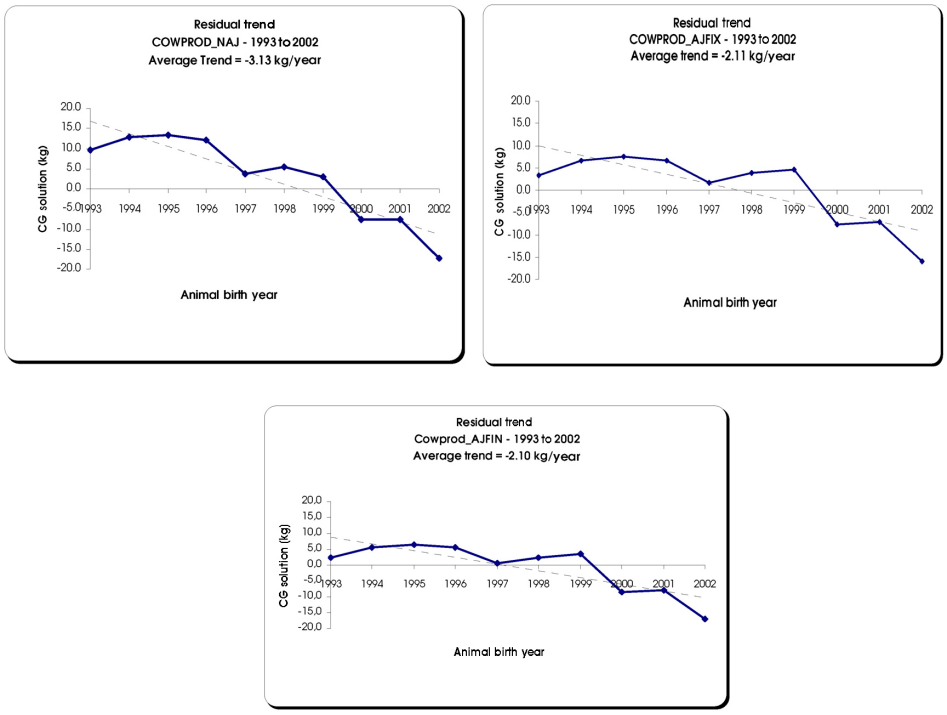

Figure 2. Observed environmental (residual) trend for the average annual productivity (COWPROD) calculated based on the non-adjusted weaning weight of the calves (COWPROD_NAJ), adjusted for the fixed effects (COWPROD_AJFIX) and adjusted for the fixed effects and for the sire's genetic merit (COWPROD_AJFIN). CG = contemporary group.

Trying to turn livestock into a competitive activity in comparison to the production of sugar cane on the high-valued lands of São Paulo State, the production systems have been intensified and the population capacity of the pastures has been drastically increased from 2 au/ha to at least 6 au/ha. The production per area unit has been increased as expected, but the individual animal performance has decreased in relation to the historical average, due to some intrinsic factors which have not yet been totally identified.

Negative environmental trends were also verified in the performance and sexual precocity traits as a consequence of the large intensification of the production system (Eler et al., 2005).

The phenotypic trend (Figure 3) was also negative and of large magnitude (around 2.2% of the trait average). The reduction of the phenotypic trend was consistent with the result of the environmental (residual) trend, showing intermediate values between the genetic and the environmental trends.

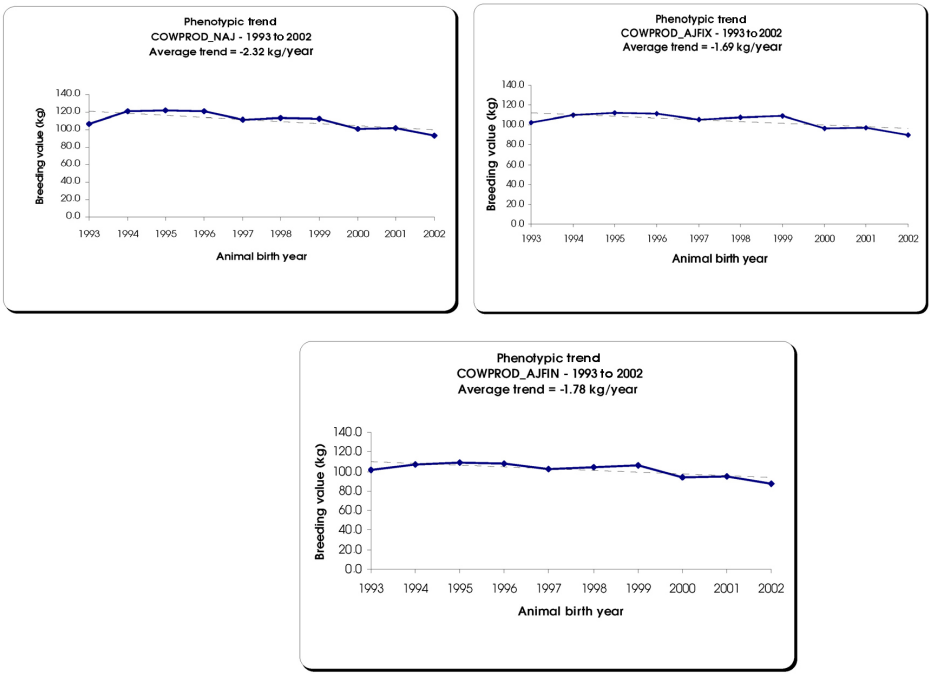

Figure 3. Observed phenotypic trend for the average annual productivity (COWPROD) calculated based on the non-adjusted weaning weight of the calves (COWPROD_NAJ), adjusted for the fixed effects (COWPROD_AJFIX) and adjusted for the fixed effects and for the sire's genetic merit (COWPROD_AJFIN).

CONCLUSIONS

The results of this study allow the conclusion that the average annual productivity (kg) of weaned calves (COWPROD), a trait of the cow, shows a moderate heritability and, consequently, a little response to selection. The selection of bulls that have a high number of progenies may, however, have an impact on the response to selection.

Even though the ranking correlation was considered high, COWPROD calculated based on adjusted weights seems to be more adequate, taking into account that some of the animals show significant differences between the adjusted and non-adjusted values.

The average genetic trend from 1993 to 2002 was small, but a selection had been performed for the traits that compose the average annual productivity, such as weaning weight and sexual precocity.

This suggests that the COWPROD data should be analyzed together with the stayability ones for assessing the correlation between the traits. Even if the correlation is high, COWPROD would be a more adequate selection criterion for including also younger animals in the evaluation.

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