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GENETIC ANALYSIS OF PERFORMANCE TRAITS IN CANCHIM CATTLE. I. BODY WEIGHT

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ABSTRACT

Data for 1290 Canchim animals (579 males and 711 females), born between 1958 and 1973, were used to estimate phenotypic and genetic parameters for weight at birth and at 6, 12, 18 and 24 months of age. Effects of sex, month and year of birth and dam age were included in the mathematical model. All parameters significantly affected weight at 6, 12, 18 and 24 months, though year of birth had no detectable effect on birth weight. Least squares means were: 35.7 kg for birth weight, 166.4 kg for weight at 6 months, 235.7 kg for weight at 12 months, 300.5 kg for weight at 18 months, and 366.6 kg for weight at 24 months. Paternal half-sib estimates of heritability for males and females separately and combined were 0.31 ± 0.13, 0.39 ± 0.12 and 0.28 ± 0.08 for birth weight; 0.62 ± 0.16, 0.27 ± 0.11 and 0.36 ± 0.09 for weight at 6 months; 0.70 ± 0.17, 0.37 ± 0.12 and 0.46 ± 0.10 for weight at 12 months; 0.53 ± 0.15, 0.47 ± 0.13 and 0.36 ± 0.09 for weight at 18 months; and 0.33 ± 0.13, 0.42 ± 0.13 and 0.26 ± 0.08 for weight at 24 months, respectively. Coefficients of genetic correlation between birth weight and weight at 6, 12, 18 and 24 months for males and females combined were: 0.14, 0.08, 0.09 and 0.02, respectively. Genetic correlations between weight at 12

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months and weight at 18 and 24 months were high (0.86), leading us to conclude that selection based on weight at 12 months for both sexes can be considered to be the best alternative for improvement of weight gain in Canchim cattle.

INTRODUCTION

After obtaining success at exhibits and in weight-gain tests, the Canchim breed has been expanding throughout Brazil, suggesting a potential for adaptation to different regions. Several farms are now involved in raising Canchim cattle both for commercial production of meat calves and for sires. However, limited information is available on the productive performance of Canchim cattle, especially with respect to post-weaning weights, although these data are of extreme importance for better knowledge of the herd, knowledgeable guidance in performance tests, and other aids for selection in attempts to increase rates of genetic progress in this new breed.

The present worldwide tendency is to obtain animals with early high slaughtering weights, and for this reason most studies on this subject are based on data for weight up to 12 and 18 months. In Brazil, where straightbred and crossbred Zebu cattle, known to develop slower than European cattle, predominate, information on later ages is needed. The objectives of the present study were to determine estimates of genetic and phenotypic parameters for weights at birth and at 6, 12, 18 and 24 months of age in Canchim cattle, and thereby evaluate the possibilities of selection for weight in this breed.

MATERIAL AND METHODS

Data were obtained from the records of the Canchim farm, São Carlos, State of São Paulo, Brazil, for animals born from 1958 to 1973. Births were distributed over every month in the year. Weight was measured at birth and at 6-month intervals up to 24 months for 1290 animals (579 males and 711 females) sired by 55 bulls. Details of climate and management program have been presented elsewhere (Oliveira *et al.*, 1982).

Statistical analysis

Data were analyzed by mixed-model least-squares procedures (Harvey, 1972). The following model was used:

$$Y_{ijklno} = \mu + m_i + a_j + v_k + s_l + t_n + e_{ijklno}$$

where Y_{ijklno} is a performance trait, μ is the least-squares mean, m_i is the fixed effect of month i, a_j is the fixed effect of year j, v_k is the fixed effect of age k, s_l is the fixed effect of sex l, t_n is the random effect of sire n, and e_{ijklno} is the residual within-animal error variance. Paternal half-sib estimates of heritability were calculated according to the following formula: $h^2 = 4\sigma_s^2/(\sigma_s^2 + \sigma_e^2)$, where σ_s^2 and σ_e^2 are the component of variance estimates for sire and error. The standard error of this estimate was obtained by the formula of Swiger *et al.* (1964).

Correlations were obtained from variance and covariance components for sire and error. The following formulas were utilized:

Genetic correlation: $$r_A = \frac{\hat{\sigma}_{S(xy)}}{\sqrt{\hat{\sigma}^2_{S(x)}\ \hat{\sigma}^2_{S(y)}}}$$

Phenotypic correlation: $$r_p = \frac{\hat{\sigma}_{E(xy)} + \hat{\sigma}_{S(xy)}}{\sqrt{(\hat{\sigma}^2_{E(x)} + \hat{\sigma}^2_{S(x)})(\hat{\sigma}^2_{E(y)} + \hat{\sigma}^2_{S(y)})}}$$

Environmental correlation: $$r_E = \frac{\hat{\sigma}_{E(xy)} - 3\,\hat{\sigma}_{S(xy)}}{\sqrt{(\hat{\sigma}^2_{E(x)} - 3\hat{\sigma}^2_{S(x)})(\hat{\sigma}^2_{E(y)} - 3\hat{\sigma}^2_{S(y)})}}$$

where $\hat{\sigma}_{S(xy)}$ and $\hat{\sigma}_{E(xy)}$ are covariance components for sire and error respectively; $\hat{\sigma}^2_{S(x)}$ and $\hat{\sigma}^2_{E(x)}$ are variance components for sire and error for trait x; and $\hat{\sigma}^2_{S(y)}$ and $\hat{\sigma}^2_{E(y)}$ are variance components for sire and error for trait y, respectively. The standard errors for genetic correlations were estimated by the method of Tallis (1959).

RESULTS AND DISCUSSION

Table I gives the number of observations and least squares means for weight at birth and at 6, 12, 18 and 24 months of age. It can be seen that the difference in weight favoring males increased with age: 3.22 kg at birth, 15.20 kg at 6 months, 35.28 kg at 12 months, 46.49 kg at 18 months, and 56.05 kg at 24 months. All effects included in the mathematical model were significant for the weights studied, except for year of birth, which did not significantly affect birth weight.

Table I -Number of observations and least-squares means for body weights.

Trait	Number of Observations	Mean
Weight at birth		
(1)	579	37.47
(2)	711	34.25
(3)	1290	35.65
Weight at 6 months		
(1)	579	175.92
(2)	711	160.72
(3)	1290	166.40
Weight at 12 months		
(1)	579	255.64
(2)	711	220.36
(3)	1290	235.65
Weight at 18 months		
(1)	579	328.19
(2)	711	281.70
(3)	1290	300.51
Weight at 24 months		
(1)	579	398.55
(2)	711	342.50
(3)	1290	366.63

(1) Male; (2) Female; (3) male and female combined.

Heritability estimates

Heritability estimates were between 0.27 and 0.70 (Table II). Their standard errors, however, were relatively small, thus conferring a certain confidence to them. Highest heritability among females was for weight at 18 months, followed in decreasing order by weight at 24 and 12 months, at birth, and at 6 months. Increased heritability for weight after 12 months perhaps suggests lower effects of prenatal and preweaning factors, which largely account for manifestation of weight at birth and at 6 months. This permitted a growing participation of the genetic potential in animal pheno-

Table II - Components of variance and heritabilities for the performance traits.

Trait	Components of variance		$h^2 \pm$ S.E.
	Sire	Error	
Weight at birth			
(1)	2.496	29.739	0.31 ± 0.13
(2)	2.577	24.114	0.39 ± 0.12
(3)	2.014	27.236	0.28 ± 0.08
Weight at 6 months			
(1)	118.703	648.102	0.62 ± 0.16
(2)	41.991	577.010	0.27 ± 0.11
(3)	63.314	633.553	0.36 ± 0.09
Weight at 12 months			
(1)	238.053	1122.835	0.70 ± 0.17
(2)	70.364	700.024	0.37 ± 0.12
(3)	129.297	992.977	0.46 ± 0.10
Weight at 18 months			
(1)	327.111	2137.965	0.53 ± 0.15
(2)	135.280	1022.062	0.47 ± 0.13
(3)	176.420	1763.826	0.36 ± 0.09
Weight at 24 months			
(1)	311.844	3444.364	0.33 ± 0.13
(2)	124.352	1071.205	0.42 ± 0.13
(3)	174.257	2509.785	0.26 ± 0.08

(1) Male; (2) Female; (3) Male and female combined.

type, i.e. expression of the genetic constitution of each individual in response to environmental effects. Thus, additive genetic variance possibly increased as maternal effects decreased. On the other hand, the lower heritability of weight at 6 months in relation to birth weight may be attributed to an additional component in the phenotypic variance of weight at 6 months, i.e., maternal environment. Weight at 6 months is the expression of several factors, the most important of which probably are cow's milk yield and calf growth capacity. Obviously, an animal with low growth potential might not utilize its mother's milk properly, whereas an animal with good growth potential may suffer impaired growth from lack of food. Thus, whereas birth weight is less affected by environmental conditions, the possible interactions between calf growth ability and mother milk yield could cause lower heritabilities for weight at 6 months.

In contrast, among males, heritability increased with age up to 12 months, after which it decreased. Heritability was lowest for birth weight. If the preceding explanations are correct, than this result is improbable and may be possibly attributed to factors already discussed that may have contributed to under- or overestimates.

Comparison of heritability for males and females separately showed highest values for females at birth and at 24 months, and highest values for males at 6, 12 and 18 months. The higher heritability of birth weight for females when compared to males was somewhat surprising, since opposite results have been reported in the literature (Pahnish *et al.,* 1963, 1964; Molinuevo and Vissac, 1972), even for the same breed (Oliveira, 1977). Results agreeing with ours were obtained by Koch *et al.* (1973) and by Verde and Bodisco (1976). On the other hand, Dunn *et al.* (1970) obtained a difference in favor of males in "pure" breeds, and a difference in favor of females in crossbred animals. The higher heritability of weight at 6 months obtained for males in relation to females in the present study agreed with results of Molinuevo and Vissac, but disagreed with those of Salvi (1960). However, there is evidence in the literature that heritability of weaning weight is higher for females than males (Pahnish *et al.,* 1964; Kosh *et al.,* 1973). Reports on weight at 12 and 18 months apparently are limited to two studies (Salvi, 1960 and Swiger *et al.,* 1963) respectively, in which results similar to ours were obtained. As for weight at 24 months, no reports were found in the literature consulted on heritabilites for males and females separately.

Varying interpretations have been made of the differences in heritabilities apparently occurring between sexes. They have been suggested to be due to different types of management used for males and females, to the methods of estimation used, and to sex-linked genes. According to the last interpretation, which postulates the existence of genes affecting growth located on chromosome X, higher genetic correlations may exist between mother and son than between mother and daughter. This would lead, therefore, to higher heritabilities for males if estimated from mother-offspring regression, a possibility that partially agrees with the results obtained in the present study by paternal half-sib analysis. However, since the two methods were not used concomitantly in the present study, we cannot draw firm conclusions on the validity of this explanation. Another possible explanation for the different heritabilities for males and females is the occurrence of an interaction between sires and progeny sex in such a way that variances between sire and progeny within sire might contain the effect of differences between sexes.

On the basis of the results obtained here, the heritabilities suggest that the herd (males and females) has sufficient additive genetic variability for a response to mass selection based on weights at birth and at 6, 12, 18 and 24 months.

Phenotypic, genetic and environmental correlations

Genetic, phenotypic and environmental correlations are given in Tables III through V. Phenotypic correlations show that the condition of being lighter or heavier tends to be a constant peculiarity throughout the life of the animals in the herd studied from birth to 24 months. Genetic correlations suggest, in general, that the genes responsible for the manifestation of the weight trait at a given age regulate the expression of this same trait at a later age. According to Falconer (1982), genetic association of traits probably is due to the pleiotropic effects of genes, or possibly to linkage effects.

Table III -Phenotypic, genetic and environmental correlations among body weights (kg) at several ages for males.

	B_W	W_6	W_{12}	W_{18}	W_{24}
B_W		0.161 ± 0.264	0.364 ± 0.238	0.378 ± 0.256	0.262 ± 0.305
W_6	0.237 0.325		0.826 ± 0.080	0.839 ± 0.089	0.745 ± 0.147
W_{12}	0.249 0.174	0.708 0.487		0.948 ± 0.038	0.963 ± 0.065
W_{18}	0.206 0.093	0.662 0.429	0.834 0.684		0.987 ± 0.036
W_{24}	0.204 0.177	0.546 0.412	0.760 0.660	0.876 0.824	

Above the diagonal: genetic correlation

Below the diagonal: phenotypic and environmental correlations.

Similarly, on the basis of environmental correlations, we conclude that environmental conditions affect weight in a similar fashion at different ages.

Table IV - Phenotypic, genetic and environmental correlations among body weights (kg) at several ages for females.

	B_W	W_6	W_{12}	W_{18}	W_{24}
B_W		0.265 ± 0.263	-0.018 ± 0.263	0.130 ± 0.240	0.101 ± 0.249
W_6	0.326 0.360		0.860 ± 0.098	0.891 ± 0.089	0.889 ± 0.110
W_{12}	0.267 0.439	0.732 0.678		0.971 ± 0.037	0.873 ± 0.070
W_{18}	0.261 0.360	0.709 0.630	0.833 0.743		0.985 ± 0.027
W_{24}	0.271 0.385	0.612 0.480	0.801 0.756	0.857 0.757	

Above the diagonal: genetic correlation

Below the diagonal: phenotypic and environmental correlations.

Table V - Phenotypic, genetic and environmental correlations among body weights (kg) at several ages (males and females combined).

	B_W	W_6	W_{12}	W_{18}	W_{24}
B_W		0.138 ± 0.212	0.075 ± 0.207	0.094 ± 0.215	0.015 ± 0.234
W_6	0.284 0.354		0.848 ± 0.065	0.901 ± 0.058	0.828 ± 0.095
W_{12}	0.251 0.359	0.707 0.614		0.962 ± 0.027	0.861 ± 0.066
W_{18}	0.220 0.280	0.666 0.532	0.815 0.720		0.954 ± 0.031
W_{24}	0.212 0.284	0.544 0.421	0.737 0.695	0.858 0.823	

Above the diagonal: genetic correlation

Below the diagonal: phenotypic and environmental correlations.

The negative correlation between female weight at birth and at 12 months was surprising. The concentration of births during a given time of year, whereby the age of 12 months coincides with the phase of scarce pasture, that slows down growth, may be a tentative explanation for this fact. However, if this assumption were valid, a negative value should be expected for males also, which was not the case in the present study. Among the papers consulted in the literature, only one (Taneja and Bhat, 1971) reported negative correlation between female weight at birth and 12 months, with a value ($r = -0.19$) similar to that obtained in this study. Further, our data were adjusted for month of birth.

Thus, the genetic correlations obtained reveal favorable associations between the various weights, indicating the absence of an antagonistic tendency that might impair a selection program aimed at simultaneous improvement of the traits studied here. The genetic correlations for birth weight would have to be excluded from this conclusion, since they suggest that birth weight does not represent a very good indicator of animal growth up to 24 months. Thus, preliminary selection for higher weight at 24 months of age can efficiently be made at 6 months or at some subsequent stage. However, the information on weight at 12 months should be more useful for a selection program than weight at 6 months, since weight at one year of age, in addition to being more highly correlated genetically with weight at later ages, has greater heritability. Several investigators, such as Sul *et al.* (1971) and Duarte *et al.* (1972), have recommended 12 months of age for early selection for weight.

Response from indirect selection

In view of criteria of Turner and Young (1969) and according to genetical parameters estimated in the present study, the following responses from indirect selection, compared to direct selection, were obtained for the traits studied:

	Relative selection efficiency	
	Males	Females
Weight at birth and at 6 months	0.11	0.32
Weight at birth and at 12 months	0.24	-0.02
Weight at birth and at 18 months	0.29	0.12

Weight at birth and at 24 months	0.25	0.10
Weight at 6 and 12 months	0.78	0.75
Weight at 6 and 18 months	0.91	0.68
Weight at 6 and 24 months	1.02	0.72
Weight at 12 and 18 months	1.09	0.86
Weight at 12 and 24 months	1.39	0.82
Weight at 18 and 24 months	1.25	1.05

The values listed above show that indirect selection for birth weight for males and females is less efficient than direct selection for weight at 6, 12, 18 or 24 months. Indirect selection for weight at 6 months also is less efficient when compared to direct selection for weight at later ages, with the single exception of indirect selection for weight at 24 months, which is more efficient for males.

When the objective is selection based on weight at 18 and 24 months, selection at 12 months for females is as efficient as indirect selection. For males, however, it is better to select at 12 months than to select directly at 18 or 24 months. On the other hand, our results suggest that indirect selection at 18 months for improved weight at 24 months is more efficient for both sexes than direct selection.

Selection based on weight at 12 months seems to be a good selecting criterion for Canchim cattle for economic reasons of both space and time. Selection thus based should improve later weight gains and at the same time imply increased preceding weights. This increase may be higher for weight at 6 months because of the high genetic correlation between this weight and weight at 12 months, and the very low correlation between weight at 6 months and at birth.

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RESUMO

Dados referentes a 1290 animais da raça Canchim (579 machos e 711 fêmeas, nascidos no período de 1958 a 1973, foram utilizados para estimar parâmetros fenotípicos e genéticos relativos ao peso ao nascimento e aos 6, 12, 18 e 24 meses de idade. Efeitos de sexo, mês e ano de nascimento e idade da vaca foram incluídos no modelo matemático. Todos os parâmetros influenciaram significativamente o peso aos 6, 12, 18 e 24 meses, embora o ano de nascimento não tivesse efeito detectável no peso ao nascimento. As médias, calculadas pelo método dos quadrados mínimos, foram: 35,7 kg para o peso ao nascimento, 166,4 kg para o peso aos 6 meses, 235,7 kg para o peso aos 12 meses, 300,5 kg para o peso aos 18 meses e 366,6 kg para o peso aos 24 meses. As estimativas de herdabilidade, obtidas pela correlação entre meio-irmãos paternos, para machos e fêmeas isoladamente e em conjunto foram, respectivamente 0,31 ± 0,13; 0,39 ± 0,12 e 0,28 ± 0,08 para peso ao nascimento; 0,62 ± 0,16; 0,27 ± 0,11 e 0,36 ± 0,09 para o peso aos 6 meses; 0,70 ± 0,17 ; 0,37 ± 0,12 e 0,46 ± 0,10 para o peso aos 12 meses; 0,53 ± 0,15; 0,47 ± 0,13 e 0,36 ± 0,09 para o peso aos 18 meses; e 0,33 ± 0,13; 0,42 ± 0,13 e 0,26 ± 0,08 para o peso aos 24 meses. Os coeficientes de correlação genética entre peso ao nascimento e peso aos 6, 12, 18 e 24 meses para machos e fêmeas em conjunto foram, respectivamente: 0,14; 0,08; 0,09 e 0,02. As correlações genéticas entre peso aos 12 meses e peso aos 18 e 24 meses foram altas (0,86), levando-nos à conclusão de que a seleção baseada no peso aos 12 meses para ambos os sexos pode ser considerada como a melhor alternativa para aumentar o ganho em peso da raça Canchim.

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