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Estimation of genetic parameters in dairy production in girolando cattle

Estimação de parâmetros genéticos na produção leiteira em bovinos girolando

Marina Mortati Dias Barbero[1*], Nicolli Maia Fort[1], Érica Beatriz Schultz[1], Ana Lúcia Puerro de Melo[1], André Morais Moura[1]

[1]Universidade Federal Rural do Rio de Janeiro (UFRRJ), Seropédica, Rio de Janeiro, Brazil
[*]Correspondent: barbero.mmd@gmail.com

Abstract
Milk production is an important economic activity in Brazil. Dairy farmers would benefit from animal breeding programs that aid in identification and selection of animals with the best cost/benefit ratio to maximize productivity, and additionally provide advice on disposal of less productive animals. This study aims to estimate the heritability and repeatability of milk production corrected for 305 days (PL305) in a herd of Girolando cattle. We analyzed 528 lactations in 251 cows. For the analysis, uniform a priori distribution was defined for systematic effects. Gaussian and inverted Wishart distributions were defined as a priori distributions for random effects. The variance components were estimated based on Bayesian inference using the MCMCglmm function available in the MCMCglmm package of the R software. Convergence was verified with the Geweke test available in the R software. The heritability and repeatability were estimated from the variance component results. Heritability was at 0.28, suggesting that selection for the milk production trait leads to efficient genetic progress in the herd. Phenotypic variance was mainly due to environmental variance; therefore, the phenotype of individuals should not be considered as indicator for additive genetic variance. Repeatability was at 0.93, indicating that the first performance of the animals based on milk production average is a good indicator of the second, and the data could be used for disposal decisions.
Keywords: heritability, repeatability, 305-day milk yield

Resumo
A produção de leite é uma das atividades econômicas mais importantes da agropecuária brasileira. Produtores podem usufruir de programas de melhoramento genético que permitem a identificação dos melhores animais e sua seleção para maximizar a produtividade com a melhor relação custo/benefício, além do aconselhamento do descarte de animais menos produtivos. Objetivou-se estimar a herdabilidade e repetibilidade da produção de leite corrigida para 305 dias (PL305) de um rebanho de bovinos da raça Girolando. Foram analisadas 528 lactações de 251 vacas. Para análise foi definida a distribuição uniforme a priori para efeitos sistemáticos. As distribuições de Wishart gaussiana e invertida foram definidas como distribuições a priori para efeitos aleatórios. Os componentes de variância foram estimados utilizando inferência bayesiana pela função MCMCglmm disponível no pacote MCMCglmm do software R. A convergência foi verificada pelo teste de Geweke disponível no software R. Após a obtenção dos componentes de variância foram estimados a herdabilidade e repetibilidade. A herdabilidade observada foi 0,28, o que sugere que a seleção para esta característica resultará em progresso genético eficiente no rebanho. A maior parte da variância fenotípica é devido a variância ambiental, com isso, o fenótipo dos indivíduos não é um bom indicador da variância genética aditiva. A repetibilidade foi de 0,93, indicando que o primeiro desempenho dos animais é considerado um bom indicador do segundo, podendo ser utilizadas em decisões de descarte.
Palavras-chave: herdabilidade; repetibilidade; produção de leite aos 305 dias

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Introduction

Milk is an important agricultural product in Brazil. According to IBGE(1), the value of dairy production is among the highest, ahead of traditional crops, such as coffee. The dairy sector has an extensive and complex value in the Brazilian agribusiness, in addition to the diverse activities involved in dairy production and its presence throughout the national territory. According to FAO(2), Brazil is the largest milk producer in Latin America, and it is projected that milk production should increase by 1% each year in Brazil because of the contribution of varied factors, including animal breeding.

Therefore, milk production plays a vital role in generating employment and income in Brazil, in addition to milk being a food with great nutritional value. Selection of specialized breeds and favorable environment would increase production, which can be achieved through animal breeding. Animal breeding can be defined as the continuous process of procreation, selection, and mating of domestic animals, to change the frequency of alleles and traits of interest in the next generation and the direction desired by humans(3). Controlling and genetic monitoring of a herd is necessary, because based on this information, decisions related to the selection and disposal of the herd for continuity of genetic gain can be made.

The selection of desirable traits, such as milk production, is of significant importance for the dairy sector because increase in milk production, and subsequent raise in income, is dependent on the volume of milk produced and its derivatives. However, exclusive selection of desirable traits can lead to reduced reproductive efficiency, disease resistance, and consequently, longevity(4). Improvement in the productivity potential of animals is also dependent on favorable environmental conditions, and unfavorable conditions would lead to loss in health and fertility.

Heritability is a genetic parameter used for selection decisions. It measures the influence of genetic variation on the total variation of a trait in a population. Repeatability is a genetic parameter used for discard decisions. It measures the ability of individuals in apopulation to repeat a certain performance for a character at different times of their productive life. The estimation of genetic parameters for different populations is essential for decision making regarding selection and expression of desirable genetic traits in animals. The heritability estimation of desirable traits such as milk production is of economic importance. This information indicates the existence or absence of sufficient additive genetic variation to allow genetic gains through selection. Additionally, repeatability can be used as a tool for discarding animals because it predicts future performance; animals that present inferior performance can be discarded. Genetic parameters can be estimated using two statistical approaches: Bayesian and frequentist. Bayesian analysis incorporates prior information into the analysis, while frequentist analysis is conducted through dataset, which gives a p-value for significance test based on maximum likelihood(5).

Furthermore, the sample size has little effect in Bayesian methods because an exact a posteriori distribution exists for each large or small dataset from which inferences can be drawn(6). In this case, the parameter estimates are close to those obtained using frequentist methods based on likelihood functions(7). Since its use in the theory of animal breeding, the Bayesian methodology has shown increasing versatility of application, in the analysis of different areas of genetics and animal evaluations(8–11).

Thus, this study aims to estimate the genetic parameters: heritability and repeatability, through Bayesian inference for milk production adjusted for 305 days of lactation in a Girolando breed of dairy cattle population in Rio de Janeiro.

Material and methods

Animals

Milk production records of crossbred cows 1/2 (Holstein × Gyr) and 1/4 Gyr were selected based on monthly milk weighing tests from a commercial herd located in the municipality of Itaperuna in Rio de Janeiro. Animals were fed a semi-intensive diet. A total of 528 lactations of 251 cows were analyzed from 2001 to 2020.

Available information includes total milk production per lactation period (kg/lactation period), average daily production per lactation period (kg/day), lactation period (days), and data on genealogy and ethnic composition.

Descriptive statistics

For the population traits days of lactation (DL), milk production corrected to 305 days (MP305), arithmetic mean, coefficient of variation, and standard deviation were calculated. Descriptive statistics were obtained using the high posterior density (HPD) function of the MCMCglmm package in the R software.

Calculating genetic parameters

Milk production was evaluated at 305 days. To obtain the average daily production per animal, the total production of the animal was divided by the number of lactation days. For this, only animals with an DL greater than 50 days were considered. For the adjustment of production data at 305 days, the information was truncated to 305 days, adjusted to reach 305 according to the average production when higher(12). Contemporary groups (CG) were formed based on the year of calving (2000–2019) and date of birth (1994–2013). CGs of fewer than three animals were excluded from the analysis. The model used for the analysis is as follows:

$$Y = X\beta + Za + Wp + e,$$

where Y is a vector of the observed feature, X is the incidence matrix of systematic effects, β is the vector of systematic effects (contemporary group and breeed composition), Z is the incidence matrix of additive genetic random effects, a is a vector of additive genetic random effects, W is the incidence matrix of permanent environmental effects, p is the vector of permanent environmental effects, and e is a vector of random error effects.

For the analysis, a uniform a priori distribution for systematic effects (β) was defined. Gaussian and inverted Wishart distributions were defined as a priori distributions for random effects.

Variance components were estimated based on Bayesian inference using the MCMCglmm function available in the R software package MCMCglmm[13]. The analysis consisted of a single chain with 500,000 cycles, with a conservative burn-in of 100,000 cycles, and thinning with 10-cycle intervals. Convergence was verified with the Geweke test[14] available in the Bayesian Output Analysis Program of the R software[15].

Heritability was calculated based on the following equation:

$$h^2 = \frac{\sigma_A^2}{\sigma_P^2},$$

where σ^2_A is the genetic additive variance, and σ^2_P is the phenotypic variance.

Repeatability was calculated based on the following equation:

$$t = r = \frac{\sigma_A^2 + \sigma_{PE}^2}{\sigma_P^2},$$

where σ^2_{PE} is the permanent environmental variance.

Confidence intervals for 95% probability were obtained using the HPD function of the MCMCglmm package in the R software.

Results and discussion

Genealogical information provided a parent lineage-based relationship spanning at least two generations. The data are shown in Table 1.

The averages obtained for the DL and MP305 traits were within the range provided by Silva et al.[16] for Girolando animals with different breed compositions (1/4 to 7/8 Hol:Gyr), in 1.726 herds from 2000 to 2020. The mean value of MP305 calculated for the first, second, and third lactations of Girolando cows with different breed compositions (1/4 to 7/8 Hol:Gyr), were 3.937 kg, 4.237 kg, and 4.471 kg, respectively, which were higher than the results of Canaza-Cayo et al. [17].

Table 1. Data summary and descriptive analysis for days of lactation (DL) and 305-day milk production (MP305) for Girolando cows

Traits	N	Mean	SD	CV (%)
DL (days)	444	288.61	75.12	26.02
MP305 (kg)	444	6002.63	1931.06	32.17

N: number of observations in the variable; SD: standard deviation; CV: coefficient of variation.

Variations in the production average compared to the literature may be attributed to difference in the genetic composition of the animals used. As noted by Daltro[18], breed composition affected the average milk production in Girolando cows for up to 305 days, with higher milk production in cows with a higher proportion of Holstein genes ranging from 7/8 to half blood. The results of the genetic parameters' estimation of heritability and repeatability for the MP305 trait are shown in Table 2. The repeatability and heritability values were significant; that is, the credibility intervals did not include zero, confirming that these traits can be used for the selection of crossbred Girolando cattle.

Table 2. Estimated genetic parameters for 305-day milk production (MP305)

Parameters	Mean	Standard Deviation	HPD Minimum	HPD Maximum
Additive Genetic Variance	834541.71	241478.3	385959.3	1311269
Permanent Environmental Variance	1907823.04	566740.3	5.250.613	2429629
Residual Variance	185482.14	537126.4	1.771.331	1845417
h^2_{MP305}	0.2828	0.069	0.1506	0.4199
t_{MP305}	0.9363	0.1841	0.3663	0.962

h^2: heritability; t: repeatability. HPD: high posterior density, confidence interval for 95% probability

Repeatability is used to predict the future production of an animal based on one or more previous productions, and the data can be used for animal disposal[19]. Repeatability shows the relative importance of genotype and permanent environment in trait expression. According to the classification presented by Mota[19], the repeatability values reported in the literature vary from moderate to high magnitude at 0.37 to 0.53[19–22].

The repeatability of MP305 was higher than that reported in the literature (approximately 0.93). A possible cause for the high magnitude of the repeatability value may be because all evaluated animals belong to the same herd, which provides increased homogeneity of effects of environmental origin. According to the estimated repeatability, there is great potential for the animals to repeat the same performance for milk production in future lactations, that is, the first performance of the animals is considered a good indicator of the second. Therefore, we can select animals to disposefrom this herd based on the prediction of cow's production capacity, by accounting individual average.

The approximate value of 0.28 found for the heritability of MP305 is of moderate magnitude and suggests the existence of sufficient additive genetic variation to allow genetic gains through selection. Moderate magnitude results for heritability ranging from 0.21 to 0.31 have been reported for Girolando cattle [17, 20, 23], similar to our results for the herd in the current study. Canaza-Cayo et al.[17] estimated the heritability of Girolando cattle at different times of lactation, and the estimates were low at the beginning of lactation, with values close to 0.18 in the first 30 days of lactation, gradually increasing with the advancement of lactation, and reaching a maximum value on day 205 ($h^2 = 0.23$). Thereafter, it gradually decreased until the end of lactation, with a value of 0.18 on day 305 of lactation. The changes throughout lactation were attributed to environmental variance, because of which the credibility intervals for heritability fluctuated from 0.15 to 0.41. Thus, traits with moderate to high heritability values have a better genetic gain.

Conclusions

The heritability estimates for MP305 in Girolando crossbred animals suggest that selection for this trait will lead to efficient genetic progress in the herd. However, heritability is of moderate magnitude; therefore, we cannot use the phenotypic value as an indicator of the additive genetic value because much of the phenotypic variance is attributed to environmental factors. Thus, selection for the milk production trait must be based on the genetic value of the animals. Repeatability values for the same trait also indicate that the first performance of the animals based on average milk production is a good indicator of the second performance. Therefore, decision to dispose animals in the herd can be made based on the production capacity.

Conflict of interest

The authors have no competing interests to declare.

Author contributions

Conceptualization: A.M. Moura, M.M.D. Barbero and E. B. Schultz; *Data curation:* A.M. Moura; *Formal analysis*: E.B. Schultz and N. M. Fort; *Methodology:* E. B. Schultz; *Writing (original draft):* N.M. Fort; *Writing (review & editing)*: A.L.P. Melo and M.M.D. Barbero; *Supervision:* M.M.D. Barbero.

References

1. IBGE (Instituto Brasileiro de Geografia e Estatística). Produção agropecuária [Internet]. 2021. Available from: https://www.ibge.gov.br/explica/producao-agropecuaria/br

2. Food and Agriculture Organization of the United Nations. Dairy market review. Food Agric Organ United Nations [Internet]. 2021;(April):1–13. Available from: https://www.fao.org/3/cb7982en/cb7982en.pdf.

3. Barbosa PF. Critérios de seleção em bovinos de corte. In: Barbosa PF., Barbosa RT., Esteves SN, editors. Intensificação da Bovinocultura de Corte: Estratégias de Melhoramento Genético [Internet]. São Carlos: EMBRAPA-CPPSE; 1997. p. 41–62. Available from: https://www.infoteca.cnptia.embrapa.br/handle/doc/44552

4. Dobson H, Smith RF, Royal MD, Knight CH, Sheldon IM. The high-producing dairy cow and its reproductive performance. Reprod Domest Anim. 2007;42(SUPPL. 2):17–23.

5. Hackenberger BK. Bayes or not bayes, is this the question? Croat Med J. 2019;60(1):50–2.

6. Breda FC, Albuquerque LG, Euclydes RF, Bignardi AB, Baldi F, Torres RA, et al. Estimation of genetic parameters for milk yield in Murrah buffaloes by Bayesian inference. J Dairy Sci [Internet]. 2010;93(2):784–91. Available from: http://dx.doi.org/10.3168/jds.2009-2230

7. Aspilcueta-Borquis RR, Araujo Neto FR, Baldi F, Bignardi AB, Albuquerque LG, Tonhati H. Genetic parameters for buffalo milk yield and milk quality traits using Bayesian inference. J Dairy Sci [Internet]. 2010;93(5):2195–201. Available from: http://dx.doi.org/10.3168/jds.2009-2621

8. Beaumont MA, Rannala B. The bayesian revolution in genetics. Nat Rev Genet. 2004;5(4):251–61.

9. Faria CU de, Magnabosco C de U, Reyes A de los, Lôbo RB, Bezerra LAF. Inferência bayesiana e sua aplicação na avaliação genética de bovinos da raça Nelore: Revisão bibliográfica. Ciência Anim Bras [Internet]. 2007;8(1):75–86. Available from: https://www.revistas.ufg.br/vet/article/view/1161

10. Gianola D, Fernando RL. Bayesian methods in animal breeding theory. J Anim Sci. 1986;63(1):217–44.

11. Silva FF e, Muniz JA, Aquino LH de, Sáfadi T. Abordagem Bayesiana da curva de lactação de cabras Saanen de primeira e segunda ordem de parto. Pesqui Agropecuária Bras. 2005;40(1):27–33.

12. Tonhati H, Fernando M, Muñoz C, Ademir De Oliveira J, Mendes J, Duarte C, et al. Genetic parameters of milk production, fat and protein contents in buffalo milk. Rev Bras Zootec. 2000;29(6):2051–6.

13. Hadfield JD. MCMCglmm: MCMC methods for multi-response GLMMs in R. J Stat Softw [Internet]. 2010;33(2):1–22. Available from: http://www.jstatsoft.org/

14. Geweke J. Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. In: Bernardo JM, Berger JO, Dawid AP, Smith M. AF, editors. Bayesian Statistics 4. Oxford: Oxford University Press; 1992. p. 169–93.

15. Smith BJ. boa: An R package for MCMC output convergence assessment and posterior inference. J Stat Softw. 2007;21(11):1–37.

16. Silva MVGB da, Gonçalves GS, Panetto JC do C, Paiva L de C, Machado MA, Faza DR de LR, et al. Programa de Melhoramento Genético da Raça Girolando - Sumário de Touros. 1°. Juiz de Fora: EMBRAPA Gado de Leite; 2021. 79 p.

17. Canaza-Cayo AW, Cobuci JA, Lopes PS, de Almeida Torres R, Martins MF, dos Santos Daltro D, et al. Genetic trend estimates for milk yield production and fertility traits of the Girolando cattle in Brazil. Livest Sci [Internet]. 2016;190:113–22. Available from: http://dx.doi.org/10.1016/j.livsci.2016.06.009

18. Daltro D dos S, Silva MVGB da, Telo da Gama L, Machado JD, Kern EL, Campos GS, et al. Estimates of genetic and crossbreeding parameters for 305-day milk yield of Girolando cows. Ital J Anim Sci [Internet]. 2020;19(1):86–94. Available from: https://doi.org/10.1080/1828051X.2019.1702110

19. Mota MDS. Parâmetros genéticos – Repetibilidade. PUBVET Publicações em Med Veterinária e Zootec. 2010;4(17):1–16.

20. Facó O, Lôbo RNB, Martins Filho R, Martins GA, De Oliveira SMP, Azevêdo DMMR. Additive and non-additive genetic effects on productive and reproductive traits in Holstein x Gir crossbred cows. Rev Bras Zootec. 2008;37(1):48–53.

21. Facó O, Filho RM, Lobo RNB, Ribeiro Azevedo DMM, de Oliveira SMP. Efeito da redução da variação da duração de lactação na avaliação genética de bovinos leiteiros mestiços. Rev Cienc Agron. 2009;40(2):287–92.

22. Gebreyohannes G, Koonawootrittriron S, Elzo MA, Suwanasopee T. Variance components and genetic parameters for milk production and lactation pattern in an ethiopian multibreed dairy cattle population. Asian-Australas J Anim Sci. 2013;26(9):1237–46.

23. Facó O, Filho RM, Nonato R, Lôbo B, Maria S, Oliveira P De, et al. Heterogeneidade de (co) variância para a produção de leite nos grupos genéticos formadores da raça Girolando. Rev Ciência Agronômica. 2007;38(3):304–9.