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Relationship between the magnitude of the inbreeding coefficient and milk traits in Holstein and Jersey dairy bull semen used in Brazil

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ABSTRACT. Artificial insemination has been used to improve production in Brazilian dairy cattle; however, this can lead to problems due to increased inbreeding. To evaluate the effect of the magnitude of inbreeding coefficients on predicted transmitting abilities (PTAs) for milk traits of Holstein and Jersey breeds, data on 392 Holstein and 92 Jersey sires used in Brazil were tabulated. The second-degree polynomial equations and points of maximum or minimal response were estimated to establish the regression equation of the variables as a function of the inbreeding coefficients. The mean inbreeding coefficient of the Holstein bulls was 5.10%; this did not significantly affect the PTA for percent milk fat, protein percentage and protein (P = 0.479, 0.058 and 0.087, respectively). However, the PTAs for milk yield and fat decreased significantly after reaching inbreeding coefficients of 6.43 (P = 0.034) and 5.75 (P = 0.007), respectively. The mean inbreeding coefficient of Jersey bulls was 6.45%; the PTAs for milk yield, fat and protein, in pounds, decreased significantly after reaching inbreeding coefficients of 15.04, 9.83 and 12.82% (P < 0.001, P = 0.002, and P = 0.001, respectively). The linear regression was only significant for fat and protein percentages in the Jersey breed (P = 0.002 and P = 0.005, respectively). The PTAs of Holstein sires were more affected by smaller magnitudes of inbreeding coefficients than those of Jersey sires. It is necessary to monitor the inbreeding coefficients of sires used for artificial insemination in breeding schemes in Brazil, since the low genetic variability of the available sires may lead to reduced production.

Key words: Artificial insemination; Dairy cows; Genetic improvement; Progeny testing; Semen

INTRODUCTION

Dairy farming is a thriving livestock industry in Brazil, with an increase in milk production of approximately 4.1% over the last decade (CNPGL - EMBRAPA, 2007). Nevertheless, according to CNPGL - EMBRAPA (2007), the country still imports more milk and dairy products than it exports. This indicates the need for increased productivity and management, both challenging factors in achieving sustainability and competitiveness in the dairy industry (Josahkian et al., 2005).

The most prevalent breeds of Brazilian cattle are Holstein and Jersey. These two breeds account for 77.35 and 20.32%, respectively, of the total imported semen used in 2006 (ASBIA, 2006). Various target traits are used in the selection process and according to Ferraz et al. (2006), the genetic improvement of cattle is indispensable for increasing their productivity.

Artificial insemination, using semen from tested (or proven) sires, has been used to improve the production indices of Brazilian livestock. Tests are conducted by the International Committee "Interbull", and show the predicted transmitting abilities (PTAs) of the bulls for traits of interest and are available in the "Dairy Bulls" (Hansen, 2006) report. These tests represent the amount of genetic value that is passed onto offspring. The PTA represents 50% of each individual's breeding value (Bergmann, 1995), the basis of animal selection.

However, the indiscriminate use of artificial insemination can lead to problems related to increased inbreeding in herds. This is largely due to the extensive use of semen from a small number of bulls (Paiva, 2006). An increased inbreeding coefficient indicates an increase in the homozygosity of individual genomes and is associated with a decreased performance in economically important traits, such as milk production and animal reproduction (Silva et al., 2001).

Reports describing this type of relationship are based on simple linear equations, suggesting that increased inbreeding causes changes that correlate with the PTA value (Smith et al., 1998, Silva et al., 2001; Paiva, 2006).

The objective of this study was to evaluate the effect of the magnitude of the inbreeding coefficient on the PTAs of traits such as milk production, fat yield and protein production in Holstein and Jersey dairy bulls with semen that was commercially available from Brazilian companies.

MATERIAL AND METHODS

The records of bulls with available semen in Brazil were found on the websites of the country's commercial dairy cow semen companies. In April 2008, tests from 392 Holstein sires and 92 Jersey sires were located and tabulated from the "Dairy Bulls" website (http://www.dairybulls.com), an American genetic database. These tests contained information for these bulls on the inbreeding coefficient and the PTAs for several traits.

We estimated quadratic polynomial regressions ($Y = b_0 + b_1x + b_2x^2$) for the PTAs of milk production (pounds), fat yield (pounds and percentage) and protein production (pounds and percentage) as a function of the inbreeding coefficient of the bulls evaluated. Regression analysis was conducted using the SAS® statistical package (SAS Institute, 1999), using the PROC REG procedure. The significance of the coefficients of the polynomial equations was tested by the Student *t*-test ($P < 0.05$). From the estimated regression coefficients for the models with significant quadratic regression coefficients, the point of maximum or minimum response was calculated for each equation, given by: $Y^* = -b_1 / 2b_2$. In this equation, b_1 corresponds to the coefficient of the first-degree polynomial equation, and b_2 corresponds to the coefficient of the second-degree polynomial equation.

The descriptive statistics, number of observations, mean, standard deviation, and the minimum and maximum values for the traits were also estimated using the statistical package SAS (SAS Institute, 1999) with the PROC MEANS procedure. Duplicate records and records lacking trait information were removed prior to analysis.

RESULTS AND DISCUSSION

The average inbreeding coefficient of the Holstein bulls evaluated in this study was 5.10% (Table 1). This result is less than the maximum value suggested by Hansen (2006) for commercial cattle, 6.25%, and is therefore favorable.

Table 1. Number of observations (N), mean (M), standard deviation (SD), minimum (MIN), and maximum (MAX) values for the inbreeding coefficients and PTAs (predicted transmitting abilities) of milk traits in Holstein and Jersey dairy bulls evaluated.

Trait	N	M	SD	MIN	MAX
Holstein breed					
Inbreeding coefficient (%)	392	5.10	2.08	1.10	15.20
Milk (pounds)	387	976.00	650.97	-1,938.00	2,869.00
Fat (%)	374	-0.02	0.08	-0.24	0.20
Fat (pounds)	386	28.07	24.79	-54.00	89.00
Protein (%)	340	0.00	0.04	-0.19	0.11
Protein (pounds)	386	28.00	18.11	-43.00	80.00
Jersey breed					
Inbreeding coefficient (%)	92	6.43	2.82	0.80	16.70
Milk (pounds)	88	650.87	664.20	-1,765.00	2,148.00
Fat (%)	85	0.007	0.13	-0.31	0.29
Fat (pounds)	88	30.54	20.62	-43.00	75.00
Protein (%)	83	-0.004	0.06	-0.12	0.14
Protein (pounds)	88	21.97	18.08	-43.00	59.00

The coefficients of the polynomial equations were significant (Table 2) for milk production, fat yield and protein production, in pounds, and the curves describing these equations were concave down (Figure 1A,B). For protein percentage, the coefficients of the polynomial equation were also significant (Table 2) with a concave up curve (Figure 1B). There was no significance for the coefficients of the polynomial equation obtained for fat percentage (Table 2), indicating that this trait was not affected by inbreeding.

Table 2. Coefficients of the second-degree polynomial equation (b_0, b_1, b_2), coefficient of determination (R^2) and point of maximum or minimum return (MAX/MIN) for the PTAs (predicted transmitting abilities) for milk production traits (fat and protein production) of the Holstein and Jersey dairy bulls evaluated as a function of the inbreeding coefficient.

Trait	b_0	b_1	b_2	R^2	MAX/MIN (%)
Holstein breed					
Milk (pounds)	454.72*	189.91*	-14.76*	0.003	6.43
Fat (%)	-0.01^{NS}	-0.004^{NS}	0.0001^{NS}	0.004	-
Fat (pounds)	13.81*	5.75*	-0.50*	0.02	5.75
Protein (%)	0.03*	-0.01*	0.0008*	0.02	6.25
Protein (pounds)	19.91*	3.13*	-0.26*	0.01	6.02
Jersey breed					
Milk (pounds)	-315.43^{NS}	195.68*	-6.51^{NS}	0.22	15.04
Fat (%)	0.09^{NS}	-0.01^{NS}	0.00^{NS}	0.10	-
Fat (pounds)	1.43^{NS}	7.08*	-0.36*	0.13	9.83
Protein (%)	0.04^{NS}	-0.01^{NS}	0.00^{NS}	0.08	-
Protein (pounds)	-4.17^{NS}	5.58*	-0.22^{NS}	0.18	12.82

*$P < 0.05$; NS = not significant.

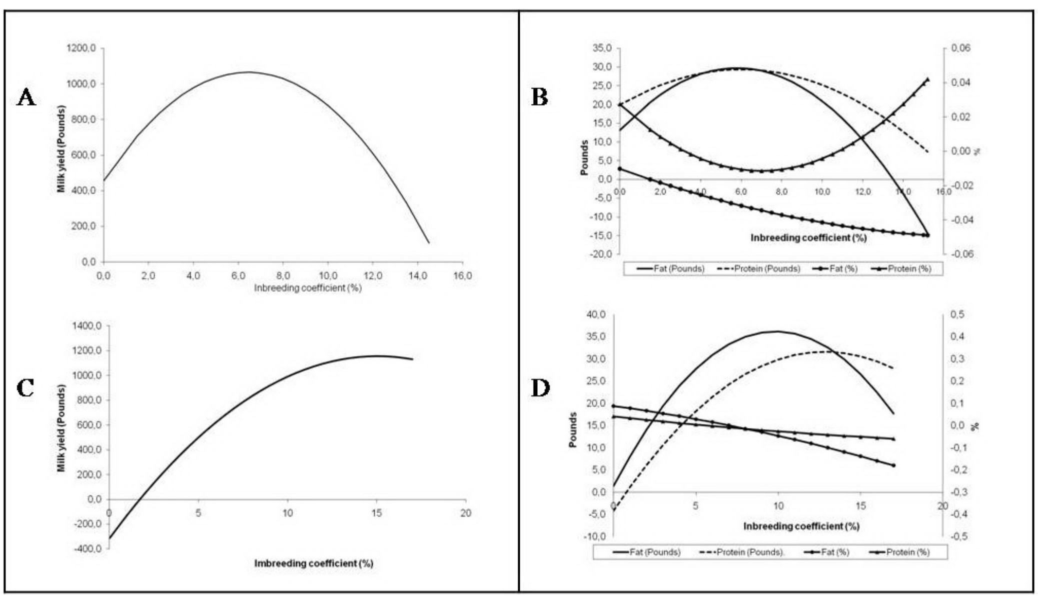

Figure 1. Behavior of PTAs (predicted transmitting abilities) for milk production traits in Holstein (**A**) and Jersey (**C**) breeds and for the production traits of fat and protein, in pounds and percentage, in Holstein (**B**) and Jersey (**D**) breeds, as a function of the inbreeding coefficient of the evaluated dairy bulls.

Given the estimates of the points of maximum response shown in Table 2, the inbreeding coefficient of the Holstein bulls evaluated in this study reduced the PTA for milk production after achieving an inbreeding coefficient of 6.43%. Using simple linear regressions, Smith et al. (1998), Silva et al. (2001) and Paiva (2006) also reported a decrease in milk production due to an increase in inbreeding coefficient. Therefore, increased levels of inbreeding coefficients for Holstein sires may harm milk production from cows, making monitoring essential.

For the traits of fat and protein yield (in pounds), the points of maximum response represented a decrease in the PTAs after reaching inbreeding coefficients of 5.75 and 6.02%, respectively (Table 2). Smith et al. (1998), using linear regressions, also observed a significant decrease in absolute levels of protein and fat due to an increase in inbreeding in the herd. Therefore, increased inbreeding coefficients in Holstein bulls may reduce the PTAs for fat yield and protein production in pounds. However, there was an increase in the PTA for protein percentage after reaching inbreeding coefficients of 6.25%; this was likely associated with an increased concentration of milk solids as milk production, due to inbreeding, was reduced.

The average inbreeding coefficient of Jersey bulls evaluated in this study was 6.43% (Table 1). This is higher than the inbreeding coefficient of 6.25% suggested by Hansen (2006) for commercial herds. It is therefore unfavorable and indicates the need for reduction mechanisms. Although the database evaluated showed that the average inbreeding coefficient in the Jersey breed was greater than that of the Holstein breed, the decrease in the PTAs of the Jersey breed was only noted at a higher level of inbreeding (when compared to that of the Holstein breed). In other words, the effect of inbreeding is more critical in the Holstein breed than in the Jersey breed, and the PTAs of the Holstein sires were impaired at even the lowest levels of inbreeding. Hansen (2006) also found a greater inbreeding coefficient for Jersey cows in a survey conducted in the United States.

In the Jersey bulls, only the PTA for fat yield in pounds showed significance in the coefficient of the polynomial equation (Table 2), and the curve that described this equation was concave down (Figure 1D).

Only the coefficients of the linear equation were significant for PTAs for milk and protein, both in pounds (Table 2). This may be due to an insufficient number of Jersey bulls in the database to determine an accurate relationship, and particularly due to the spread of data found for these variables. The curves for these traits were also concave up (Figure 1C,D).

There was no significance for any of the coefficients of the equations for the PTAs for the fat and protein percentages in the Jersey breed (Table 2), indicating that these traits were not affected by inbreeding. As was previously noted, the use of a larger number of Jersey breed records may modify this result.

Given the estimates for the points of maximum response shown in Table 2, the inbreeding coefficients of Jersey bulls evaluated in this study were able to induce a decrease in the PTA for fat yield in pounds at 9.83%. Likewise, the behavior of the curves and the maximum points obtained for milk and protein in pounds in this breed, 15.04 and 12.82%, respectively, indicate that there is decreased production for these two traits at these levels of inbreeding (Table 2).

Using simple linear regressions, Smith et al. (1998), Silva et al. (2001) and Paiva (2006) also observed a significant decrease in milk production due to an increase in the inbreeding coefficient of the herd. Similarly, increased inbreeding coefficients for Jersey sires may negatively affect the PTAs for fat and protein yield (in pounds).

CONCLUSIONS

The magnitude of the inbreeding coefficients of the Holstein and Jersey sires evaluated, based on defined values, reduced the PTAs for milk, fat and protein, in pounds. In Holstein sires, the magnitude of inbreeding increased the PTAs for percent protein production.

The magnitude of the inbreeding coefficients of the Holstein and Jersey sires analyzed did not interfere with the PTAs for percent milk fat and, in Jersey sires, did not affect the PTAs for percent milk protein.

In the database evaluated, the average inbreeding coefficient of the Jersey breed was greater than that of the Holstein breed. However, the PTAs of the Holstein bulls are affected by smaller inbreeding coefficients than those of the Jersey bulls.

Monitoring the inbreeding coefficients of sires used for artificial insemination is necessary for breeding schemes to prevent the reduction of milk and solid production in the country's dairy cattle, since the low genetic variability of the herds could lead to an increased inbreeding coefficient and consequently to a reduced production.

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