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Effect of including inbreeding coefficients for animal and dam on estimates of genetic parameters and prediction of breeding values for reproductive and growth traits of Piedmontese cattle

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Abstract

Effects of inbreeding of animal and dam on estimates of genetic parameters and predictions of breeding values for five productive and reproductive traits of Piedmontese cattle were studied. Traits were (a) age at first insemination, (b) age at first calving, (c) 120-day weight, (d) yearling weight of males, and (e) yearling weight of females. Data for animals born from 1970 to 1995 were used. Inbreeding coefficients were computed using pedigree records back to 1900. A sire model was used for estimating genetic parameters and predicting breeding values. Two models were used for each trait. Model 1 included fixed effects of herd–year (for traits a, b, d, and e) or herd–year and sex–age of dam (trait c) and covariates for inbreeding coefficient of animal for traits a and b and inbreeding of animal and dam for traits c, d and e. Random effects were associated with sires and dams for traits c, d, and e. Model 2 did not include covariates for inbreeding. Inbreeding increased age at first insemination and calving and decreased 120-day and yearling weights of males and females. Inbreeding was not needed in the model for estimation of variance components or for prediction of breeding values for this population.
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1. Introduction

Following Falconer's (1981) definition, inbreeding is the result of mating of individuals that are related to each other by common ancestors. The use of inbreeding in animal production has been associated with selection to obtain more uniform characteristics in cattle breeds or lines (an example is the development of Santa Gertrudis breed; Rhoad, 1949), with creating inbred lines to be used to obtain heterotic crosses, and for production of genetically uniform strains of animals for scientific research.

One effect associated with inbreeding is the so-called ''inbreeding depression'' which is a reduction

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of mean phenotypic values for reproductive and efficiency traits in animals that are inbred. Inbreeding seems not to affect all traits with the same intensity. For instance, Alexander and Bogart (1961) mentioned that birth weight, growth and food conversion ratio are not negatively affected by inbreeding, but pre-weaning growth and weight at certain ages seem to be influenced. Lasley (1978) concluded that traits associated with fitness and having low heritability, such as survival rate, mothering ability, growth and reproduction are severely affected by inbreeding depression. In studies on laboratory animals and some livestock species (Falconer, 1981; Pirchner, 1985) it was found that an increase in inbreeding can be expected to reduce the mean performance for fitness and viability traits, though the effects are not always consistent. Belonsky and Kennedy (1988) pointed out that using accurate selection methods such as those based on estimated breeding values could cause a rapid increase of inbreeding level in closed herds, because related animals would tend to have similar breeding values leading to a higher probability of mating of relatives.

The effects of inbreeding on animal performance have probably been recognized since ancient times, but the first scientific works were carried out at the beginning of this century using Guinea pigs (Wright, 1922a,b). It was evident that inbred animals showed depression for all litter traits including individual weights, fertility, gain from birth to weaning and mortality. Further studies have found definite effects of inbreeding on productive and reproductive traits: e.g., Burrow (1993) reported in a review of literature for cattle that for each 1% increase of inbreeding coefficient of individuals, average effects were: -0.06 kg for birth weight, (greater in females, -0.11 kg, than in males, -0.05 kg, with no influence of inbreeding of dam), -0.44 kg for weaning weight, -0.69 kg for postweaning weight and -1.3 kg for mature weight of beef cattle. Inbreeding effect of dam was -0.30 kg at weaning and -0.21 kg for postweaning weight. For age at first calving, Smith et al. (1989) reported an effect of $+0.209$ days, i.e., a delay for age at first calving.

The aim of this work was to estimate, using a sire model, the effects of inbreeding coefficients of animal and dam, used as covariates, on estimates of variance components and heritability for some reproductive and growth traits in Piedmontese breed and on predictions of breeding values. Piedmontese is an italian beef cattle breed, reared mainly in Piedmont, in north-eastern Italy. In 1995, the Piedmontese Herd Book consisted of 95 064 heads, including 47 995 cows and 899 bulls in 1911 herds. The breed is well known worldwide for its double muscling conformation; it is an excellent producer of lean meat in Italy and is used in Europe and Northern America as male breed in several crossings. Gigli et al. (1993) found that Piedmontese bulls carcass had significantly lower content of subcutaneous and intermuscular fat compared to Chianina purebreeds, and crosses Piedmontese by Chianina showed an intermediate fat content compared to purebreeds; on the other hand, gross and net dressing percentage was significantly higher in Piedmontese bulls. The ability to transmit to progeny high gross and net dressing percentages, due to light skeleton and skin and double muscling, and the leanness of its meat makes Piedmontese appreciated both as a purebred and crossing breed.

2. Materials and methods

Five traits were studied: two reproductive traits (age at first insemination and age at first calving, both expressed in days from birth) and three growth traits [120-day weight, yearling weight for males (YWM) and females (YWF), all expressed in kg live weight]. The splitting of yearling weight by sexes was made based on knowledge of differences in mean weights and apparent phenotypic variances leading to the supposition that the yearling weights of males and females could be considered as different traits.

The available records for weight traits were not taken at the typical ages, because field weight recording in Piedmontese breed is done twice a year for all animals between 7 and 630 days of age. Data collected in Italy by the A.I.A. from 1970 to 1995 were used. For all animals, live weight was taken using a scale or taking chest circumference and transforming it into live weight by appropriate formulas. Valid records were assumed to be those weights taken a maximum of 1 month before or after 120 and 360 days of age. Table 1 shows the number

Table 1
Number of sires and progeny and phenotypic means and unadjusted standard deviations (S.D.)[a]

Trait	Sires	Progeny	Phenotypic (mean±S.D.)[a]	Average inbreeding of animals	Average inbreeding of dams
Age at first insemination (days)	6418	69 514	638.2±132.7	0.017	[b]
Age at first calving (days)	6418	61 964	961.2±152.3	0.017	[b]
120-day weight (kg)	7645	57 172	137.9±27.9	0.016	0.010
Yearling weight, males (kg)	7645	18 949	367.5±68.1	0.020	0.010
Yearling weight, females (kg)	7645	36 184	279.2±46.5	0.017	0.011

[a] Phenotypic standard deviation uncorrected for the model.
[b] Not included in the model.

of sires and progeny and the phenotypic means and standard deviations (S.D.s) for the traits.

A pedigree file of 446 809 animals was used, comprising the whole of the Piedmontese population recorded in Italy. The file traced back to 1900, while the youngest animals were born in 1995. Due to the dimensions of the data set, in order to estimate the variance components, 10 random samples were taken for both reproductive and weight traits. The criterion for the sampling was to create a fixed effect for herd by year of birth, sort and then re-number it; then, the last digit of the sorted fixed effect was taken and the data grouped by it. In this way, 10 random samples, with last digit from 0 to 9, were created but with inbreeding calculated from the complete pedigree file.

A sire model was applied to all traits, basically to reduce the number of equations in the mixed model equations (MMEs). Two different models were used. Model 1 included the inbreeding coefficients of animals and/or dams as covariates, while Model 2 did not. Age of animal at weighing, expressed in days, was applied as covariate for each live weight trait in both models, due to the use, in this research, of records taken at a range of 1 month before or after the typical age (120 or 360 days). Table 2 shows the fixed and random factors for Model 1 and Model 2 for the all the considered traits.

The MTDFREML program (Boldman and Van Vleck, 1991; Boldman et al., 1995) was used to estimate variance components and heritability for each sample for each model.

From the set of estimates of variance components for the 10 samples, an average set of estimates for each trait and model was computed and used with the whole data set to obtain predictions of transmitting ability for sires and solutions for fixed effects and covariates.

In the model, a regression covariate was used for estimating the inbreeding effect on each trait. The regression coefficient could be considered to be the change in the trait when the animal and/or its dam has an inbreeding coefficient of 1 rather than 0, or, in other words, when the increase of the coefficient is from 0 to 100%. The transformation from 100 to 1% increase in inbreeding was made to show the changes in performance expected for an increase of 1% in the inbreeding coefficients.

The rankings of sires for transmitting ability either with or without inbreeding in the model were

Table 2
Fixed and random effects in Model 1 for each trait

Trait	Fixed effects		Random effects	
	Fixed classes	Covariates	Related	Uncorrelated
Age at first insemination	Herd × year of birth	Inbreeding of animal	Sire	None
Age at first calving	Herd × year of birth	Inbreeding of animal	Sire	None
120-day weight	Herd × year of birth, sex × age of dam (years)	Inbreeding of animal and dam, age at weighing (days)	Sire	Dam
Yearling weight, males	Herd × year of birth	Inbreeding of animal and dam, age at weighing (days)	Sire	Dam
Yearling weight, females	Herd × year of birth	Inbreeding of animal and dam, age at weighing (days)	Sire	Dam

compared only for sires born after 1984. The rankings were computed by solving MME using average variances for both models. To take into account the effect of selection and genetic trend on these traits, the comparison between transmitting abilities for the first 1, 2 and 10% of the top ranked sires born in the last 10 years was made using Spearman and Pearson correlation coefficients, by year of birth. Model 1, which includes the covariates for individual and dam inbreeding coefficients, was assumed to be the basis of the comparisons.

3. Results and discussion

3.1. Estimates of variance components and heritability

Table 3 shows the estimates of variance components and heritability for the two models averaged over 10 samples and their empirical standard errors.

For age at first insemination and age at first calving, the estimates of variance components were only slightly different for the two models. The heritability estimate for age at first insemination was not affected by the introduction of inbreeding coefficient of animal as a covariate, while for age at first calving including the inbreeding coefficient for animal resulted in a slight decrease in estimate of heritability from 0.124 to 0.116. The heritability estimates for these reproductive traits were low. Particularly, for age at first calving, the estimates were less than that of 0.18 reported by Franci et al. (1997) for field data on Chianina breed, while Bozzi et al. (1999), using different models on field data, found that heritability ranged from 0.06 to 0.19 for the same breed and Koots et al. (1994) reported an overall unweighted and weighted mean heritability of 0.14 and 0.06, respectively. On the other hand, Bourdon and Brinks (1982) reported an heritability estimate of 0.07 for Angus, Red Angus and Hereford cattle.

For 120-day weight, practically no difference in estimates of heritability was found for the two models. The estimate of 0.120 seems to be low compared to the heritability estimates for the trait reported in the review by Mohiuddin (1993). In this review, the use of a sire model produced a wide range of heritability estimates (from 0.09 to 0.64 for both sexes and from 0.12 to 0.46 for males only). The average heritability estimate for combined sexes, according to Mohiuddin (1993), is 0.20, ranging from 0.06 to 0.88, while Grotheer et al. (1997), using field data on Charolais cattle, found a heritability estimate of 0.21. A partial explanation for low estimates in this research may be due to the method the estimates were computed, that is, a sire model with dams considered as uncorrelated random effects; such model would reduce confounding of sire and dam effects which could have inflated estimates of heritability.

For yearling weights, there was no difference in estimated heritability for the two models. A distinction between estimates of variance components for males and females was observed, which may signify a difference between sexes for the trait and possibly confirmed the need to split the original trait into two traits. Estimates for phenotypic variance differed little for YWM (1717 vs. 1726) for the two models, while those for YWF differed even less (758 vs. 761). Neither the estimated sire variances (114 vs. 115 and 49 vs. 50, respectively, for YWM and YWF) nor dam variances (221 vs. 221 and 58 vs. 58, respectively) varied between models. The estimates

Table 3
Estimates of variance components and heritability with the two models (average from the 10 samples)

Trait	σ_p^2		σ_s^2		σ_d^2		σ_e^2		h^2	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Age at first insemination (days)	8348±91	8359±21	397±19	405±50	–	–	7951±89	7954±89	0.19	0.19
Age at first calving (days)	12 077±110	11 958±109	357±19	371±19	–	–	10 720±103	11 587±108	0.11	0.12
120-day weight (kg)	358±19	58±11	10±3	10±3	27±5	27±5	321±8	321±18	0.12	0.12
Yearling weight, males (kg)	1717±41	1726±41	114±11	115±11	221±15	221±15	1381±37	1389±37	0.27	0.26
Yearling weight, females (kg)	758±28	761±28	49±7	50±7	58±8	58±8	650±26	657±26	0.26	0.27

of environmental variances also differed only slightly (1381 vs. 1389 for males, 650 vs. 657 for females). These differences resulted in an only slightly higher heritability estimate for YWM with Model 1 (0.268) compared to Model 2 (0.260). For YWF, the inclusion of inbreeding coefficients seemed to result in a slightly smaller heritability estimate (0.264 vs. 0.268 for Models 1 and 2, respectively). Such estimates were greater than those found by Wollert and Kalm (1988), who reported a heritability of 0.21 on performance tested bulls belonging to Charolaise and Simmental breeds and crosses of them; on the other hand, the heritability estimates in the present work are similar to those reported by Grotheer et al. (1997) with a value of 0.26 found on Charolaise cattle using field data, and by Koots et al. (1994) showing overall unweighted and weighted mean heritability of 0.27 and 0.24, respectively.

3.2. Effect of inbreeding

The inbreeding coefficient (F) for each animal was computed following the algorithm of Quaas (1976). The average F value for the whole data set was 0.0127, with 107 680 animals having F values greater than 0 (average F value: 0.0593), of which 47 963 were males (average F value: 0.0504) and 59 717 were females (average F value: 0.0551).

The literature suggested that three methods were available for estimation of inbreeding effects on productive traits (e.g., Burrow, 1993): (i) the use of regression techniques in which inbreeding coefficients of the individual and/or the dam are fitted as covariates in models that include other environmental and genetic sources of variation, (ii) comparison of the mean performance of inbred lines with the performance of control or crossline populations, and (iii) the use of inbreeding as a fixed effect in analysis of variance models using discrete classes of inbreeding (Keller and Brinks, 1978). In this research, the first method, i.e., use of regression to fit inbreeding coefficients as covariates in a model including environmental and genetic sources of variation was used. The regression coefficients for inbreeding on the studied traits are shown in Table 4, for a 1% change in inbreeding coefficient of animal and dam.

The estimate of the effects of inbreeding of an animal on reproductive traits was rather high compared to other studies. For beef cattle, Smith et al. (1989) reported for Hereford and Angus heifers a 1% increase of inbreeding coefficient delayed age at puberty by 0.146 days and age at first calving by 0.209 days. Burrow (1993), in a review of inbreeding effects on beef cattle, stated that inbreeding had a negative effect on all measurements of female fertility of beef cows, and that such effects were more pronounced in younger animals and in animals having higher levels of inbreeding.

Table 4
Regression coefficients of the traits on inbreeding of animal and/or dam for a change of 1% in inbreeding

Trait	Animal	Dam
Age at first insemination (days)	0.623	–
Age at first calving (days)	0.763	–
120-day weight (kg)	− 0.116	− 0.0059
Yearling weight, males (kg)	− 0.874	− 0.0286
Yearling weight, females (kg)	− 0.350	− 0.0129

For growth traits, the increase of inbreeding corresponded to a decrease in liveweight at 120 and 360 days. The effect was greater in males (−0.87 kg) than in females (−0.35 kg). The effect of inbreeding of dam was less for 120-day weight than for yearling weight, although both effects were small.

The overall negative effect of inbreeding on liveweights resulted, as expected, in lighter weights at the different ages. Burrow (1993) reported, for weights at ages ranging from 320 to 386 days, and using regression techniques, an average effect for 1% increase in inbreeding of − 0.53 kg for inbreeding of the animal and − 0.21 kg for inbreeding of the dam in a collection of studies, where the average inbreeding coefficients were 13.1% for individuals and 6.1% for dams. From the summary by Burrow (1993), the average from different estimation techniques can also be computed. The overall mean effects were − 0.69 kg for individual and − 0.21 kg for dam inbreeding. The effects were − 0.87 kg for individual and − 0.28 kg for dam inbreeding for YWM males, while for YWF females the average effects were − 0.52 and − 0.43 kg, respectively.

The previous results are quite different from those found in the present study, especially for the effect of inbreeding of the dam. The smaller average inbreeding coefficients for animals, the higher number of animals in the study and the use of a sire and dam model, rather than an animal model, may partially explain the differences.

3.3. Effect of inbreeding on sire ranking

Sire rankings for transmitting ability were studied specifically considering males born after 1984. The average *F* value for all animals born after 1984 was 0.015 and 0.044 for only inbred animals. The rankings were compared for both models. To take into account the effect of selection and genetic trend on these traits, comparisons between the best 1, 2 and 10% of sires born in the last 10 years of data were made for each year of birth. Model 1, including inbreeding coefficients, was assumed to be the best model because the use of inbreeding coefficient as further effect is expected to increase model's fit.

First, Pearson and Spearman correlation coefficients were computed between the predicted transmitting abilities with the two models for all animals. Table 5 shows these correlation coefficients. The correlations were also calculated for sires born from 1984 to 1992. Pearson and Spearman correlations coefficients for all, best 10, 2 and 1% of sires were computed, and changes in ranks from Model 1 to Model 2 were considered (Tables 6–10). Pearson and Spearman correlation coefficients, when all predicted transmitting abilities are considered, indicate that use of inbreeding coefficients for animal

Table 5
Pearson and Spearman correlation coefficients between sire ranking for transmitting ability for all males (for models including or ignoring inbreeding of animal and dam)

Trait	Pearson	Spearman
Age at first insemination	0.998	0.997
Age at first calving	0.998	0.997
120-day weight	0.999	0.998
Yearling weight, males	0.990	0.985
Yearling weight, females	0.996	0.995

Table 6
Pearson and Spearman correlations for transmitting abilities for all, best 10, 2 and 1% of males, by year of birth (for models including or ignoring inbreeding of animal and dam for yearling weight of males)

Birth year	No. of sires	Pearson all	Spearman all	Pearson best 10%	Spearman best 10%	Pearson best 2%	Spearman best 2%	Pearson best 1%	Spearman best 1%
1984	366	0.990	0.986	0.962	0.952	0.973	0.857	0.993	1.000
1985	346	0.989	0.988	0.891	0.828	0.509	0.214	− 0.107	− 0.200
1986	372	0.992	0.986	0.984	0.915	0.999	0.964	1.000	1.000
1987	403	0.985	0.978	0.975	0.882	0.996	0.821	0.997	0.800
1988	444	0.992	0.990	0.958	0.874	0.971	0.714	0.966	0.800
1989	460	0.993	0.987	0.987	0.941	0.997	1.000	0.999	1.000
1990	453	0.993	0.987	0.977	0.955	0.689	0.714	− 0.293	− 0.600
1991	430	0.995	0.990	0.994	0.973	0.992	0.964	0.998	1.000
1992	344	0.994	0.987	0.988	0.951	0.988	1.000	0.994	1.000

Table 7
Pearson and Spearman correlations for transmitting abilities for all, best 10, 2 and 1% of sires, by year of birth (for models including or ignoring inbreeding of animal and dam for yearling weight of females)

Birth year	No. of sires	Pearson all	Spearman all	Pearson best 10%	Spearman best 10%	Pearson best 2%	Spearman best 2%	Pearson best 1%	Spearman best 1%
1984	366	0.996	0.996	0.942	0.939	0.938	0.714	0.734	0.400
1985	346	0.996	0.995	0.978	0.927	0.965	0.964	0.999	1.000
1986	372	0.997	0.997	0.983	0.963	0.938	0.964	0.746	0.800
1987	403	0.997	0.996	0.989	0.951	0.994	1.000	1.000	1.000
1988	444	0.997	0.996	0.981	0.977	0.977	1.000	0.996	1.000
1989	460	0.996	0.996	0.970	0.973	0.847	0.857	0.802	0.800
1990	453	0.996	0.995	0.974	0.966	0.923	0.893	0.785	0.800
1991	430	0.997	0.996	0.989	0.977	0.979	0.750	0.972	1.000
1992	344	0.995	0.993	0.957	0.956	0.978	0.821	0.977	1.000

Table 8
Pearson and Spearman correlations for transmitting abilities for all, best 10, 2 and 1% of sires, by year of birth (for models including or ignoring inbreeding of animal and dam for 120-day weight)

Birth year	No. of sires	Pearson all	Spearman all	Pearson best 10%	Spearman best 10%	Pearson best 2%	Spearman best 2%	Pearson best 1%	Spearman best 1%
1984	366	0.998	0.998	0.997	0.986	0.993	1.000	0.988	1.000
1985	346	0.999	0.998	0.997	0.992	0.996	0.964	0.999	1.000
1986	372	0.998	0.998	0.993	0.995	0.999	0.893	1.000	1.000
1987	403	0.998	0.998	0.996	0.989	0.994	0.643	0.996	0.800
1988	444	0.999	0.998	0.995	0.984	0.974	0.962	0.905	0.800
1989	460	0.999	0.999	0.992	0.962	0.994	0.964	1.000	1.000
1990	453	0.909	0.999	0.997	0.987	0.986	1.000	0.991	1.000
1991	430	0.999	0.999	0.998	0.983	1.000	1.000	1.000	1.000
1992	344	0.998	0.998	0.985	0.988	0.983	1.000	1.000	1.000

Table 9
Pearson and Spearman correlations for transmitting abilities for all, best 10, 2 and 1% of sires, by year of birth (for models including or ignoring inbreeding of animal and dam for age at first insemination)

Birth year	No. of sires	Pearson all	Spearman all	Pearson best 10%	Spearman best 10%	Pearson best 2%	Spearman best 2%	Pearson best 1%	Spearman best 1%
1984	325	0.997	0.997	0.985	0.975	0.944	1.000	0.888	1.000
1985	309	0.994	0.998	0.980	0.967	0.866	0.486	0.993	1.000
1986	316	0.998	0.996	0.988	0.976	0.993	1.000	0.983	1.000
1987	349	0.998	0.996	0.992	0.971	0.997	0.943	0.999	1.000
1988	345	0.998	0.997	0.992	0.955	0.994	1.000	1.000	1.000
1989	366	0.998	0.998	0.990	0.981	0.997	0.943	0.992	1.000
1990	363	0.997	0.996	0.993	0.977	0.991	0.829	0.996	1.000
1991	220	0.998	0.997	0.994	0.985	0.994	1.000	0.989	1.000
1992	29	0.999	0.996	0.997	0.943	0.997	1.000	1.000	1.000

Table 10
Pearson and Spearman correlations for transmitting abilities for all, best 10%, best 2% and best 1% of sires, by year of birth (for models including or ignoring inbreeding of animal and dam for age at first calving)

Birth year	No. of sires	Pearson all	Spearman all	Pearson best 10%	Spearman best 10%	Pearson best 2%	Spearman best 2%	Pearson best 1%	Spearman best 1%
1984	325	0.997	0.996	0.983	0.937	0.996	0.943	1.000	1.000
1985	309	0.998	0.997	0.991	0.984	0.985	0.943	0.999	1.000
1986	316	0.997	0.995	0.969	0.942	0.919	0.943	0.995	0.500
1987	349	0.997	0.997	0.970	0.961	0.759	0.829	0.996	1.000
1988	345	0.997	0.997	0.998	0.974	0.948	0.829	0.999	1.000
1989	366	0.997	0.996	0.983	0.957	0.980	0.943	0.871	0.500
1990	363	0.996	0.997	0.985	0.948	0.983	1.000	0.999	1.000
1991	220	0.997	0.993	0.977	0.957	0.944	0.829	1.000	1.000
1992	29	0.999	0.996	0.997	0.943	0.997	1.000	1.000	1.000

and dam did not cause important changes in ranking. Pearson and Spearman coefficients greater than 0.99 seem to assure little change in sire ranking. Only for yearling weight for males was the Spearman coefficient less than 0.990 (0.985).

Although for all sires the correlations between solutions for the two models are high, the situation may change if a contemporary group of animals is considered for selection. However, for all animals born in the same year, Pearson and Spearman correlations were greater than 0.99 for all considered traits. The analysis of the top 10% of sires resulted in similar correlation coefficients, except for trait YWM in year 1985, for which Pearson and Spearman coefficients were 0.891 and 0.828, respectively.

With the best 2% of sires as evaluated from the model with inbreeding included, the correlations, and particularly Spearman coefficients, were less stable. Year 1985 was different for YWM (Pearson, 0.05 and Spearman, 0.21), as well as year 1990. Age at first insemination in year 1985 had a decrease in Spearman compared with Pearson correlation coefficient for comparison of best 10%, but the correlation increased up to 1.00 for best 1% of sires. When the top 1% of sires was considered, the small number of animals and their possible shift in ranking caused Spearman correlations to be more sensitive and decrease compared to Pearson correlation coefficients. Again, year 1985 for YWM was the exceptional year, with Pearson and Spearman correlations, respectively, of −0.11 and −0.20, as well as for year 1990 (−0.29 and −0.60, respectively). Less evident decreases were found for years 1984, 1986, 1989 and 1990 for YWF, and for the Spearman correlation test only, for years 1987 and 1988 for 120-day weight and in years 1986 and 1989 for age at first calving. Generally, if the best 4–5 sires had no shift of rank or small changes, the Spearman correlation coefficient tended to be about 1.00.

4. Conclusions

From the available data on Piedmontese cattle, the following conclusions can be made:

1. The use of inbreeding coefficients for animal and/or for dam appeared not to have important effects on estimates of variance components and heritability for the studied traits.
2. The use of inbreeding for animal and/or for dam in the model for analysis appeared to affect sire rankings very little.
3. Inbreeding has definite effects on all traits studied as increases in inbreeding delayed reproductive times and resulted in lighter weights at 120 and 360 days.

Inbreeding coefficients do not seem to be needed as covariates in models for variance component estimation and prediction of genetic values for these data. Nevertheless, possible inbreeding coefficients should be considered when deciding on mating of sires and dams, in order to limit the possible negative effects of inbreeding on productive and reproductive traits.

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