Heterosis and Breed Effects for Milk Production, Udder Health and Fertility in Danish Herds with systematic crossing

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ABSTRACT: Use of systematic crossbreeding in dairy cattle has been increasing the last decades. The aim of this study was to estimate the effect of breed proportion and heterosis on protein yield (PY), somatic cell score (SCS) and days from calving to first insemination (CFI) in first lactation crosses between Danish Holstein (DH), Danish Red (DR) and Danish Jersey (DJ). The effect of breed proportions was estimated relatively to a pure DH. There was a significant difference in PY between DH and DJ, but no difference between DH and DR. For SCS, there was a significant difference between DH and the two other breeds. The difference in CFI was only significant between DH and DR. For all combination of breeds, heterosis for PY was significant, ranging from 2.2% to 6%. There was no significant heterosis for SCS. For CFI, only combinations of DH and DR showed significant heterosis.
Keywords:
dairy cattle
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somatic cell score
calving to first insemination

Introduction

Crossing of lines or breeds is systematically used in breeding programmes for pig and poultry and it has also proved to be beneficial in dairy cattle breeding (Lopez-Villalobos et al., 2000; 2007; Sørensen et al., 2008). Therefore, the use of systematic crossbreeding has been increasing during the last decade in dairy cattle herds in Denmark. When applying crossbreeding, the differences in additive genetic level between breeds are utilized in addition to the heterosis expressed by the crossbred animals. Crossbred animal are supposed to be more economically efficient and more robust compared to the parental breeds (Mäki-Tanila, 2007). Profit is mainly improved if the breeds used have approximately the same genetic level for total merit. On top of that, heterosis is added as a bonus. For milk production traits, heterosis effects have been reported to range from 1.5 to 8.4% (Sørensen et al., 2008). Even heterosis is expected to be largest for functional traits, studies on udder health shows contradictory results (VanRaden and Sanders, 2003; Dechow et al., 2007; Sørensen et al., 2008). Several studies dealing with crossbreeding and fertility traits present favorable heterosis (2003; Wall et al., 2005). However, most studies reporting heterosis effects are based on a limited number of animals, and often it has been impossible to distinguish between breed effects and heterosis effects as records on purebred cows in crossbred herds has not been available.

In this study, records on both purebred and crossbred animals from herds applying systematically crossbreeding programs have been used to estimate the effect of breed and heterosis. The traits included in this study are protein production (PY), somatic cell score (SCS) and days from calving to first insemination (CFI).

Materials and Methods

Data. Records on 305 days PY (56,242), log transformed SCS (50,856) and CFI (48,450) from first lactation dairy cows collected from 2004 and onwards in 104 herds practicing systematic crossbreeding were included in this study. More than 50% of the cows were crosses between DH, DR and /or DJ and the remaining were pure DH, DR or DJ. Only cows with more than 45 DIM and a calving age between 18 and 40 months were included. For cows without information on second calving, mean calving interval was inserted. Prior to the statistical analysis for PY, data were corrected for variance heterogeneity between breeds.

Statistical analyses. Effect of breed proportion and heterosis were estimated with a uni-variate animal model using the AI-REML algorithm in the DMU package (Madsen and Jensen, 2010). If cross bred animals are offspring from genetically inferior animal or vice versa, this is accounted for in the model. The pedigree was traced back four generations in the Danish Cattle Database, and the pedigree file included 143,133 animals. To avoid too many breed proportions internal breed proportions within the three external breeds DH, DR and DJ were merged. The statistical model is described below:

$$Y_{ijk} = H_i + M_j + bci + bbp_{DH} + bbp_{DR} + bbp_{DJ} + bhet_{DH/DR} + bhet_{DH/DJ} + bhet_{DR/DJ} + a_k + e_{ijk}$$

where;

Y_{ijkl} = record on PY, SCS or CFI;
H_i = fixed effect of herd*year *i* (*i* = 1, …, 905);
M_j = fixed effect of calving month *j* (j =1, …, 12);
b*ci* = regression on age at first calving in months;
bbp_{DH} = regression on proportion Danish Holstein genes;
bbp_{DR} = regression on proportion Danish Red genes;
bbp_{DJ} = regression on the proportion Danish Jersey genes;
b$het_{DH/DR}$= regression on degree of heterozygosity between Danish Holstein and Danish Red;
b$het_{DH/DJ}$= regression on degree of heterozygosity between Danish Holstein and Danish Jersey;
b$het_{DR/DJ}$= regression on degree of heterozygosity between Danish Red and Danish Jersey;
a_l = additive genetic effect of cow *k*;
e_{ijkl} = random residual.

Results and Discussion

Effect of breed proportion. Means of traits and effects of breed are presented in Table 1. The effect of breed is presented relatively to a pure DH. There was no significant difference in PY between DH and DR. This estimate is lower than expected and may be due to the more equal treatments of breed, which is not the case when herd are in breed transationbut as expected, a significant difference between DH and DJ in favor of DH. There was a significant effect of breed proportion for SCS between DH and the two other breeds. The difference in CFI was only significant between DH and DR, however, there was a tendency that DJ had lowerCFI compared with DH.

Heterosis. Heterosis in measured units for a F1-cross is given in Table 2. For all combination of breeds, heterosis for PY was significant. The degree of heterosis range from 2.2% (crosses between DH and DR) to 6% (crosses between DR and JER). These figures correspond well with the estimated heterosis for crosses between Holstein and Jersey, Holstein and Ayrshire and Ayrshire and Jersey presented by Lopez-Villalobos et al. (2000). As expected was heterosis largest for F1 crosses where DJ was involved, which also was supported by Lopez-Villalobos et al. (2000). The reason for that is that the genetic distance between DJ and the other breeds are larger than the genetic distance between DR and DH. According to quantitative genetic theory, heterosis is expected to be largest on fitness traits and traits with low heritability. However, empirical evidences for this from studies with dairy cattle are not always pointing in this direction. In our study, the heterosis effects on SCS were not significant, even there is a tendency that crossing DH and DR, and DR and JER have a slightly favorable effect on the SCS. Dechow et al. (2007) found a significant favorable heterosis effect on SCS when analyzing data from crosses between Holstein and Brown Swiss while VanRaden and Sanders (2003) found a small unfavorable effect. The unfavorable effect on SCS is explained by the increased milk production seen for crossbreed cows, which may increase the stress on the udder.

For CFI, only combinations of DH and DR showed significant heterosis. This result correspond well to what has been found earlier by VanRaden et al. (2004), Wall et al. (2005) and Dechow et al. (2007). The heterosis ranged from 1.01 days to -3.20 days

Conclusion

The results obtained in this study demonstrate the existence of heterosis on PY, however there was no significant heterosis for SCS in crosses between the three Danish dairy breeds. For days from CFI, only a combination of DH and DR expressed any heterosis.

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Table 1. No of crosses, pure Danish Holstein (DH), Danish Red (DR) and Danish Jersey (DJ) and breed proportion of crossbred animals.

	Crosses	DH	DR	DJ
No cows	25,182	27,664	3,327	69
Breed prop	-	0.51	0.38	0.09

Table 2. Mean of kg protein (mPY), SCS (mSCS) and days from calving to first insemination (mCFI) for pure bred Danish Holstein (DH), Danish Red (DR) and Danish Jersey (DJ) and effect of breed on kg protein (bpPY), SCS (bpSCS) and calving to first insemination (bpCFI) derived from the models are presented relative to a pure DH.

	mPY	mSCS	mCFI	bpPY	bpSCS	bpCFI
DH	273.6	11.17	81,0	-	-	-
DR	265.5	11.06	71.1	-4.3	-0.14	-6.29[a]
DJ	208.7	11.37	85.3	-39.9[a]	0.20	-4.11

[a]significant different from DH (p<0.05)

Table 3. Heterosis in kg protein (hetPY), SCS (hetSCS) and days from calving to first insemination (hetCFI) with standard errors in brackets expressed for a F1

cross between Danish Holstein, Danish Red and Danish Jersey.

	hetPY	hetSCS	hetCFI
DH*DR	5.99[a]	-0.03	-1.59[a]
DH*DJ	11.7[a]	-0.08	-3.20
DR*DJ	14.2[a]	0.01	1.01

[a]indicates values significantly different from 0 ($p<0.05$)

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