ABSTRACT: Use of systematic crossbreeding in dairy cattle has been increasing in the last decades. The aim of this study was to estimate the effect of breed 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 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. There was no significant heterosis for SCS. For CFI, only combinations of DH and DR showed significant heterosis. Keywords: crossbreeding; protein yield; somatic cell score; calving to first insemination

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. The statistical model is described below:

\[ Y_{ij} = \delta + H_i + M - bci + bdp_{DH} + bdp_{DR} + bdp_{DJ} + bhet_{DH/DR} + bhet_{DH/DJ} + bhet_{DR/DJ} + a_i + e_{ij} \]

where:

- \( Y_{ij} \) = record on PY, SCS or CFI;
- \( H_i \) = fixed effect of herd*year \( i = 1, \ldots, 905 \);
- \( M \) = fixed effect of calving month \( j = 1, \ldots, 12 \);
- \( bci \) = regression on age at first calving in months;
- \( bdp_{DH} \) = regression on proportion Danish Holstein genes;
- \( bdp_{DR} \) = regression on proportion Danish Red genes;
- \( bdp_{DJ} \) = regression on the proportion Danish Jersey genes;
- \( bhet_{DH/DR} \) = regression on degree of heterozygosity between Danish Holstein and Danish Red;

Crossing of lines or breeds is systematically used in breeding programs for pig and poultry and it has also proved to be beneficial in dairy cattle breeding (Lopez-Villalobos et al., 2000; 2007; Sorensen 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% (Sorensen 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; Sorensen et al., 2008). Several studies dealing with crossbreeding and fertility traits present favorable heterosis (Van Raden et al., 2004; 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.

Introduction

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).
Results and Discussion

Effect of breed proportion. Number of animals and breed proportion in crossbred animals is shown in Table 1. The majority of the genes originate from DH and DR, while DJ only contribute with 69 pure bred animals and 0.09% in average in the crossbred animals. Phenotypic means of traits and genetics effects of breed are presented in Table 2. The effect of breed is presented relatively to a pure DH. There was no significant difference in PY between DH and DR but 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 lower CFI compared to DH.

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

<table>
<thead>
<tr>
<th>Crosses</th>
<th>DH</th>
<th>DR</th>
<th>DJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>No cows</td>
<td>25,182</td>
<td>27,664</td>
<td>3,327</td>
</tr>
<tr>
<td>Breed prop</td>
<td>-</td>
<td>0.51</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Table 2. Phenotypic mean of 305 days 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 305 days kg protein (bePY), SCS (beSCS) and calving to first insemination (beCFI) derived from the models presented relative to a pure DH.

<table>
<thead>
<tr>
<th></th>
<th>mPY</th>
<th>mSCS</th>
<th>mCFI</th>
<th>bePY</th>
<th>beSCS</th>
<th>beCFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DH</td>
<td>273.6</td>
<td>11.17</td>
<td>81.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DR</td>
<td>265.5</td>
<td>11.06</td>
<td>71.1</td>
<td>-4.3</td>
<td>-0.14</td>
<td>-6.29</td>
</tr>
<tr>
<td>DJ</td>
<td>208.7</td>
<td>11.37</td>
<td>85.3</td>
<td>-39.9</td>
<td>0.20</td>
<td>-4.11</td>
</tr>
</tbody>
</table>

Heterosis. Heterosis in measured units for a F1-cross is given in Table 3. 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). This is because 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.

Table 3. Heterosis in 305 days kg protein (hetPY), SCS (hetSCS) and days from calving to first insemination (hetCFI) expressed for a F1-cross between Danish Holstein, Danish Red and Danish Jersey.

<table>
<thead>
<tr>
<th></th>
<th>hetPY</th>
<th>hetSCS</th>
<th>hetCFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DH*DR</td>
<td>5.99</td>
<td>-0.03</td>
<td>-1.59</td>
</tr>
<tr>
<td>DH*DJ</td>
<td>11.7</td>
<td>-0.08</td>
<td>-3.20</td>
</tr>
<tr>
<td>DR*DJ</td>
<td>14.2</td>
<td>0.01</td>
<td>1.01</td>
</tr>
</tbody>
</table>

*a indicates values significantly different from 0 (p<0.05)

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).

Conclusion

The results obtained in this study show the genetic effect of breed on PY, SCS and CFI. It demonstrates 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.

Literature Cited

Madsen, P. and Jensen, J. (2013). DMU. Ver. 6, rel. 5.2 (http://www.dmu.agrsci.dk/DMU/Doc/Current/dmuv6_guide_5.2.pdf)