RATE OF INBREEDING AND EFFECTIVE SIZE IN THE BELGIAN BLUE CATTLE BREED

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INTRODUCTION
Since the advent of population genetics and the introduction of the coefficient of inbreeding (Wright 1922, 1923), pure breeds of livestock were regularly submitted to genetic analyses regarding their inbreeding and effective size. Lush (1946) published the first summary of the results of such studies carried out in cattle, pig and horse breeds. Artificial insemination by a limited number of sires of superior genetic merit and selection for progeny test of young bulls out of a small number of sires can turn a large population into a population with a rather small effective size. Inbreeding appears therefore as a corollary of genetic improvement and is an increasing concern in several cattle breeds (Boichard et al. 1996, Young and Seykora 1996, Smith et al. 1998, Hanset 2000, Weigel and Lin 2000).

MATERIAL AND METHODS
To study the evolution of inbreeding that took place during the last decade, pedigrees were constructed going back to the year 1950, where possible, for:
1) 3440 bulls having completed the performance test in station and born during the period 1988 – 2000 (number of animals = 19528);
2) 182 A.I. bulls born from 1986 to 1990 (number of animals = 2404);
3) 140 A.I. bulls born from 1987 to 2000 (number of animals = 3643).
The Herdbook remaining open, all the pedigrees were not complete along the maternal side. The rate of inbreeding, $\Delta F$, was estimated from the difference between the inbreeding of the individuals ($F_t$) and that of their parents ($F_{t-1}$) divided by $(1-F_{t-1})$. To characterise, within each of the two groups of A.I. bulls, the variation in the number of offspring per sire (S), sire of sire (SS), sire of sire of sire (SSS), sire of dam of sire (SDS), the following parameters were considered: the current number (CN) of sires, sires of sires, …; the average (Ave) and the variance (Var) of the number of offspring per sire, …; the ratio Var/Ave (K1); the effective number (EN) of sires, … given by the reciprocal of the probability that two random bulls had the same sire, same sire of sire, …; the ratio EN/CN (K2).

RESULTS AND DISCUSSION
The average coefficient of inbreeding of the station tested bulls increased from 1.19 % in 1990 to 3.67 % in 2000, while the percentage of individual coefficients equal or greater than 6 % increased from 1.0 % to 9.86 %. For the period 1995 – 2000, the rate of inbreeding had an average value of 1.3 % and the resulting effective size of the population (Ne) amounted to 38.5 breeding animals (50 % males and 50 % females) but to 9.6 males (Nm) for an infinite number of females. To understand the origin of this increasing inbreeding, the group of 182 A.I. bulls born in 1986 – 1990 was compared with that of 140 A.I. bulls born in 1997 – 2000 for the parameters characterising the variation in the number of sons, grandsons, … per sire, sire of
The average inbreeding of the first group was 1.23% (% of $F \geq 6\% = 1.25\%$) and that of the second group 3.82% (% of $F \geq 6\% = 12.14\%$). Table 1 shows for each group of A.I. bulls, at each level (generation) of the pedigree (S, SS, SSS, SDS) the parameters defined above. This table reveals striking differences between these two groups. The variances (Var) and the $K_1$ ratios were markedly greater, while the effective numbers (EN) and the $K_2$ ratios were smaller in the 1986 – 1990 group. In fact, at that time, very few sires contributed numerous sons, grandsons, … while several other sires contributed very few.

Table 1. The genesis of inbreeding in the Belgian Blue cattle breed – Current and effective numbers of sires (S), sires of sires (SS), sires of sires of sires (SSS) and sires of dams of sires (SDS) within two groups of A.I. bulls

<table>
<thead>
<tr>
<th></th>
<th>182 A.I. bulls born from 1986 to 1990</th>
<th></th>
<th>140 A.I. bulls born from 1997 to 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CN</td>
<td>Ave</td>
<td>Var</td>
</tr>
<tr>
<td>S</td>
<td>71</td>
<td>2.56</td>
<td>13.48</td>
</tr>
<tr>
<td>SS</td>
<td>45</td>
<td>4.04</td>
<td>70.32</td>
</tr>
<tr>
<td>SSS</td>
<td>35</td>
<td>5.20</td>
<td>102.22</td>
</tr>
<tr>
<td>SDS</td>
<td>47</td>
<td>3.66</td>
<td>27.75</td>
</tr>
</tbody>
</table>

CN = current number of sires, sires of sires, …
Ave = average number of A.I. bulls per sire, sire of sire, …
Var = variance of number of A.I. bulls per sire, sire of sire, …
$K_1$ = Var/Ave
EN = effective number of sires, sires of sires, …
$K_2$ = EN/CN

For instance, the bull “Christophe” born in 1981 had 53 grandsons among the 182 A.I. bulls. Obviously, the bottleneck of the years 1986 – 1990 influenced greatly the current rate of inbreeding and the main sires and grand-sires of that time appeared repeatedly as “common ancestors” in the pedigrees of the 140 A.I. bulls (1997 – 2000) : Christophe (87 times), Opticien (48 times), Riant (39 times), Beaujolais (38 times), Galopeur (33 times), Precieux (33 times). Furthermore, the average relationships (potential inbreeding) of these ancestors with a sample of the registered population (680 individuals born in 1998 and 1999, in 364 herds, from 205 sires; average inbreeding = 3.56%) were : Christophe = 7.20%, Opticien = 8.36%, Riant = 7.67%, Beaujolais = 6.33%, Galopeur = 8.80%, Precieux = 3.06%, while the average relationship of 31 A.I. bulls born in 1999 with this sample of the breed was 4.63% (Hanset 2000). That time span (1999 – 2000) corresponds to a period of sustained genetic improvement of muscular development, independent of the $mh$ gene (Hanset et al. 2001). The
breeds of farm animals represent populations of limited effective size all the more so as the male sex is fewer in number, this being accentuated by artificial insemination and because of the great inequalities in the number of offspring inherent to selection. But, if in such circumstances, inbreeding is unavoidable, nevertheless, the rate of inbreeding could be kept under control if, as prescribed by theory, we had a larger number of sires with more equal genetic influences. In practice, it is recommended to take into account:

1) the proportion of sons and grandsons of the same progenitor allowed to enter A.I. or parameters of inequalities like those considered above;

2) the average inbreeding expected in the offspring of bulls candidates to A.I. (“potential inbreeding”);

3) at the herd level, the selection of mating pairs.

But, even so, the conflict between selection and the control of inbreeding will be permanent.

CONCLUSION

Inbreeding in the Belgian Blue breed was shown to result from great inequalities in the number of A.I. bulls coming from the same sire, sire of sire,… the larger this variation, the higher the subsequent rate of inbreeding. Such a situation resulted from intense selection on the basis of progeny performances and was paralleled by a sustained genetic improvement of muscular development, independent of the mh gene.

REFERENCES

Wright S. (1923) J. Hered. 14 : 339-346