Genetic Relationships in the Holstein Cow Population of Three Major Dairy Countries

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Introduction

A major concern about the emergence of the global breeding structure of the Holstein breed has been the apparent reduction in effective population size (Ne) and loss of genetic diversity. Wickham and Banos (1998) reported that the ratio of Ne to actual population size was about 0.22 for sires born in 1990 compared to 0.98 in 1975. Mrode *et al.* (1998) indicated for bulls with progeny test results, the percentage which were the sons of the 5 most used sires increased from about 30% in 1981 to about 50-70% in 1991 in many countries. However, the genetic relationships among cows in large dairy cattle populations from different countries have not been studied. This study therefore examines the genetic relationship among cows born from 2003 to 2006 in 3 major dairy countries. The use of a profit index should help increase selection differential and hence reduce the rate of decline in Ne. Thus the average genetic relationship among top cows based on index or milk evaluations are examined in addition to trends in inbreeding and Ne across the three populations.

Materials and Methods

For cows born from 2003 and 2006, evaluations for milk yield and the profit index value (PIV) in each country and their full pedigree were obtained from Great Britain (GBR), Italy (ITA) and Ireland (IRL). Cows born in 2005 and 2006 were too young to be evaluated, so a pedigree index was calculated for these cows. Inbreeding coefficients (F) were computed for each population and for a combined pedigree for the 3 populations. The number of equivalent generations (t) was calculated for all cows in the pedigree as the sum over all known ancestors of the term $(0.5)^n$, where n is the number of generations between ancestor i and the cow (Maignel *et al.*, 1996). The Ne per year was calculated as 1/2b, where b is the regression of F on t and it roughly estimates inbreeding rate.

The computation of average genetic relationship (AGREL) for cows within year of birth was not feasible due to the large number of cows. Therefore AGRELwas computed for the top and bottom 4000 cows ranked on PIV or milk evaluations both within and across countries. All computations of inbreeding and AGREL were carried out using the software RelaX2 (Stranden and Vuori, 2006). To gauge the degree of relatedness among the 3 populations, estimates of F and AGREL from the combined pedigree were compared with a situation when it is assumed there was no relationship among the populations (referred to as *expected*). For instance, consider the AGREL among the top 4000 index cows calculated initially within each country. If the 3 populations were unrelated, then, AGREL expected (AGREL-E) from the combined pedigree equals

$$\frac{1}{n}\sum_{i=1}^{3} a_i \ ;$$

where a_i is the sum of non-zero elements of the relationship matrix among the top 4000 computed within the i^{th} population, and $n = 0.5(m(m+1))$, with m =12000. The deviation of the actual AGREL calculated from the combined pedigree from AGREL-E, indicates the degree of relatedness among the 3 populations.

The relationship among the 3 populations could be due to the use of similar or related sires and progeny of similar or related sires. In addition, the importation of embryos could imply that similar foreign cows are used as dams across the 3 countries. There were 791 and 384 common sires and dams respectively across the 3 populations for cows born from 2003 to 2006. The degree of relatedness among the 3 population due to common foreign dams was estimated by deleting these cows from the pedigree and comparing estimates of *F* and AGREL with those from the full pedigree. The degree of relatedness from the use of similar and related sires was examined by estimating the AGREL among all sires with at least 20 daughters and for those that accounted for 80% of all daughters born across the 4 years.

Results and Discussion

The numbers of cows born from 2003 to 2006 used for the analysis are shown in Table 1 in addition to the estimated average *t*. The low numbers of IRL cows in 2005 is due to the fact it is based on 2005 born calves that had just calved in 2007 and were milk recording at the time of extraction. The high numbers in 2006 reflect all females present in the database without a restriction on being milk recorded. The number of cows with both parents known varied from 94 to 99%. The average *t* was about 5, apart for IRL when it was about 4 in 2003 and 2004. The estimates of *t* from the combined pedigree are higher indicating that the 3 countries could further improve the depth of pedigree by exchanging data on these cows.

The average *F* was about 2% per year for GBR and ITA but it is about 1% in IRL (Table 2). The average *F* from the combined pedigree was generally higher than observed within each country and was 10 to 15% higher compared to the expected value if the 3 populations were unrelated. The use of common foreign dams accounted for 1 to 1.5% increase in average *F* relative to the expected. Thus as expected the use of similar and related sires accounts for the majority of genetic relationship among the 3 populations.

The Ne calculated for the 3 populations assuming no relationships among the countries decreased from 107 in 2003 to 98 in 2006. Corresponding estimates from the combined pedigree were 97 and 87 respectively. This indicates a decrease of about 10% in Ne across the 3 countries, reflecting the increasing rate of inbreeding with time. The Ne estimated with foreign dams deleted from the pedigree indicated their use accounted only for 1% of the reduction in Ne.

AGREL among the top 4000 index cows (Table 3) was about 0.088 for ITA across the 4 years, increased from 0.057 to 0.103 in GBR and 0.029 to 0.272 for IRL. The high AGREL in the year 2006 for IRL and GBR is mainly a result of ranking the cows on pedigree indexes. Across the 3 populations, the AGREL varied from 0.044 to 0.08 and were lower than within each country. However, these were about 44 to 142% higher compared to a situation when the 3 populations were unrelated, with the use of foreign cows accounting for about 2 to 22% of this increase. As expected AGREL for the bottom 4000 index cows were very low in the GBR and ITA apart from IRL where these were higher compared to the top cows.

Within each country, the AGREL for top 4000 cows on milk evaluations were in general less related compared with the top index cows for GBR and ITA (Table 4), but were higher for IRL. The high weight on protein in the PIV for GBR and ITA and a negative or zero weight on milk could imply that more related cows were selected on the basis of the index. The opposite is true for IRL. However, interestingly, the AGREL was about 20% higher in the top 12000 cows ranked on milk compared to the index across the 3 populations for the first 2 years not based on pedigree index. Thus selection on the basis of the index seems to increase the degree of relatedness of top cows within GBR and ITA, but reduced the relatedness across the 3 countries.

The use of similar sires and progeny of related sires accounted for most of the relatedness between the 3 populations. About 4713, 4986 and 1532 bulls with at least 20 daughters accounted for 94, 90 and 82 % of all daughters born across the 4 years in GBR, ITA and IRL respectively. Out of these bulls, common sires between GBR/ITA, GBR/IRL and ITA/IRL were 367, 278 and 146 bulls respectively. However, about 750, 1129 and 269 sires accounted for about for 80% of the daughters in GBR, ITA and IRL when considering cows which were daughters of bulls with at least 20 daughters. The AGREL across countries and the number of common bulls indicate that GBR and IRL are sampling a lot of common bulls (Table 5). About 44% of these bulls in IRL are common to those in the GBR while 16% of bulls used in ITA are common to those used GBR. The AGREL within ITA was highest indicating that more related bulls are being used than in GBR and IRL.

Conclusion

The average *F* was 10-15% higher and Ne was about 10% lower from the combined pedigree compared with a situation when the 3 populations were unrelated. The use of PIV compared with milk, seem to increase relatedness among top cows within GBR and ITA but decreased the relationship among countries. Lower weight on production as in IRL is required for indexes to effectively reduced relatedness. The use of similar sires or progeny of related sire accounted for majority of the relatedness among cows. More common bulls were sampled in GBR and IRL but more related bulls were used in ITA.

References

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Table 1. The number (N) of cows born in each country, percentage with both parents known (Both) and average number of equivalent generation (Gen) per year of birth.

Year	GBR			ITA			IRL		
	N	Both	Gen[1]	N	Both	Gen[1]	N	Both	Gen[1]
2003	319510	99	4.95 (5.20)	327998	94	5.19 (5.46)	80899	94	4.07 (4.78)
2004	301873	99	5.08 (5.33)	314657	94	5.28 (5.61)	62429	96	4.19 (4.98)
2005	277957	99	5.21 (5.46)	309744	95	5.39 (5.74)	6661	99	4.56 (5.42)
2006	84749	99	5.28 (5.53)	297532	95	5.55 (5.89)	115760	99	4.57 (5.41)

[1]Numbers are in brackets are equivalent generations estimated from the combined pedigree.

Table 2. Average percentage inbreeding coefficient in each of three populations and in combined pedigree by year.

Year	GBR	ITA	IRL	ALL-E	ALL-O	%P
2003	1.85	2.13	1.04	1.89	2.06	9.4
2004	1.96	2.15	1.03	1.96	2.17	10.6
2005	2.09	2.21	1.07	2.14	2.38	11.2
2006	2.15	2.32	1.16	2.02	2.32	14.9

ALL-E=Expected inbreeding if 3 populations were unrelated, ALL-O = Observed average inbreeding coefficient in 3 populations; %P= percentage increase in observed compared with expected.

Table 3. Average relationship among the top (Top) and bottom (Bott) 4000 index cows within each country and across the three countries by year of birth.

Year	GBR		ITA		IRL		ALL-E		ALL-0		%P	
	Top	Bott	Top	Bott	Top	Bott	Top	Bott	Top	Bott	Top	Bott
2003	0.057	0.017	0.088	0.022	0.029	0.045	0.019	0.009	0.046	0.025	142	178
2004	0.057	0.022	0.083	0.019	0.031	0.043	0.019	0.009	0.044	0.031	132	244
2005	0.103	0.024	0.088	0.011	0.033	0.029	0.025	0.007	0.058	0.020	132	185
2006	0.083	0.023	0.087	0.010	0.272	0.044	0.049	0.009	0.086	0.020	76	122

ALL-E, ALL-O & %P are as defined in Table 2.

Table 4. Average relationship among the top (Top) and bottom (Bott)4000 cows on milk evaluations within each country and across the three countries by year of birth.

Year	GBR		ITA		IRL		ALL-E		ALL-0		%P	
	Top	Bott	Top	Bott	Top	Bott	Top	Bott	Top	Bott	Top	Bott
2003	0.051	0.019	0.069	0.021	0.041	0.015	0.018	0.006	0.051	0.018	183	200
2004	0.055	0.024	0.065	0.020	0.044	0.017	0.018	0.007	0.052	0.018	189	157
2005	0.063	0.018	0.072	0.013	0.037	0.025	0.019	0.006	0.055	0.022	189	267
2006	0.063	0.018	0.079	0.014	0.051	0.037	0.021	0.008	0.065	0.016	209	100

ALL-E, ALL-O & %P are as defined in Table 2.

Table 5. Number of (common) bulls that accounted for 80% of daughters born between 2003-2006 in the three populations and average genetic relationships among them in brackets.

GBR	ITA	IRL
750 (0.053)		
176 (0.059)	1129 (0.069)	
119 (0.041)	69 (0.044)	269 (0.033)