Challenges and Opportunities for Global Dairy Cattle Breeding – A Canadian Perspective

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Abstract

Around 6,000 Holstein bulls are newly proven each year worldwide, and 80% of those newly proven bulls are sampled in 9 countries. The major semen exporters are from US, Canada and the Netherlands, but other countries have been increasing their share of the global market. In 2008, Canada has exported $71M of dairy semen. The advent of genomic selection will provide new opportunities and challenges in the global dairy semen market. The market will partly shift from proven sires to young genotyped bulls, provided one can confirm over the next few months that the genetic level and accuracy of evaluation of these young bulls are as high as expected. There is a global race to be among the first to offer this new 'product'. However, it becomes a priority to be cautious and take all the steps necessary to offer on the market something that is consistent and reliable. Because of the large number of tested bulls, genomics will be first applied in the Holstein breed. The other dairy breeds, like Jersey, Ayrshire and Brown Swiss will run the risk to fall behind, if genomic selection is attempted only at the national level. Global cooperation among countries for those breed may be the best alternative to test and adopt this new technology. Another might be the use of SNP haplotypes to mark a large number of QTL, an approach that would require a smaller "training set" of bulls than genomic selection per se. Finally, genome wide selection may make it easier for multinational AI organizations to offer different groups of young bulls for different selection objectives corresponding to various local markets.

Current situation

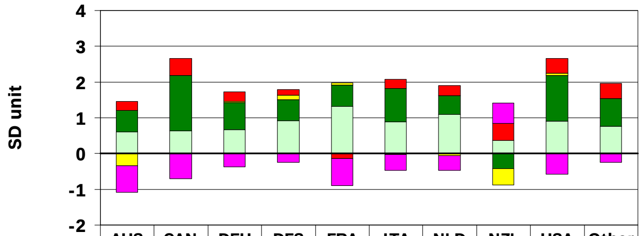
Data. Interbull evaluations from the April 2009 official run were used for each country scale for four breeds (Holstein, HOL; Red Dairy Cattle, RDC; Brown Swiss, BSW; Jersey, JER) in order to compare genetic level and progress, and assess global and foreign markets across countries. Bull EBV for protein yield, overall udder, direct longevity, SCS and first service to conception were analyzed as trait indicators of production, conformation, longevity, health and fertility, respectively. EBV were standardized within each country scale, and then averaged across country scales. Finally an aggregate index was computed as the sum of the five analyzed traits. Countries were compared based on two groups of bulls: a) bulls born in 2002-2003 (genetic level); and b) bulls born between1997 to 2003 (genetic progress). Country of origin for each bull was assumed to be the country where the bull had the largest number of daughters. Domestic, foreign and overall market share was estimated as the proportion of daughters sired by proven AI bulls from a given country of origin among the daughters of all bulls born in the same country, in foreign countries or overall. Daughters used in the calculation were from bulls born since 1986 that were included in the April 2009 Interbull production evaluations.

Results – Genetic level and progress. Table 1 shows the total number of production proven bulls across all country scales for the 4 studied breeds. With the exception of the Jersey breed, the number of proven bulls has decreased over time. As expected, the Holstein breed has the largest share of proven bulls (~6,000 bulls per year), followed by Red Dairy Cattle, Jersey and Brown Swiss.

Table 1. Total number of bulls proven for production.

Birth Year	HOL	RDC	BSW	JER
1997	6,817	546	443	410
1998	6,459	505	398	432
1999	6,150	465	438	439
2000	5,937	530	406	454
2001	5,956	515	376	460
2002	5,950	433	323	417
2003	5,751	435	325	405

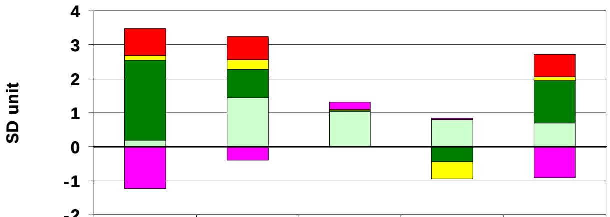
Figure 1. Genetic level (SD unit) of bulls by country (HOL).



	AUS	CAN	DEU	DFS	FRA	ITA	NLD	NZL	USA	Other
Fertility	-.743	-.698	-.379	-.251	-.757	-.445	-.407	.567	-.573	-.233
Longevity	.251	.471	.270	.159	-.137	.251	.285	.483	.408	.432
SCS	-.342	-.006	.023	.129	.067	-.023	-.057	-.454	.061	-.013
Udder	.602	1.548	.764	.594	.601	.931	.533	-.428	1.286	.762
Protein	.610	.642	.669	.916	1.310	.888	1.088	.361	.902	.768

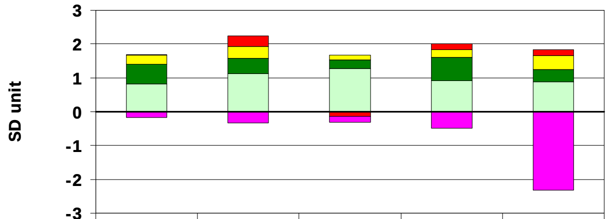
Figure 1 reports the average standardized bull proofs of the 5 studied traits by country of origin for HOL. Figures 2 to 4 are for RDC, BWS and JER, respectively. For HOL it is easy to observe how countries differ by genetic level in various traits. For example, Canada has the highest genetic level for Overall Udder, whereas France has the highest genetic level for protein yield. The scale of SCS is reversed, thus higher value of proof is desirable. The Nordic countries (DFS) have the highest value for SCS. It is interesting to observe how the genetic level of fertility is negative in all countries with the exception of New Zealand. Differences are even stronger in RDC (Figure 2), where Canada again has the highest value of overall udder, and the Nordic countries (DFS) together with Norway have the highest value for protein yield. Differences are also marked in JER (Figure 4), where US and Australia have the highest values for protein yield, and Canada has the highest value for overall udder and longevity. Differences among countries are less noticeable in BSW (Figure 3).

Figure 2. Genetic level (SD unit) of bulls by country (RDC).



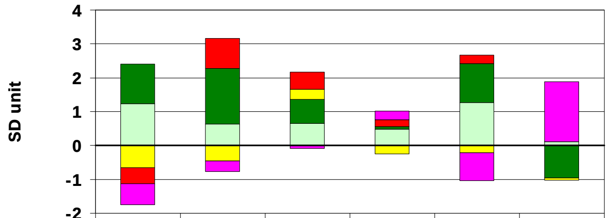
	CAN	DFS	NOR	NZL	Other
Fertility	-1.220	-.396	.220	.038	-.904
Longevity	.780	.678		.010	.667
SCS	.152	.285	.017	-.508	.114
Udder	2.341	.838	.034	-.429	1.246
Protein	.201	1.435	1.037	.795	.699

Figure 3. Genetic level (SD unit) of bulls by country (BSW).



	CHE	DEA	ITA	USA	Other
Fertility	-.180	-.331	-.170	-.490	-2.320
Longevity	.015	.317	-.148	.182	.162
SCS	.260	.338	.144	.219	.415
Udder	.595	.459	.257	.693	.370
Protein	.816	1.127	1.272	.918	.877

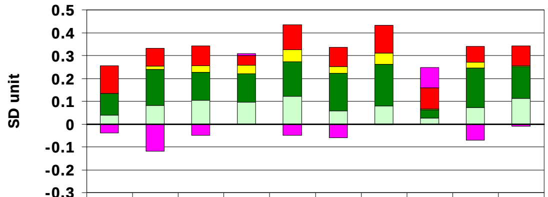
Figure 4. Genetic level (SD unit) of bulls by country (JER).



	AUS	CAN	DFS	NZL	USA	Other
Fertility	-.610	-.310	-.085	.239	-.834	1.770
Longevity	-.481	.881	.512	.205	.238	
SCS	-.656	-.453	.290	-.242	-.209	-.067
Udder	1.171	1.641	.717	.078	1.154	-.950
Protein	1.238	.639	.653	.486	1.275	.116

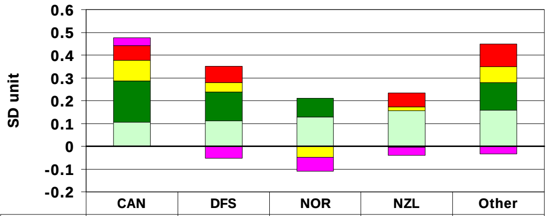
Figures 5 to 8 show average genetic progress by country for HOL, RDC, BSW and JER, respectively. In HOL, most countries have positive genetic progress for protein yield, overall udder and direct longevity, and negative genetic progress for first service to conception.

Figure 5. Genetic progress (SD unit) of bulls by country (HOL).



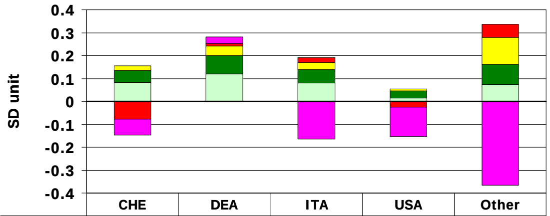
	AUS	CAN	DEU	DNK	FRA	ITA	NLD	NZL	USA	Other
Fertility	-.037	-.118	-.050	.008	-.050	-.061	-.003	.090	-.071	-.010
Longevity	.122	.079	.086	.043	.108	.084	.121	.091	.070	.088
SCS	-.001	.015	.029	.038	.054	.030	.049	.005	.026	.004
Udder	.095	.156	.122	.124	.150	.164	.182	.036	.172	.139
Protein	.039	.082	.105	.095	.122	.058	.080	.026	.073	.112

Figure 6. Genetic progress (SD unit) of bulls by country (RDC).



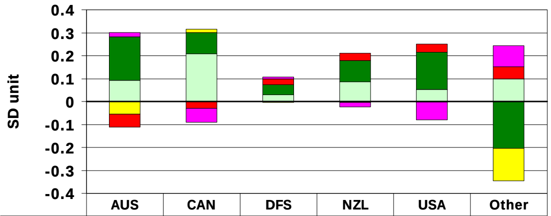
	CAN	DFS	NOR	NZL	Other
Fertility	.032	-.052	-.062	-.036	-.033
Longevity	.067	.071		.061	.099
SCS	.090	.044	-.048	.017	.069
Udder	.181	.125	.083	-.005	.122
Protein	.105	.112	.128	.155	.158

Figure 7. Genetic progress (SD unit) of bulls by country (BSW).



	CHE	DEA	ITA	USA	Other
Fertility	-.070	.030	-.165	-.128	-.367
Longevity	-.078	.010	.021	-.026	.057
SCS	.021	.043	.032	.008	.117
Udder	.051	.080	.058	.032	.090
Protein	.083	.120	.080	.014	.073

Figure 8. Genetic progress (SD unit) of bulls by country (JER).



	AUS	CAN	DFS	NZL	USA	Other
Fertility	.019	-.062	.010	-.018	-.077	.094
Longevity	-.058	-.029	.025	.032	.036	.052
SCS	-.054	.013	-.004	-.005	-.002	-.141
Udder	.190	.093	.044	.092	.162	-.204
Protein	.092	.209	.029	.087	.052	.099

Results – Global share of market. Figure 9 shows the percentage by country of the global dairy market for HOL, where the market is defined as the total number of daughters (N= 50,930,477) sired by proven AI bulls born since 1986 that were included in the April 2009 Interbull production evaluation. Figure 10 is a partial breakdown of Figure 9 and shows only the percentage by country of the foreign dairy market for HOL, where foreign market here means the total number of daughters (N=11,090,314) sired by foreign proven AI bulls born since 1986. Figures 11 to 16 show corresponding results for RDC (Total N=4,779,081; N by foreign sires=220,007), BSW (Total N=2,390,154; N by foreign sires=503,434) and JER (Total N=4,360,179; N by foreign sires=447,620), respectively. In HOL (Figure 9), all major dairy countries have at least 10% of the global market, led by US (22%), Germany and France. However, when only daughters from foreign bulls are considered (22% of global market for HOL; Figure 10), US and Canada dominate with 2/3 of the foreign market, followed by The Netherlands with 14%.

Figure 9. Global market by country (HOL).

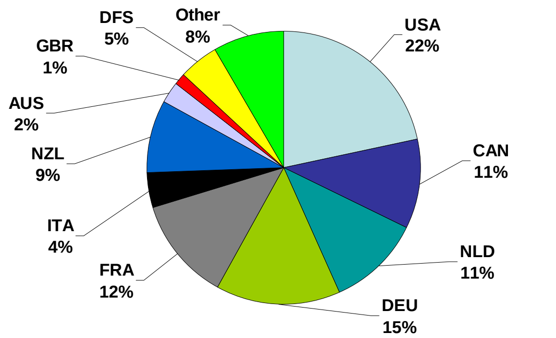


Figure 10. Percentage of foreign market by country (HOL).

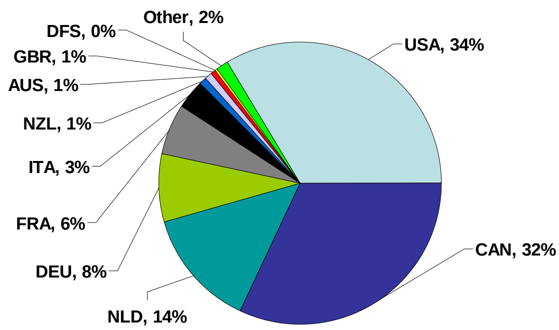


Figure 11. Global market by country (RDC).

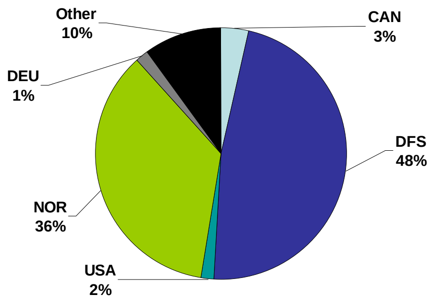


Figure 12. Percentage of foreign market by country (RDC).

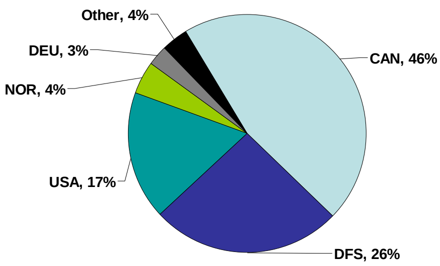


Figure 13. Global market by country (BSW).

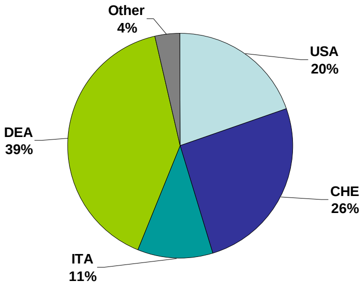


Figure 14. Percentage of foreign market by country (BSW).

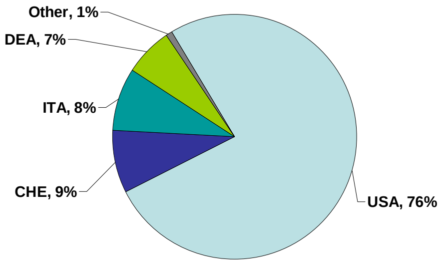


Figure 15. Global market by country (JER).

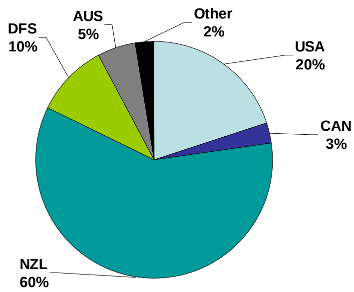
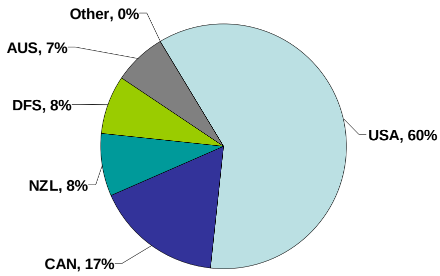


Figure 16. Percentage of foreign market by country (JER).



In RDC (Figures 11-12), most daughters tended to be sired by local bulls, thus only 5% of daughters are sired by foreign bulls, and Canada dominates with almost half of those. In BSW (Figures 13-14), the percentage of foreign market is as high as for HOL (21%) and mostly dominated by US with ¾ of the foreign market. In JER (Figures 15-16), the foreign market is smaller (10%), and again with a large percentage of US (60%). It should be noted that those market share are quite retrospective (bulls born since 1986) and may not represent accurately emerging trends in recent years.

Where Are We Going?

The advent of genomic selection has provided new opportunities and challenges in the global dairy semen market. The potential of genomics has already been proven in terms of parentage verification. Incorrect identification of parents is a minor problem in Canada (~3%) where average herd size is relatively small; however, it has been proven to be a problem in other countries (e.g. U.S.) where misidentification can be as high as 20%. Genomics has had an effect on selection against some known genes (BLAD, CVM), but its biggest impact today is through marker assisted selection, particularly genomic selection.. As a result, the market will partly shift from proven sires to young genotyped bulls, provided one can confirm over the next few months that the genetic level and accuracy of evaluation of these young bulls are as high as expected. The advent of genomic selection has been made possible by the dramatic decrease of genotyping costs, which went from 40$ per marker in 1990 (specific test), to 2-3$ in 2000 (micro-satellites), 0.04$ in 2005 (10K SNP panel), and 0.005$ in 2009 (50K SNP panel). The bottom line is that genomics has caused a revolution in the dairy cattle industry. Adoption by AI organizations and by elite dairy producers has been very rapid. Genomic selection is already part of the business of dairy cattle improvement. Up to now, the benefits of genomics in terms of increased genetic gains have only been showed through simulation studies. Compared to the classic progeny test scheme, they represent an increase of 10 to 100%, depending on the level of use of young genotyped animals as parents of the next generation. Genomic selection will likely affect the rate of increase of inbreeding. Large SNP panels permit better monitoring of the proportion of homozygous alleles in the population. In addition, genomic selection can theoretically reduce inbreeding per generation, as co-selection of sibs decreases. In practice, however, the shorter generation interval resulting from genomic selection is likely to lead to higher increases in inbreeding per year than in the past. It remains to be seen whether AI organizations, which face strong competitive pressures, will be able to adopt methods to better balance genetic progress and inbreeding. An international effort in this area may therefore be required to reduce the risks associated with a rapid decrease in the genetic variability of commercial breeds of dairy cattle.

Impact on dairy industry

Genomics has brought upon new collaborative efforts never seen before in the AI industry. Some successful examples are: a) US and Canada (via AIPL, NAAB, CDN and University of Guelph); b) Ireland and New Zealand (via ICBF and LIC); c) Germany, France, Netherlands, Denmark and Sweden (via the very recent creation of Eurogenomics, a partnership between DHV, VIT, UNCEIA, CRV and Vikings Genetics). AI organizations are still highly competitive but at the same time are increasingly willing to share genotypes in order to estimate SNP effects more accurately. The breeding scheme has already drastically changed with the genotyping of a large population of males calves, followed by pre-selection of the top 20-25% to be commercialized and progeny tested. Thus, a new product is on the market, young bulls with very high Genomic Parent Average, and the pricing system has already changed. A reduction of progeny testing schemes is expected over time. Research has mainly focused on improving SNP estimation and genomic evaluation, but little has been done yet in terms of optimizing breeding schemes in the presence of genomic selection. There are plenty of opportunities for new ideas outside of the box. Genomics has also affected breed societies. Due to the lower number of proven bulls in breeds other than Holstein, collaboration across breed societies from various countries is essential. The Brown Swiss breed is a successful example, where the European Brown Swiss Federation has reached an agreement among their members for providing genotypes to Interbull, and for Interbull to develop a genomic evaluation for this breed. Breed societies are taking advantage of genomics in two ways: parentage testing, and genotyping of elite cows. Finally, the impact of genomics on dairy producers is observable both for the commercial farmer (heifer/cow management with low density panel soon to arrive) and for the breeder, who will feel 'obligated' to genotype elite stock for sale/export (GEBV have become an added value for those cows). Of course, the larger impact will be faster genetic progress with more accurate selection of females in the herd, and sires with higher genetic levels than before genomics.

Conclusions

- Traditional progeny testing has produced tangible and successful results across all countries.
- Genetics competition varies by country and breed.
- Genomics is not a cure for inbreeding and could potentially make things worse
- Genomics is already part of the dairy industry; however, simulation results and validations with historical data still have to be confirmed with future data.

A transition period will be needed before full implementation of genomic selection. Progeny testing has not disappeared yet. Most importantly collection of phenotypes must continue since traditional genetic evaluations are required for the continuous re-estimation of SNP effects, and to permit genomic association studies and genomic selection for relevant novel traits. Finally, dairy producers should be reminded that progeny tested sires are still significantly more reliable than genomically tested bulls.