

# Genetic Diversification of the Holstein Breed in Canada and Internationally

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## Introduction

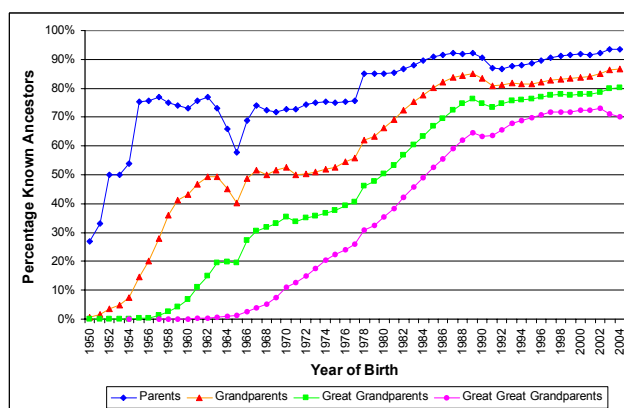
The increasing level of average inbreeding in most dairy cattle populations is gaining awareness and creating concern amongst producers and other others involved in genetic improvement. In fact, from a genetic selection perspective, it is not surprising that the genetic evaluation systems and selection programs used in dairy cattle breeding for the past decade or two have led to these increased levels of the inbreeding. Annual rates of genetic progress are maximized when the intensity of selection is high and significant genetic variation exists in the population, but these forces act against each other.

Given the current global interest in monitoring inbreeding levels and trends within various dairy cattle populations, the main objective of this study was to quantify the level of genetic diversification that exists within the Holstein breed in Canada and internationally.

## Data and Methods

The pedigree database at Canadian Dairy Network (CDN), the national dairy cattle genetic evaluation centre for Canada, was used as the starting point for this study. In addition to all known herdbook registrations in the Holstein breed as provided weekly by the Holstein Association of Canada, the CDN database was enhanced to include all ancestry information for Holsteins with a registration number originating from the United States (i.e.: nation code “USA”), as provided by AIPL-USDA. For the pedigree analysis at the international level, the Interbull pedigree file of February 2005 was loaded into the CDN database in its entirety as well as all known animal identification cross-references. In

total, the pedigree file used for this study included 7.69 million females and 382,725 males of the Holstein breed. The completeness of pedigree information is presented in Figure 1.



**Figure 1.** Completeness of pedigree by year of birth defined as the percentage of known parents, grandparents, great grandparents and great-great grandparents.

## Inbreeding

Based on all known pedigree information, the inbreeding coefficient for each animal was computed as usual. In addition, the method of VanRaden (1999), which accounts for missing pedigree information, was applied to the Canadian registered Holstein population.

## Relationship Value (R-Value)

Since February 2004, CDN computes and officially publishes an R-Value for every animal in each dairy cattle breed in Canada (Van Doormaal *et al.*, 2003). R-Value represents the percentage of genes that the

animal has in common (i.e.: its genetic relationship) with a defined reference population. In Canada, the official R-Value calculation uses the population of “active females” within each breed as the reference group, which includes cows still alive in a milk-recorded herd plus herdbook registered heifers up to 30 months of age that have not yet calved in a milk-recorded herd (i.e.: >1 M females). Currently, the range in R-Value for Canadian Holsteins is from zero for totally outcross animals to a high of 20% for Hanoverhill Starbuck (HOCANM352790). R-Value is a similar measure of genetic relationships and inbreeding levels within a population to the Expected Future Inbreeding (EFI) values published by AIPL-USDA (VanRaden and Smith, 1999). For a bull with a given R-Value in Canada, when mated to a random group of females in the “active” population used as the reference group, his EFI in Canada would be half his R-Value.

The method for computing official R-Values was modified for this study by changing the reference populations. To evaluate changes in R-Value over time within the Canadian Holstein breed, separate calculations were done by changing the reference group at 4-year increments of birth year (i.e.: 1980, 1984, 1988, ... , 2004). For the analysis at the international level, the reference group was all herdbook registered Holsteins in Canada born in 2004 and countries were compared based on the percentage of genes that were in common between this reference group and the proven bulls born in 1999 with country defined according to the nation code of the international identification number used by Interbull, which normally represents each bull’s country of birth.

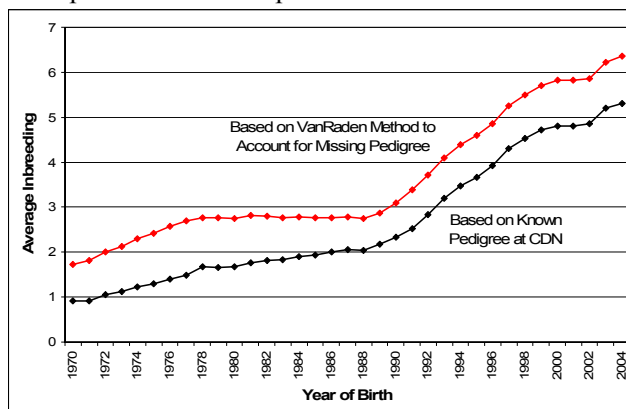
To quantify the specific impact of key animals on the Holstein population in Canada and other countries, the pedigree file was also used to identify the percentage of animals born within each year that are their descendants. At the national level the number of generations between the animal of interest and each descendant was identified based on the closest link between them.

## Results and Discussion

### Inbreeding

Estimated inbreeding trend for Canadian Holsteins is presented in Figure 2 using all known pedigree data as well as from the method of VanRaden (1992) that accounts for missing pedigree, which was also applied by Wiggans *et al.* (1995). After ten iterations using the VanRaden method the average inbreeding level within each year of birth was stabilized.

While both estimation methods yielded essentially parallel trends and rates of increase over time, the absolute level of average inbreeding within any birth year was  $.95 \pm .13$  percentage points higher after accounting for missing pedigree data using the VanRaden method. For Canadian registered Holsteins born in 2004, the average inbreeding level is 6.4% based on VanRaden method versus 5.3% using all known pedigree data. Consistent use of the VanRaden method, or another approach such as using only animals with four complete generations of pedigree information, by all organizations responsible for estimating average inbreeding levels in various countries or breed populations would facilitate proper interpretation and comparison of results.



**Figure 2.** Estimated inbreeding trend in Canadian Holsteins using all known pedigree data and the VanRaden method.

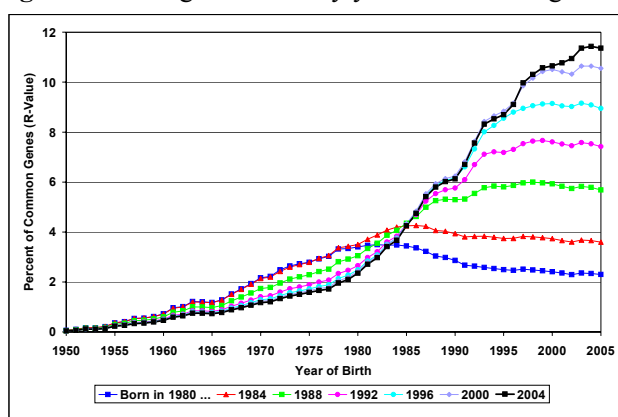
### Relationship Value (R-Value)

Trends of increasing inbreeding levels indicate that animals born more recently have more genes in common amongst themselves compared to animals born in earlier years. To demonstrate this point graphically, average R-Values by year of birth are presented in Figure 3, relative to reference populations that change at 4-year intervals starting with animals born in 1980.

Using Canadian Holsteins born in 2004 as the reference group, their average R-Value amongst themselves is 11.4%. For the same reference group, the average R-Value for animals born in previous years decreases steadily to below 2% for heifers born before 1979.

An interesting observation from Figure 3 is the eventual plateau in average R-Value that is established regardless of the reference population used, followed by only a very gradual decrease sometime thereafter. In other words, for any given reference birth year, the average genetic relationship between animals born in that year and those born for many years later seems to stabilize at a given R-Value. This phenomenon suggests that once average inbreeding levels in a population reach a certain level, it is extremely difficult to reduce them back to lower levels, at least within a 10 to 15-year time period.

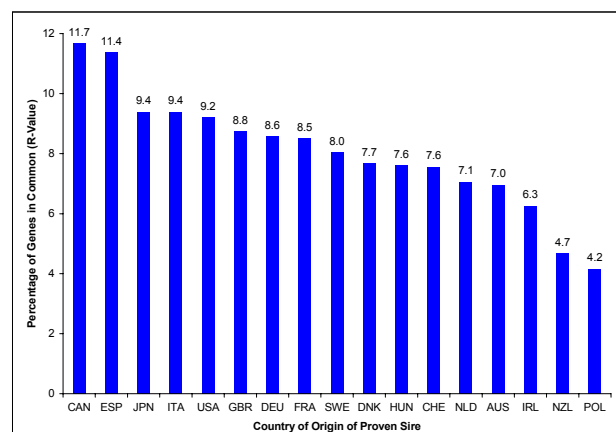
**Figure 3.** Average R-Value by year of birth using 4-



year increments in birth year for defining the reference population.

To quantify the level of genetic relationships across various Interbull member countries with

several Holstein bulls proven annually, average R-Value was computed for proven bulls in each country born in 1999 with Canadian Holstein heifers born in 2004 as the reference population (Figure 4).



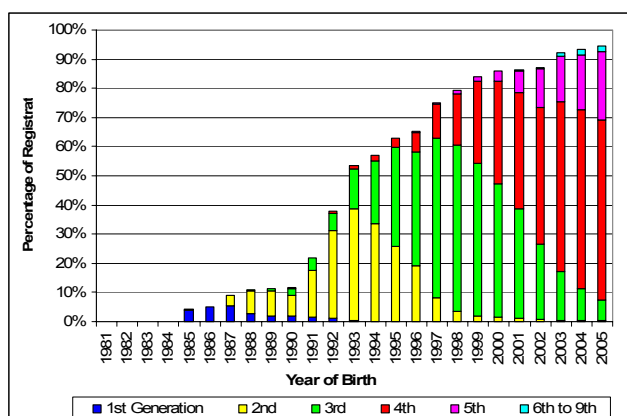
**Figure 4.** Average R-Value for 1999-born proven sires by country of origin relative to Canadian Holstein heifers born in 2004.

From this analysis, the proven bulls from Canada and Spain, born in 1999, have the highest percentage of genes in common with the Canadian Holstein population born in 2004 with R-Values of 11.7% and 11.4%, respectively. Proven bulls born in 1999 in Japan, Italy and the United States have the next highest average R-Value with Canadian Holsteins born in 2004 at 9.4%, 9.4% and 9.2%, respectively. On the other end of the spectrum, proven bulls born in Poland and New Zealand are the least related to Holstein heifers born in Canada with R-Values of only 4.2% and 4.7%, respectively. Ireland (6.3%), Australia (7.0%) and the Netherlands (7.1%) also seem to have proven sires less related to the Canadian Holstein population based on this analysis.

### Impact of Key Animals

Pedigree enthusiasts and breeders often look for key individuals as ancestors in pedigrees of heifers born today. While the main objective of this approach is to maximize the possibility of capitalizing on known strengths of various bulls or bloodlines, it is also an indirect way of monitoring inbreeding. In Canada, the domination of Hanoverhill Starbuck in Holstein pedigrees is well known but has never been

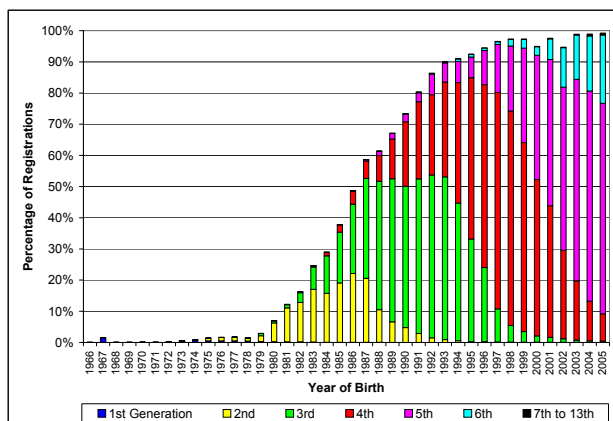
quantified. The pedigree file was used to identify all progeny of this sire as well as the descendants for each subsequent generation based on the closest link back to Hanoverhill Starbuck in their pedigree. Once all descendants were identified, the percentage of all heifer registrations in the Canadian Holstein herdbook that are descendants was computed for each year of birth as shown in Figure 5.



**Figure 5.** Percentage of Canadian Holstein heifer registrations by year of birth that are descendants of Hanoverhill Starbuck.

For Canadian Holsteins born since 2003, 93% are descendants of Hanoverhill Starbuck with nearly two-thirds being four generations and 18% being five generations away. The arrival of his first proven sons in 1990, grandsons in 1996, and great grandsons in 2002 resulted in a significant penetration of Hanoverhill Starbuck in Canadian pedigrees.

Figure 6 shows the results of the same computation for Round Oak Rag Apple Elevation (HOUSAM1491007), who was proven in the United States and is the sire of Hanoverhill Starbuck. His penetration in Canadian Holstein pedigrees has reached the 99% level for heifers born since 2003.



**Figure 6.** Percentage of Canadian Holstein heifer registrations by year of birth that are descendants of Round Oak Rag Apple Elevation .

At the international level, pedigrees of proven bulls born in 1999 were analyzed to determine the percentage within each country of origin that are descendants of Round Oak Rag Apple Elevation or Hanoverhill Starbuck (Table 1).

**Table 1.** Percentage of proven bulls born in 1999 that are descendants of Round Oak Rag Apple Elevation or Hanoverhill Starbuck by country of origin.

Country of Origin	Elevation	Starbuck
Australia	95.6%	31.9%
Canada	99.5%	85.0%
Denmark	96.0%	47.9%
France	96.0%	46.9%
Germany	99.7%	65.8%
Great Britain	94.7%	39.1%
Ireland	82.3%	40.4%
Italy	98.5%	56.0%
Japan	99.4%	34.1%
Netherlands	94.6%	35.1%
New Zealand	89.1%	23.9%
Sweden	94.2%	44.6%
United States	96.5%	38.2%

For Elevation, 11 of the 13 countries analyzed had at least 94% of the 1999-born proven sires as descendants with New Zealand (89.1%) and Ireland (82.3%) as exceptions. In the case of Starbuck, his domination in Canadian pedigrees was obvious at 85% and was followed by Germany (65.8%) and Italy (56.0%). Other countries have between 35% and 50% with New Zealand being the only exception at 23.9%.

## Summary

Pedigree analysis of Canadian Holsteins yielded an estimated average inbreeding level of 6.4% for heifers born in 2004, after accounting for missing information. These same heifers have an average R-Value of 11.4%, representing the percentage of genes in common. For Canadian Holsteins born since 2003, 93% are descendants of Hanoverhill Starbuck while at least 99% are descendants of his sire, Round Oak Rag Apple Elevation.

Analysis of bull pedigrees from Interbull member countries showed that outside of Canada, 1999-born proven bulls in Spain had the highest genetic relationship with Canadian Holstein heifers born in 2004 while those from Poland, New Zealand and Ireland showed the lowest average genetic relationship to Canadian Holsteins. Round Oak Rag Apple Elevation appears in the vast majority of proven bull pedigrees worldwide whereas greater variability exists across countries in the impact of Hanoverhill Starbuck in 1999-born proven bull pedigrees.

## References

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