Application and Cost Effectiveness of Dairy Genomics

Blair Murray

Murray Agri Consulting, Kemptville, ON
Email: bmurray2008@sympatico.ca

■ Take Home Messages

- Genomic testing has been very rapidly accepted by dairy breeders as it provides a more accurate estimate of genetic value for males and females early in life.
- Sires with only a Genomic Parental Average can be used successfully in a herd provided they are used on a group basis.
- Largest effect on genetic gain from using genomics will come from using improved accuracy in order to make selection decisions early in life for AI sires, cows and heifers: shortening the generation interval
- A number of strategies can be used for within-herd selection using the 6k genomic test to test all replacements or only a portion.
- Turnover rate including calf survival rate and herd reproduction rate is key to profitable use of genomic testing for within-herd selection.

The use of genomic information in genetic evaluation has brought about revolutionary change in dairy cattle selection. Genomic evaluations increase the accuracy of genetic evaluations and have the potential to rapidly increase the rate of genetic improvement in many traits. Their use is especially effective where there is limited information such as with females and young bulls, and with traits of lower heritability.

The sequencing of the bovine genome in 2004 spurred a worldwide effort to use basic information about genetic coding to improve how the genetic values of cows and bulls are estimated. The bovine is made up of about 3 billion DNA base pairs (Genome Canada) of which there are about 25-30,000 known useful genes. For genomic selection, the genome researchers look for markers or single nucleotide polymorphisms (SNPs). A SNP is a place in a chromosome where the DNA sequence can differ among individuals. SNPs are particularly useful when they occur on a gene or close to a gene that contributes to an important trait. As most traits are controlled by many genes, the process is complex, and real progress in application of this technology was not made until a genotyping computer chip called the Illumina 50k test was developed that could identify over 50,000 SNP's on the genome.

The 50k chip test continues to be used for high-end breeding stock and for screening young artificial insemination sire entries. A simpler cheaper test, the 6k chip test, has been developed which identifies about 6000 carefully chosen SNPs that are the most useful in identifying economically important dairy traits. This test has been developed to enable herd owners to make use of genomic testing on a more widespread basis. Provided that at least one parent has been tested with the 50k test, the more economical 6k test can be used with only a small loss in accuracy due to the use of a computing method called imputation, which uses knowledge of the known parental genome in the calculations.

■ Tests Available

The initial genomic test available used the Illumina 50k chip, which evaluated about 54,000 SNPs that were of value on the bovine genome. This has become the accepted standard for genomic testing of AI sires, potential bull dams and screening of young sires. The cost of using this test has declined since it was first introduced; however, it is still very expensive for widespread use by dairy farmers. In 2010, Holstein Canada and the Semex Alliance partners launched Geno Test, a program that makes the 6k test available to Canadian producers at a cost of $45 per test (Table 1). See the website for updated information:
https://www.holstein.ca/Lite/Aspx/GeneticsGenomicsGenomicTestingLite.aspx

Table 1. Genomic Tests Available and fees as of June 2012

Genomic Test	Hair or Swab DNA
Low Density 6k SNP Test	$45*
50k SNP Test	$135*
800k (HD) SNP Test	$250 USD**

* Check with Holstein Canada for details
** Available through Holstein USA
(http://www.holsteinusa.com/programs_services/genomics_6k_snp.html)

Although genomic testing can be carried out on a variety of tissue samples, the preferred samples are hair, including roots, or, in the case of young calves, a nasal swab. Refer to the website for detailed instructions and order forms.

Making Genetic Improvement

Genetic improvement depends upon four factors:

- Selection intensity – what top percentage of selection candidates are kept as parents.
- Selection accuracy – how well true genetic merit is identified
- Genetic variation – how much variation there is to work with (heritability)
- Generation interval – how long it takes to identify superior individuals and produce offspring (average age of the parents when offspring are born).

Genomic selection can improve three out of four factors important to genetic improvement: selection intensity by screening more animals to be parents of the next generation, improved accuracy of identifying superior individuals, and shortening the generation interval by allowing selection of individuals early in life.

Sire Selection

The publication of the August 2009 dairy genetic evaluations marked a new era in Canada for bull proofs to include genomic information (GEBV). With current releases it is only the exceptional bull that does not have a GEBV. It is very important to keep in mind that the genomic evaluation methodology was developed as a cooperative effort of major bull studs, USDA and the Canadian Dairy Network and remains in the public domain available for the good of the dairy industry unlike genetic advances in some other species and with crops.

With progeny proven sires, who have many daughters and a reliability over 90%, the estimated breeding value (EBV) is already a pretty accurate measure of the genetic value that a bull passes on to his offspring. For these sires the addition of genomic information improves this accuracy only a small amount for most traits. However, the improvement in accuracy can be substantial for traits with low heritability such as mastitis resistance and other health traits, which are difficult to evaluate through traditional methods.

With genomic testing, it is now possible to screen thousands of candidate young sires for AI selection and select the best possible candidates to enter the progeny testing program. This increases the selection intensity and also reduces the costs of maintaining large numbers of young sires awaiting proofs, counterbalanced a bit by higher prices for the sires actually purchased.

Dairy producers can now use, along with proven sires, young sires that have genomic information or GPA's – genomic parent average. These bulls' GPA's are equivalent to the addition of 9-20 daughters for production and type traits in a traditional progeny proof. They are not as accurate as a progeny proof, and breeders should consider using them in groups rather than trying to select one or two top bulls to use exclusively.

- A group of 5 genotyped young sires has an average reliability nearly as good as that of proven bulls
- A group of 10 genotyped young sires has the same average reliability equivalent to proven sires.

These young bulls on average can impart superior genetics as long as one does not concentrate on one particular bull given their lower reliability.

A strategy could be to use top, highly proven sires on 50% of the herd and a group of highly ranked young genomic sires on the remaining 50% of the herd. Set a limit to the number of breedings to any one sire and then replace it with a new top bull. Review the list of sires at every genetic evaluation and add and delete individuals as better bulls come along.

An added advantage of having GPA's on young sires is the availability of more accurate information on traits such as calving ability and fertility, opening up the possibility of using best genomic bulls on heifers. The accuracy with GPA's is still less than with highly proven progeny tested bulls, so the breeder should exercise some caution in their use. One AI organization recommends that when using GPA bulls on heifers, the bulls should be rated higher than average for calving ease.

Sex sorted semen from high genomic bulls would be a much better choice for breeding heifers, yielding all female offspring to take advantage of the advanced genetics and female calves and a much better chance of fewer calving difficulties and better survival at calving.

▪ Female Selection

Although parent averages (PA) have been available for qualifying females for a number of years, they often were not used for within-herd selection, given their low reliability. Because of breeders' lack of confidence in PA's, decisions were usually based on the knowledge of the family members, the appearance of the animal, or the heifer's status after one or even two lactations. A lot of heifer culling decisions are random or depend upon the time of year the heifer calves are born or whether there is room in the milking string. As a result, heifer selection contributes little to herd improvement.

For potential bull mothers, embryo donors, and parents of genetic material for export, the 50k test is the standard genomic test used. The ease of use and relatively low cost of the 6k test makes it a good choice for screening potential superior breeding stock and also for within-herd selection of females.

The accuracy of heifer selection increases substantially when selection is based on genomic evaluations using the 6k test. The reliability of the genomic parent average (GPA) of a genotyped heifer is more accurate than that of a non-genotyped cow with records of two or three lactations (Table 2).

Table 2. Average gain in LPI reliability due to genomics

Sub-group Holstein breed	Average LPI Reliability (%)		
	Traditional (parent average)	Genomics	Gain
50K young bulls and heifers	37	66	29
3K heifers (born 2008-11)	35	61	26
Younger cows: 1st and 2nd lactation	54	70	16
Foreign cows with MACE[1] in Canada	43	68	25
1st crop proven sires in Canada	85	89	4
Foreign sires with MACE[1] in Canada	70	81	11

[1] Multiple-trait across country evaluations

Source: Canadian Dairy Network. April 2011. Average gain in LPI Reliability Due to Genomics.

■ Selection Strategies

Genotype Heifers Shortly After Birth

There are a number of possible strategies to make use of genomic testing. Greatest impact can be attained by testing just after birth and practicing selection well before the replacement heifers have their first calf. Not only does this allow the opportunity to select the best possible replacements to enter the herd but selection decisions can be made early reducing the cost of raising replacements.

Genotype all Heifers and Select Best

Modeling carried out by Dr. Jacques Chesnais and associates shows possible advantages in using heifer genotyping to select the best replacement heifers to enter a milking herd, based upon the resulting improved production of the heifers and their offspring over three lactations.

Table 3 shows the potential to profit from the use of genotyping according to the replacement rate in the herd and the relative number of heifers that are available from which to select replacements. Having a large number of replacement heifers increases the power of genomic selection. The number of replacement heifers available for selection can be increased by improving herd calving interval and lowering calf mortality.

Table 3. Net current day value ($) of genotyping all available heifers in a herd of 100 milking cows and selecting the best ones based on GPA, after accounting for the cost of genotyping

Mortality rate of female calves from birth to genotyping		Herd replacement rate (%) 25	30	35	40
5%	# of heifers available	47	48	49	50
	% of heifers to keep	59%	69%	79%	88%
	Net benefits ($)	7,580	5,420	3,310	1,160
10%	# of heifers available	44	45	46	47
	% of heifers to keep	63%	73%	84%	94%
	Net benefits ($)	6,960	4,690	2,440	30

Source: Dr. J.P. Chesnais, Semex Alliance. Genotyping heifers to maximize profits. December 2011.

Assumptions:

- Net economic value: $29 per 100 points in LPI
- Cost of genotyping: $47 per heifer
- Calving interval: 14 months
- 30% of culled cows calving in current year
- Inflation rate 5% to calculate net current value
- Number of heifers kept: 10% above replacement rate (safety margin)

With a moderate replacement rate of 30%-35%, selecting the best replacements using genotyping information is profitable. The potential return from genotyping could be from $3,300 to $5,400 due to improved production in a 100-cow herd.

Turnover Rate Important

On the other hand, if a herd has a high turnover rate and/or a low number of replacements available, heifers can be brought into the herd with little or no selection; investing in genotyping would not be worthwhile. Very important factors in turnover rate are:

- High calf survival rate so there are adequate replacements
- Good cow and heifer reproduction is necessary to minimize cow culling and maximize calves born per year.

Sell Excess Heifers

Using genotyping to increase accuracy and ability to identify top replacement heifers allows ranking of potential replacement heifers and provides opportunities to keep or remove heifers early based on their genetic value compared to the cost of raising them. Recent estimates put the cost of raising a heifer to 24 months at $2250.

If the market value is lower than the cost of raising heifers to milking age, consider selling excess heifers at an early age to reduce costs. If on the other hand there is a market for replacement heifers that returns a profit, consider selling heifers at a time it is most profitable to do so.

Genotyping at an early age provides flexibility as to when heifers might be sold, depending upon market conditions. More information on the cost of raising heifers can be found in the OMAFRA Factsheet, The Cost of Raising Replacement Dairy Heifers, Order No. 11-055.

Genotype only the Candidates for Culling

A lower cost approach to genotyping replacements could be to rank all replacements according to parent average, then only genotype the candidates for culling. In the example herd, if the replacement rate is 30%, then the lowest 50% of the heifers could be genotyped (24 in this case) and the lowest 14 would be culled. The cost of genotyping is halved and similar results are obtained as if all heifers were genotyped.

This strategy reduces the cost of genotyping but has the disadvantage of not providing genomic information to use in management, mating decisions or sales of higher genetic value replacements.

Use Sexed Semen

A final strategy to consider is using sexed semen to breed all replacement females and some of the benefits could be:

- Increases the power of genotyping as it increases the number of replacements from which to select.

- Use of sexed semen nearly doubles the impact of genotyping due to increased opportunity to select the best replacements.
- More heifers are available for sale providing additional income.
- Female calves born to replacement heifers result in less difficult calvings with associated costs in setbacks to the mother as well as loss of calves.

Genomics in Herd Management

The availability of genomic parent averages or GPA's for replacement heifers will provide new tools by which the owner can make management decisions as well as breeding decisions.

Genomic information may alter management of some heifers. Heifers with an exceptionally high GPA for production may be managed differently prior to calving and in the milking herd. Heifers with a high genetic value for somatic cell score or other health conditions might be managed differently to compensate.

Summary

The dairy industry has rapidly taken advantage of the benefits of genomic testing. Nearly all regular service AI bulls have genomic EBV's. All potential young sire entries are screened with a genomic test resulting in fewer young sires being brought onto progeny testing. There is a trend toward heavier use of young genomic proof bulls which will shorten the generation interval and speed up the rate of genetic advancement.

There are a number of strategies that can be used to take advantage of genomic testing in selection within a herd that can return a profit over the cost of testing. Turnover rate is key to profitable use of genomics for within herd selection.

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