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The Use and Economic Value of the 3K SNP Genomic Test for Calves on Dairy Farms[1]

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Dairy producers have had the opportunity to test their female animals with the low density 3K SNP genomic test since September 2010. The 3K genomic test provides an estimate of an animal's genetic merit for many traits, including milk production and Net Merit (NM$). As one of several available genomic tests, the 3K genomic test works by comparing an animal's DNA to a database that associates DNA patterns with genetic merits of traits. Therefore, a genomic test can provide a fairly accurate estimate of an animal's genetic merit early in her life without any other data, such as her phenotypic records or information from parents or siblings. Various vendors (for example, Holstein Association USA and Pfizer Animal Health) sell genomic test kits that help a producer collect a DNA sample and send it to a processing office. The USDA then calculates the genetic merits of the traits of the animal tested. The producer gets the results back within a month or two. As of August 2011, approximately 45,000 animals have been tested with the 3K genomic test, most of them females. Still, many dairy producers wonder if the 3K genomic test might have value for their operation.

The benefits of using a 3K genomic test include discovering or confirming parentage for mating decisions that minimize inbreeding and selecting candidates for embryo transfer. Our objective in this article is to explore how dairy producers who primarily sell milk might benefit from using a 3K genomic test on young calves in order to select which calves to raise as replacements. Non-selected surplus calves would

then be sold at an early age. Because of the increase in reproductive efficiency and use of sexed semen is producing heifer calves on many dairy farms, choosing which calves to raise based on their genetic merit, among other factors such as early life health events, has become a real option that needs to be considered. Later in the publication, we'll also briefly address the topic of how many, if any, heifer calves can be considered surplus.

Genetic progress is made by selecting superior animals as the parents of future generations. If all heifer calves are raised, virtually no genetic progress is made on the female side. In other words, all genetic progress in the herd then comes only from using genetically superior AI (artificial insemination) sires. But if there is a way to select the genetically better heifer calves to be raised as replacements, the dairy producer can make genetic progress on the female side as well, which in turn causes total genetic progress to increase faster.

One of the values the 3K genomic test provides is an animal's genetic merit for NM$. Net Merit is an estimate of the expected lifetime profit of a female compared to the breed base (an average cow born in 2005) in the same environment; this trait shows a direct impact on the income an animal can generate within its lifetime and later affects its offspring. The NM$ index includes economically relevant traits related to milk yield, health, longevity, fertility, calving ease, etc. An animal's breeding value is her genetic merit

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compared to the genetic merit of the breed base animal. For example, a calf with a breeding value of $300 for NM$ is expected to be $450 more profitable during her productive life (about 3 lactations) than a calf with a NM$ of -$150, provided that all environmental factors are the same. Selecting the calves with the highest NM$ should directly impact the profitability of lactating cows. Furthermore, the daughters and future generations of the selected $300 NM$ calf are expected to have a greater NM$ (in a decreasing way) than the future generations of the calf with the -$150 NM$ genetic merit.

What Is Needed for Genetic Progress?

Three factors determine the amount of genetic progress made in one generation in a population (for example, the current group of available heifer calves). First, there must be genetic variation in the trait NM$ in the population of calves. This variation is expressed by the standard deviation. Estimates of the standard deviation of the breeding value of NM$ vary from approximately $300 to $400. In the analysis below we chose a standard deviation of $350. If the standard deviation is $0, that would mean that genetically all animals are the same and no superior animals can be selected regardless of how good the genomic test is.

Second, genetic progress depends on how accurately we can estimate the true breeding value of an animal for NM$. This true breeding value is unknown, but a 3K genomic test provides a good estimate of that true breeding value with a reliability of approximately 65%. If only the sire of the calf is identified (meaning there is no genomic test information), the reliability of her breeding value for NM$ would be about 20%. If a calf's full pedigree is identified, the reliability of her breeding value for NM$ would be about 34%. These traditional methods of estimating a calf's breeding value for NM$ have a lower percentage of reliability than that obtained from a genomic test because in these traditional methods it is not known which sample of the good or bad genes the calf inherited by chance from her parents. The reliability is also a measure of how well we can rank animals on their true breeding values based on a prediction of those breeding values (for example, if the information is provided by the 3K genomic test or the information is from relatives). Thus, a 3K genomic test results in a better ranking of calves on NM$ breeding values, among other traits.

The third component of genetic progress is the selection intensity. This is a function of the fraction of ranked animals actually selected. The fewer calves selected, the greater the selection intensity. If the top 90% of the calves are selected (almost all), the average breeding value will be lower than if the top 50% of the calves are selected. In other words, the smaller the fraction selected, the greater the average breeding value of the selected animals. On most commercial dairy farms, the supply of heifer calves will not be much greater than the number needed to be raised as replacement animals. Therefore, the selection intensity is low; perhaps only 10% to 30% of heifer calves could be called surplus and culled.

Purchasing a 3K genomic test for a heifer calf is an investment. The cost of a 3K genomic test is approximately $40 per animal. Now the question is clear: Is there value in using a 3K genomic test in order to rank animals better by their NM$ breeding values and to increase genetic progress, given that only a certain number of heifer calves need to be selected? More specifically, which calves should be tested, and how does that depend on pre-ranking of calves based on traditional sire-only or full-pedigree information? In order to be profitable, the value of using the selected calves to increase the genetic progress must exceed the cost of testing the calves. In the analysis that follows, the average value of the kept calves depends on their estimated genetic values, whereas the average value of the calves sold does not depend on their estimated genetic values.

We wrote a simulation program that tested various fractions of calves with the 3K genomic test (for example, all calves, the top 30% if calves were pre-ranked, the bottom 40%, the calves ranked 30% to 80%, etc.). The genetic progress of the kept calves, as well as the total cost of testing, and the net value of the test was calculated. For example, if 90% of all calves are tested, and 80% of all calves are kept, then the cost of testing per kept calf is $40 * 0.9 / 0.8 = $45. If the increase in genetic progress of the average kept calf is worth $100 as result of the testing, then the value of the test would be $100 - $45 = $55 per kept calf.

Value of the 3K Genomic Test When Calves Cannot Be Pre-ranked on NM$ Breeding Value

When calves cannot be pre-ranked on NM$ breeding value, we assume that we have no information about a calf's genetic potential for milk production, fertility, longevity, etc. This may be the case when natural service bulls are the sires of the calves or no genetic information from the AI sires is available. Before testing, all calves are considered equal and the calves selected (kept) would be on average of

the same genetic value as the calves not selected. Applying a 3K genomic test to some or all of these calves has the greatest value to a dairy producer, compared to a scenario in which pre-ranking is possible with a reliability > 0%.

Table 1 shows the value of a $40 3K genomic test per kept calf, depending on how many calves are tested and how many of the available calves need to be kept. The table shows that all calves should be tested to obtain the greatest net value per selected calf. Testing more calves increased the average genetic value of the kept calves, as well as the cost of testing per kept calf. Yet, by testing more calves, the increase in genetic value is greater than the increase in the cost of testing. When all calves are tested, the value of the test per kept calf is $32, $87, or $137 depending on whether 90%, 80%, or 70% of the tested calves need to be kept.

Using information from Table 1, it would be wrong to conclude that keeping fewer calves is more valuable than keeping more calves. Determining how many calves to keep as replacement heifers on a dairy farm requires a complicated analysis. For example, replacing more cows faster increases genetic progress and affects production of the current herd. Further, the availability of excellent reproductive programs and sexed semen allows dairy producers some flexibility in how many surplus heifer calves they can create, so selection intensity could vary. Other sources of information that predict a calf's future performance should also be considered, including health events early in life, the dam's age or calving difficulty, or season of calving. Alternatively, the expenses of the 3K genomic testing could be used

instead of purchasing more expensive semen from sires with a greater genetic merit, or it could be used elsewhere if the money spent would result in a greater return on investment. If semen from more superior AI is purchased, genetic progress is then increased through the male side instead of the female side. Another option is embryo transfer from selected females, which makes determining the costs and benefits of these different methods even more complicated. We are currently quantifying many of these aspects of this complicated but interesting problem. The goal is to provide dairy producers with some guidelines that take all important factors into consideration.

Value of the 3K Genomic Test When Calves Can Be Pre-ranked with 20% Reliability

Calves can be pre-ranked for genetic merit when the genetic merit of a relative (or relatives) is known, such as when their sire or full pedigree is known. Applying a 3K genomic test to such calves is less valuable because we can already rank these calves on genetic merit with some accuracy.

Assume that all calves can be pre-ranked for breeding value of NM$ with a reliability of 20%, such as when their sire is identified. If the top 90% of calves are kept (without applying a 3K genomic test), the increase in breeding value of these selected calves compared to all calves is approximately $43. When the top 80% or 70% is kept, the advantage in breeding value for NM$ of the kept calves increases to $76

Table 1. Value of genetic superiority in Net Merit $ (Δ NM$), cost of 3K genomic testing (Cost), and net value of the 3K genomic test (Value), all per selected calf. Value = Δ NM$ - Cost. The dairy producer has earlier decided to select (keep) 90%, 80%, or 70% of all available calves.

Calves tested	90% selected Δ NM$	80% selected Δ NM$	70% selected Δ NM$	90% selected Cost, $	80% selected Cost, $	70% selected Cost, $	90% selected Value, $	80% selected Value, $	70% selected Value, $
0%	0	0	0	0	0	0	0	0	0
10%	8	13	19	4	5	6	3	8	14
20%	15	28	39	9	10	11	7	18	28
30%	23	41	58	13	15	17	10	26	41
40%	30	54	77	18	20	23	13	35	55
50%	38	69	98	22	25	29	16	43	69
60%	46	82	117	27	30	34	19	53	83
70%	53	96	136	31	35	40	22	61	96
80%	61	110	156	36	40	46	25	70	110
90%	68	123	175	40	45	51	29	78	124
100%	76	136	194	44	50	57	32	87	137

Assumptions: Standard deviation of breeding values is $350 (multiplied by 1.39 to account for genetic progress in two future generations and 5% annual interest); cost per 3K genomic test is $40; and reliability of the 3K genomic test is 65%. There is no pre-ranking of calves.

and $108, respectively. This gain comes from having only the traditional sire information available. We assumed no cost for the sire identification that gave the 20% reliability of the pre-ranking.

Figure 1 shows the value of testing a fraction of these pre-ranked calves with a 3K genomic test. The figure also shows which range of calves to test. In this range, 0% is the highest pre-ranked calf for NM$, and 100% is the lowest pre-ranked calf for NM$. These values are a combination of the increase in average breeding value and the increase in the cost of testing with the 3K genomic test when more calves are tested. Not all calves need to be tested with the 3K genomic test because calves that are pre-ranked high are very likely to be good enough to be selected. It does not pay to test them. Figure 1 primarily shows that calves ranked in the bottom 50% (pre-ranking 50% to 100%) should be tested. However, the range depends on the number of calves that needs to be kept. For example, if 90% of all calves need

to be kept, the best policy is to test the bottom 30% (pre-ranked 70% to 100%) of calves when they are pre-ranked with 20% reliability. The value of testing the bottom 30% with a 3K genomic test is $15 per kept calf. Testing other ranges (in increments of 10%) is less profitable, although not by much. The fewer calves are kept (70% instead of 90%), the greater the value of testing. Furthermore, the optimal range of calves to test changes with the fraction of calves kept. Testing all calves increased the net value of the test per kept calf by -$10, $11, or $30 when 90%, 80%, or 70% of the calves were kept.

Value of the 3K Genomic Test When Calves Can Be Pre-ranked with 34% Reliability

Now assume that all calves can be pre-ranked for breeding value of NM$ with a reliability of 34%, such as when
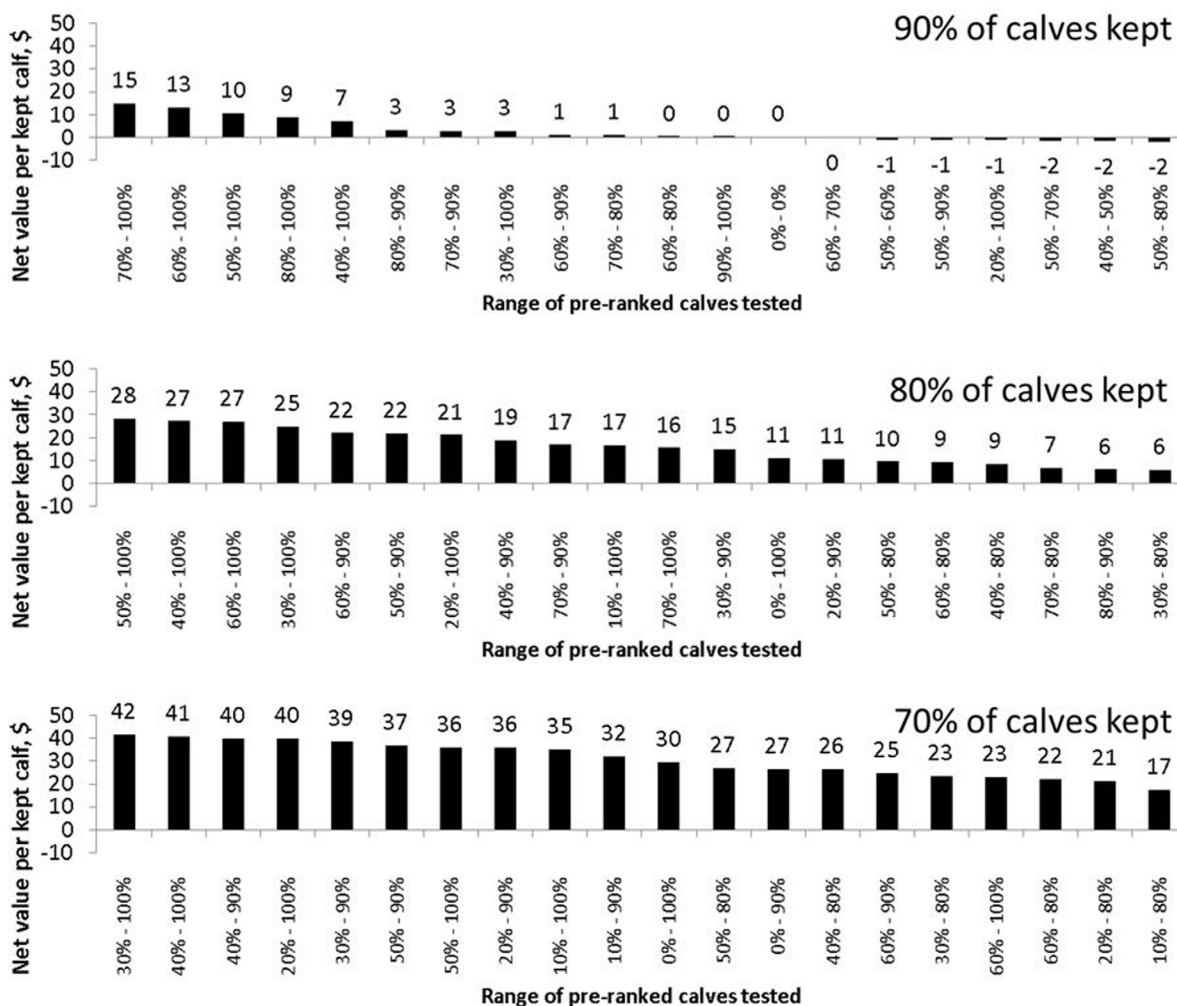

Figure 1. Value of the 3K genomic test per kept calf, depending on how many calves are kept, and the range of pre-ranked calves tested with the 3K genomic test. All calves are pre-ranked for breeding value of NM$ with 20% reliability. The 3K genomic test is applied to a fraction of the pre-ranked calves (0% is the highest pre-ranked calf for NM$, and 100% is the lowest pre-ranked calf for NM$).

genetic information on the sire and dam is available. Again, in the current analysis we assumed no cost to obtain the 34% reliability for the pre-ranking. If the top 90% of calves are kept (without applying a 3K genomic test), the average increase in breeding value of these selected calves compared to all calves is approximately $55. When the top 80% or 70% is kept, the advantage of the average breeding value for NM$ of the kept calves increases to $99 and $141, respectively. This gain from having traditional full pedigree information available is greater than when only the sire is identified. Testing calves with the 3K genomic test is less valuable when pre-ranking is done more accurately. Still, Figure 2 shows that testing the correct range of calves can make the 3K genomic test add value in addition to the pre-ranking. When 90% of calves are kept, at most $7 per kept calf can be gained. The bottom 30% of calves would be tested. Testing all calves decreased the net value of testing per kept calf by $24, $12, or $3 when 90%, 80%, or 70% of

the calves were kept. Therefore, testing all calves is not cost effective.

In practice, the reliability of the predicted breeding values of the 3K genomic test results depends on the other information available. Calves with full pedigree information would have a slightly higher reliability of the breeding values after the 3K genomic test compared to when no prior information is available. However, this difference is small. In this article, we used 65% reliability, regardless of the availability of other information. The accuracy of parent identification also plays a role.

The availability of genomic tests is rapidly changing genetics in the dairy industry. AI companies have been using genomics to select AI sires. Now also commercial dairy producers can find value in testing their calves to help decide which ones to keep.
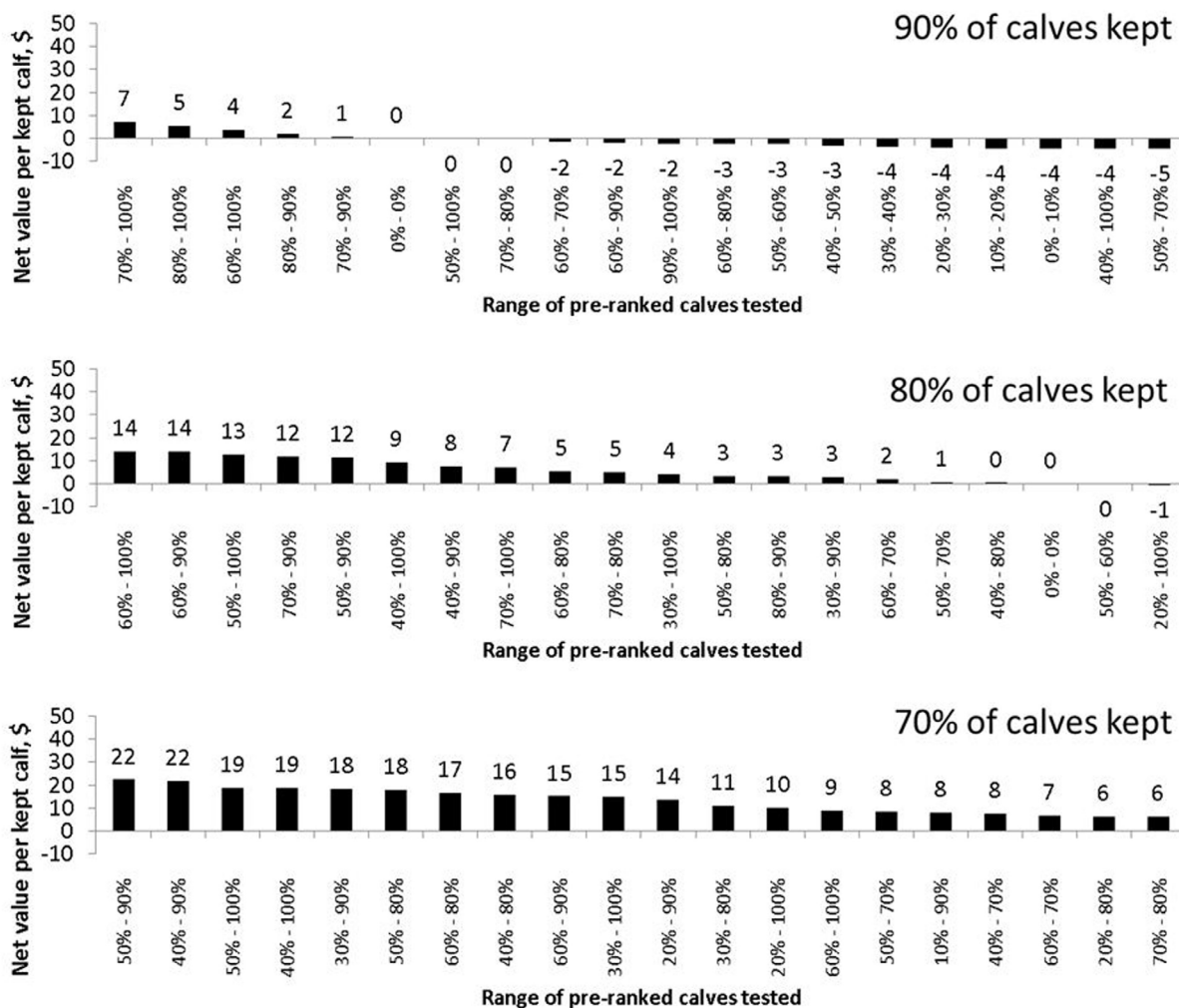

Figure 2. Value of the 3K genomic test per kept calf, depending on how many calves are kept and the range of pre-ranked calves tested with the 3K genomic test. All calves are pre-ranked for breeding value of NM$ with 34% reliability. The 3K genomic test is applied to a fraction of the pre-ranked calves (0% is the highest pre-ranked calf for NM$, and 100% is the lowest pre-ranked calf for NM$).