Genetics 472

Round Two

Heritability

• Phenotype = Genotype + Environment
• Genotype is the measure of heritability, the measure of genetic merit of one individual
• Milk 25-40%
• Fat 27-43%
• Fat% 32-87%
• Prot. % 48-88%
• Udder Comp. 20-40%
• Calving Interval 0-15%

Heritability estimates

• Most traits of importance are approximately 25%-35% heritable
• Most of the gain therefore can be made on the management side.
• However, significant gain in improved production can be made on the genetic side.
Problems with Single Trait Selection

- Loss of genetic progress in other traits, milk production as an example in previous table
- Loss of genetic variability in the population
- Rate of gain in trait progress decreases over time.
- Negative relationships
  - Milk yield traits and mastitis
  - Milk yield and reproductive performance

Selection Indices

- Selection index is a tool that combines PTA of several traits into one measure
- Choice of the index is a function of the goals of the dairy operation and the rewards, perhaps
  - Registered breeder type and production and market
  - Commercial dairy, market first?
  - Correct faults in herd or individuals

TPI & NM$ 2015
**Fluid Merit $ Index (similar to NMI and Cheese Merit)**

<table>
<thead>
<tr>
<th>Trait</th>
<th>LSU Ag center 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>24</td>
</tr>
<tr>
<td>Fat</td>
<td>22</td>
</tr>
<tr>
<td>Protein</td>
<td>9</td>
</tr>
<tr>
<td>Productive Life</td>
<td>11</td>
</tr>
<tr>
<td>Somatic Cell Score</td>
<td>9</td>
</tr>
<tr>
<td>Udder Composite</td>
<td>7</td>
</tr>
<tr>
<td>Feet &amp; Legs Composite</td>
<td>4</td>
</tr>
<tr>
<td>Body Size Composite</td>
<td>3</td>
</tr>
<tr>
<td>Daughter Pregnancy Rate</td>
<td>7</td>
</tr>
<tr>
<td>Service Sire Calving Ease</td>
<td>2</td>
</tr>
<tr>
<td>Daughter Calving Ease</td>
<td>2</td>
</tr>
</tbody>
</table>

**CMI vs NMI vs FMI**

- Cheese emphasizes protein, less on total production and more on SCC
- Fluid merit, emphasizes milk and fat and less on quality (SCC)
- Net merit emphasizes against size, more on overall efficiency considering feed costs more

**Selection goal**
- Herd average after 23 years
- Changes after 23 years

**Bull Breeding Services (trait selected)**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Milk</th>
<th>Butterfat</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Controls (unselected)</td>
<td>5797</td>
<td>3.85</td>
<td>3.35</td>
</tr>
<tr>
<td>Selection for milk yield</td>
<td>8853</td>
<td>3.46</td>
<td>3.01</td>
</tr>
<tr>
<td>Selection for butterfat yield</td>
<td>7844</td>
<td>4.32</td>
<td>3.55</td>
</tr>
<tr>
<td>Selection for protein yield</td>
<td>7631</td>
<td>3.99</td>
<td>3.62</td>
</tr>
</tbody>
</table>
Negative Correlation Between Desirable Traits

- Milk production negatively correlated with: fertility, BCS, SCS, BF & Protein
- Indexes will help

<table>
<thead>
<tr>
<th>Number of independent Traits</th>
<th>Relative Improvement for Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Milk Production</td>
<td>100%</td>
</tr>
<tr>
<td>2 Milk Production + % Fat</td>
<td>71%</td>
</tr>
<tr>
<td>3 Milk Production + % Fat + Udder</td>
<td>58%</td>
</tr>
<tr>
<td>4 Milk Production + % Fat + Udder + Legs</td>
<td>50%</td>
</tr>
</tbody>
</table>

Selection Pressure

Semen Selection

- Cost - cost benefit
- Goals and traits or indices desired
- Loyalty or service superior by one stud/Co.
- ......................... others?
Sire Selection
- Random
- Computer
- Individual
- Herd Mating

Mating
- Random
  - Breeds are gaining significantly in genetic merit of most traits. For example, milk production genetic merit is increasing more than 240 lbs. per year.
  - Advantage, no thought and can perhaps capture the least cost... without control of benefit

Mating
- Computer
- Let a program take over breeding
- Advantages, no bias, can account for least cost and maxim benefit
- But... no artful intervention- the human element
**Individual**

- Targeted, very intensive selection to improve the traits of one cow in future generations without compromising current attributes.
- A lot of work, planning in evaluation, mating, purchase, and fighting the odds
- Do you breed best to best or best to worst

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**Herd mating**

- Decide on what traits the herd needs improved and concentrate on bull selection for the lowest cost that meet those needs in a cost benefit mode
- Just like feeding a string or a pen of cows, you breed a “pen” or herd of cows. The identity of the individual morphs into the identity of the herd.

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**Herd Mating**

- Easy to use
- Semen can be given in a random way
- Yet more difficult to monitor/control inbreeding over the short term. Over the long term with a herd mating program you can build in guards against in breeding by building selection against inbreeding into your selection criteria
Inbreeding and Linebreeding

- Inbreeding coefficient for Holsteins and Jersey cattle are ~ 7%
  - For every 1% there is
  - Loss of 50-80 lbs of milk and 2 lbs fat and protein
- 24 distinct genetic lines in Holstein breed, fewer for colored breeds.
- How can inbreeding be controlled?

Control of inbreeding

DeChow, Hoards, March 25, 2014, page 218

- Increase the population of bulls sampled
  - This is occurring, but
  - The number of bulls selected tends to come from the same families

Control on the farm
- Use of mating programs that guard against inbreeding

Inbreeding and Purebred Industry

- Currently all sires need to be purebred, yet in Holsteins for example, only ~10% of all cattle are purebred
- What would happen to inbreeding if this was eliminated as a requirement??
- Crossbreeding, even more extreme?
Inbreeding Continued

- Control in the population
  - Classify bulls by Effective Future Inbreeding value (EFI)
- Producers use only bulls will low EFI- promoting genetic diversity
- AI studs can develop breeding lines, and then bulls can be selected an out-line crossed
  - In development
- Dip into the bank of stored semen over generations to “outcross”
  - Might be able to identify genetic variation, but loss of genetic merit for current important traits??

Inbreeding by time

| TABLE 1. AVERAGE PEDIGREE INBREEDING OF HOLSTEIN FEMALES BY BIRTH YEAR. |
|-----------------|------------------|
| Birth year | Inbreeding, % |
| 2001 | 4.7 |
| 2003 | 4.9 |
| 2005 | 5.2 |
| 2007 | 5.4 |
| 2009 | 5.6 |
| 2011 | 5.8 |
| 2013 | 6.1 |
| 2015 | 6.5 |

Les Hansen, July 16, 2015, DHM

Inbreeding in the population

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed</td>
<td>Year surpassed 6.25%</td>
</tr>
<tr>
<td>Jersey</td>
<td>2002</td>
</tr>
<tr>
<td>Guernsey</td>
<td>2007</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>2011</td>
</tr>
<tr>
<td>Ayrshire</td>
<td>2013</td>
</tr>
<tr>
<td>Holstein</td>
<td>2014</td>
</tr>
</tbody>
</table>

Les Hansen, July 16, 2015, DHM
Inbreeding: The Future

TABLE 3. AVERAGE OF GENOMIC FUTURE INBREEDING (GFI) BY BIRTH YEAR FOR GENOMICALLY-TESTED HOLSTEIN BULLS.

<table>
<thead>
<tr>
<th>Birth year</th>
<th>Genomic future inbreeding*%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>6.8</td>
</tr>
<tr>
<td>2010</td>
<td>7.0</td>
</tr>
<tr>
<td>2012</td>
<td>7.3</td>
</tr>
<tr>
<td>2015</td>
<td>7.5</td>
</tr>
</tbody>
</table>

*GFI predicts inbreeding from random mating of Holstein bulls with Holstein females in the future

Les Hansen, July 16, 2015, DHM

Les Hansen warns:
- Random breeding will only lead to an increase in inbreeding
- This may result in inbreeding depression
- Crossbreeding will protect and also paying attention to pedigrees.

Crossbreeding
- Counters the inbreeding problem
  - Calving difficulty
  - Fertility
- Traits other than total milk production are being rewarded
- Longevity is an issue
- Time for hybrid vigor?
How to Crossbreed

- 3-Breed Rotational System with AI sires
- Breed of sires change: An example
  - Offspring of Holsteins are bred to Jersey sire
  - Offspring of the H X J are bred to Swedish Red
  - Offspring of the H X J X SR are bred to Holstein

86% of full heterosis is maintained by the 3 breed rotational cross.

Crossbreeding

- Two way cross provides 67% hybrid vigor
  - Remember, hybrid vigor is should be considered for the important traits
  - A Holstein X Brahman cross will yield many improvements in offspring, but perhaps not that a dairy breeder in a temperate zone would value

- Sire and Dam are important, epigenetic differences:
  - Jersey X Holstein vs.
  - Holstein X Jersey

Crossbreeding the Future?

- Mating systems take much effort, recordkeeping, organization, to be most effective.

- Are the traits really that important, can they be maximized within breed and having breed specific pens?

- Should crossbreeding be done at the sire-level, let the studs do the crossing........
Recent Review by Diaz and Garcia
July 2014 Hoards

- J X H crosses:
  - Grazing, crosses more efficient
  - Confinement, Holstein more efficient
  - Efficiency: feed energy:milk, acres:milk

- Other factors
  - Climate
  - Milk market (fluid vs. fat vs. components)
  - Sale of culls and bull calves (meat market)

California Crossbreeding Trial
Results for Normande x Holstein, Montbeliarde x Holstein, Scandinavian Red x Holstein crossbred cows and Holstein cows.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Holstein</th>
<th>Normande x Holstein</th>
<th>Montbeliarde x Holstein</th>
<th>Scandinavian Red x Holstein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to first breeding (d)</td>
<td>70</td>
<td>67 $$^{**}$$</td>
<td>73 $$^{**}$$</td>
<td>70 $$^{**}$$</td>
</tr>
<tr>
<td>Days open (d)</td>
<td>186</td>
<td>182 $$^{**}$$</td>
<td>188 $$^{**}$$</td>
<td>182 $$^{**}$$</td>
</tr>
<tr>
<td>Fat+protein (lb)</td>
<td>1,679</td>
<td>1,644 $$^{**}$$</td>
<td>1,522 $$^{**}$$</td>
<td>1,632 $$^{**}$$</td>
</tr>
<tr>
<td>Survival to 2nd calving (%)</td>
<td>75</td>
<td>88 $$^{**}$$</td>
<td>76 $$^{**}$$</td>
<td>88 $$^{**}$$</td>
</tr>
<tr>
<td>Survival to 3rd calving (%)</td>
<td>51</td>
<td>62 $$^{**}$$</td>
<td>54 $$^{**}$$</td>
<td>62 $$^{**}$$</td>
</tr>
<tr>
<td>Survival to 4th calving (%)</td>
<td>29</td>
<td>32 $$^{**}$$</td>
<td>29 $$^{**}$$</td>
<td>32 $$^{**}$$</td>
</tr>
<tr>
<td>Days of herd life (d)</td>
<td>946</td>
<td>934 $$^{**}$$</td>
<td>972 $$^{**}$$</td>
<td>946 $$^{**}$$</td>
</tr>
<tr>
<td>Lifetime profit ($)</td>
<td>4,347</td>
<td>4,337 $$^{**}$$</td>
<td>4,436 $$^{**}$$</td>
<td>4,326 $$^{**}$$</td>
</tr>
</tbody>
</table>

Estimating Genetic Merit

- Progeny testing
- Sires and grand sires provide > ½ the genetics, how do you value milk production in a sire?
A) Elite cow identified

Contract mating

Breeder mating

Bull is sire of sons and more daug.

Bull calves born

Breeder bulls

Bull is a "stud"

Bull is culled

Semen collected

Semen to herds for random sampling

Heifer calves raised and id'd

Prod data collected

Dau begin production

Industry reviews data

RELIABILITY

- Young sires 36%
- Proven bulls (first-crop daughters) 84%
- Proven bulls (second-crop daughters) 99%

Is there a better way to estimate genetic merit?

- Problem is, there is no single gene for milk production
- Milk production is a trait influenced by many genes, as are most dairy traits of importance
- So selecting for milk production does not have a heritability of 1 and many daughter comparisons need to be made.
- Genomic or DNA analysis?
Genomics

- Genomic testing is DNA testing
- Dairy Cow genome was mapped in 2004, the chromosomal sequences are known.
- We can look for variation in the chromosome, and determine what variants are linked to high milk production, as an example
- Genomic analysis for dairy production or other traits is an estimation of genetic merit

From Phenotype to Genotype: diacylglycerol acyltransferase 1

- Enzyme involved in triglyceride synthesis
  - Chromosome 14
  - Knockout mice: complete absence of milk production
- Bi-nucleotide substitution: lysine to alanine
  - +300 lbs milk
  - +5 lbs protein
  - +0.17% fat -0.17% Fat
  - +13 lbs fat
  - Fatty acid profiles altered
- Terrific – but...
  - Dechow 2012
  - Grisart et al., 2002

Association of SNP with Fat Yield

A single gene change has a significant effect. However, only accounts for 1-2% of milk and fat produced by the cow.
Advantage of Genomics

- Genomic analysis can be used on young cattle, calves, to determine the probability they have of having the traits desired:
  - Good udders
  - Resistance to mastitis
  - Good milk production
  - Good stature

Thus, a calf as a future sire, or a calf as future cow, can be determined as “good” or “bad” before they are raised to production maturity.

Advantage of Genomics

- Genomics on cows and calves
- Using genomic analysis of cows to improve estimates of genetic merit, and then breed the “elite” cows using sexed semen to increase the crop, via selection pressure, of elite heifer calves.
- These heifer calves can be genomically tested to be used as future dams, replacements.
- In this way, genomics can be used to increase accuracy of selection of replacements and increase the selection pressure.

Genomics in a breeding program

- Cost is clearly a consideration-
  - Cost of testing cows and calves
  - Cost of using sexed semen
- How many replacements needed?
  - Is it better to replace from within?
    - More control of biosecurity
    - More control of genetics
- But this can be a strategy to get better and bigger.....
Advantage of Genomics

- Genomics can be used to improve PTA estimates. Coupled with phenotypic information, more accurate genetic merit can be determined.
- Genomics can shorten the generation time
  - Typically it might take 4-6 years to determine a bull's genetic merit
  - If we can screen a bull calf's genomics first.....we can improve the odds of selecting bulls.

Advantage of Genomics

- Genomics can improve the accuracy of selection of sires and dams of better genetic merit
- Genomics can improve the reliability
- Genomics provides additional information
  - Number of sires screened as increased more than 5 fold over the last decade-
  - Unfortunately inbreeding continues to rise, selection for the same traits, and these traits are linked to relatives.

Genomics

- Test snippets of DNA- SNP
- Correlate DNA analysis with desired traits
- Estimate genetic merit of
  - Traits of interest
  - From bull mothers
  - Young bull calves
- No single gene for production or fore-udder attachment or ......
How Accurate is Genomics: It depends on the trait

Comparison of Jan 2009 to Dec 2012 Daughters Deviations

617 bulls: 6 daughters in 2009 and 1100 daughters currently

Dechow, 2013

How Accurate is Genomics: It depends on the trait

Realized Reliabilities

Dechow, 2013

Net Merit Changes

NM will change over time, but for some genomic tests underestimate, some over estimate (Dechow, 2013)
Use of Genomic Testing

• To decide which heifers to keep or cull, important when using sexed semen and realizing that there are more heifers than need for replacements.
• ROI is improved when only the best heifers are kept and a dairy manager is not keeping the genetically inferior heifers.

Use of Genomic Testing

• Likely to increase inbreeding as the generation interval is shortened.

Genomics and the herd bull

• Herd bull genetic merit lags
Genomics and the herd bull

- Herd bull genetic merit lags
- If you use a herd bull, purchase a genomically tested bull from another herd:
  - Avoid inbreeding
  - Assure genetic merit (hopefully herd bull is a result of AI matings- maternal and paternal)
What we learned from genomic tests: Hoard’s, October 10, 2014

• Cull poor genomic youngstock
  – Cull bottom 20%
  – Worst calves expected to have $1200 less profit
• Breed only ½ heifer population with sexed semen but:
  – Breed top 50% twice
  – Breed bottom 50% once
  – Now breeding everyone just once
  – Therefore, used same amount of sexed semen with more targeted genetics.

What we learned from genomic tests: Hoard’s, October 10, 2014

• “If we have good management on a farm, genetics matter more because a cow’s genetic ability has an even greater opportunity to express itself”: Pat Hoffman of Vita Plus

Read the scientific article in PLoS Genetics here.
Published: January 02, 2014
DOI: 10.1371/journal.pgen.1004049
http://www.plosgenetics.org/article/info:doi/10.1371/journal.pgen.1004049

• Correlation between milk production and fertility has long been known to be negative. The primary explanation: Negative Energy Bal.
• However........
  – A single mutation, deletion of a single gene sequence, might explain a significant part of this negative correlation
  – 4 gene deletion is associated with recessive embryonic lethal mutation
4 gene deletion

- More likely to have embryonic death
- Would appear as insemination failure
- But since it is recessive, ½ of the trait is carried by the bull- can this trait be weeded out- mark the offending bulls?
- It is present in Nordic Reds, but not Nordic Holsteins....
- The trait (4 gene deleted sequence) has been concentrated because of intense selection for milk production.

What we learned from genomic tests:  
Hoard's, October 10, 2014

- "If we have good management on a farm, genetics matter more because a cow's genetic ability has an even greater opportunity to express itself": Pat Hoffman of Vita Plus
- Hoard's Farm: Jersey 20,223milk, 984fat, 794pro 
  - Cows on average yield 51% more milk
  - Daughters of 1000 lb PD bull produce 1590 lbs milk
  - 20% increase in daughter preg rate over genetic est.
  - Less inbreeding: 5.6% vs 7.3% for the breed