Dairy Cattle Breeding and Genetics

AS/AVS 472

History of modern dairy cattle genetics

- *Bos primigenius* - aurochs - very widespread
  - Europe
  - Asia
  - Africa
- Domesticated cattle became:
  - *Bos indicus*
  - *Bos taurus*

History

- Cattle originally more for meat and temperament
- Often wild auroch DNA was brought back into the herd
<table>
<thead>
<tr>
<th>Breed</th>
<th>2007 (%)</th>
<th>2014 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein</td>
<td>91.0</td>
<td>85.0</td>
</tr>
<tr>
<td>Jersey</td>
<td>6.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Crossbred</td>
<td>1.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Other</td>
<td>1.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Therefore, Holstein prevalence has gone from 84% in 1970 through its peak. In 1935, Jerseys most common (42%), Holsteins (40%), and Guernsey (16%). What does this say about traits that are currently desired vs. used to be desired?

What traits does a dairymen want to improve in his/her herd?

- Production (protein, milk, fat)
- Reproduction (fertility)
- Health (SCC, metabolic disorders....)
- Feed efficiency
- Body confirmation
- Longevity, profitability....
How much trait improvement is:
- Management
- Genetics
- \( P = G + E \)

Is there a single gene for:
- Production (protein, milk, fat)
- Reproduction (fertility)
- Health (SCC, metabolic disorders….)
- Feed efficiency
- Body confirmation
- Longevity, profitability…….

What is genotype?
- CC and “Rainbow”
What is genotype?

- Identical twins?
- Epigenetic effects

Genetic Progress: The Herd

- To increase the frequency to “beneficial” genes
- To optimize gene combinations

How do we make genetic improvement?

- Identify the animals that are genetically superior and allow them to reproduce. Don't allow the others to reproduce.
  - Must be able to evaluate traits.
  - Trait must be heritable.
  - Must know the genetic correlations.
Genetic Goals

- Establish genetic goals that have economic importance.
- Production: Milk, Fat, Protein.
- Longevity: Functional type traits.
- Key to setting goals is: How is income generated in a specific herd?

What controls genetic progress?

- Three factors that control genetic gain in a trait are:
  - Heritability: the likelihood of a trait to be passed and the ability to accurately measure that trait.
  - Selection differential: superiority of parents over the mean of the population.
  - Generation interval: the time interval between generations.

Genetic Progress = \[
\frac{\text{Mean Heritability} \times \text{Selection Intensity} \times \sqrt{\text{Generation Interval}}}{\text{Generation Interval}}
\]
Selection Differential

S is for Accuracy (heritability as a component) and Variance

U.S. dairy population & yield

Genetic Progress

- How does this speed genetic progress?

\[ \Delta_{t/\text{Year}} = \frac{\sqrt{\text{reliability}} \times \text{Selection Intensity} \times \sqrt{\text{Genetic Variance}}}{\text{Generation Interval}} \]

1. Lower generation interval
2. Higher accuracy for females
3. Selection Intensity

Dechow, 2012
Heritability
- The portion of the variation among individuals in the same herd that is genetic.
- Each trait's heritability remains fairly constant and, therefore, sets a limit on the rate of genetic progress.

Heritability
- Is not how much of the measured trait will appear in the next generation but is the amount of superiority of parents above their contemporaries. (*The fraction of phenotype variance caused by genotype difference*)
  - Phenotype=Genotype + Environment
Selection Differential

- The superiority of the animals selected to be parents.
- Selected parents should be better than the present generation average for improvement to take place.
- Genetic differences provide the only opportunity for selection. If all cows were genetically the same, selection would not produce change.

Selection Intensity

- Number of traits under selection
  - When fewer traits are under selection there will be faster progress for any particular trait.
Generation Interval

- Represents the average age of parents at the birth of their progeny.
- can only be changed significantly through embryo transfer and other new technologies.

Breeding Value

A measure of the average value of an individual's genetic potential for a given trait above or below the population average.

20,000 lbs 22,000 lbs

BV = 2,000 lbs.

National evaluation of breeding values in dairy cattle

DHI-A-Dairy Herd Information Association-USDA (Animal Improvement Program Lab-Al PL).
- Pounds of Milk & Protein, % Fat & Protein, SCC,
- Type Evaluations- Breed Associations
- Linear Type Trait Scores
- NAAB-Survey information
- Calving ease.
Genetics is Affected by:
- True Genetics
  - Breed
  - Sire
  - Dam
- The ability to estimate genetic merit-
  - Good accurate records

DHIA
- Why USDA?
- Why NAAB?
- Why Purebred associations?

DHIA
- SPECIFIC GOALS AND PRIORITIES Maintain channels of communication with members and other users of DHIA records.
- Administer the Quality Certification Program.
- Coordinate appropriate meetings, workshops, and seminars as needed.
- Ensure that the Code of Ethics, Uniform Data Collection Procedures, and Quality Certification standards remain up-to-date and appropriate for industry needs.
- Coordinate the testing of new weighing and sampling devices and related new products.
- Provide materials and resources to regional caucuses to ensure sufficient background information for complete discussion of current issues.
- Keep abreast of modern technologies and apprise the members of possible applications in DHIA.
- Cooperate with USDA, NAAB, and PDCA in providing the dairy industry with needed, meaningful, and affordable programs with minimal duplication.
- Operate the office in an efficient manner to make the best possible programs and service available to members at reasonable cost.
DHIA

- History
- Assessment
- Record keeping: computerization

Process:
- Independent tester arrives on the farm
- Tests about 1x/mos, 12 per year, +15/-45 days
- Records milk weights, collects samples (SCC, fat, and protein), and records data
Current System Used

Animal Model

- Animal Model is a statistical method that gives us the best possible predictor of genetic merit considering -
  1. The animal's own performance
  2. The animal's ancestors
  3. The animal's progeny

- Expressed as Predicted Transmitting Ability (PTAs estimate production genetic merit)

PTAs (Predicted Transmitting Ability)

- Are expressed as deviations from the average cow born in 2015.
- Base change every 5 years - last change was 2015.
- Are recomputed 4x/year by USDA.
- Published by bull studs and breed associations.

Standard Transmitting Ability

- STAs the expected deviation of the average daughter of the bull from the average score for the linear trait expressed in standard deviation units.
- Range score of -3 to +3.
Accuracy
- DHIA records, standardized and if official, calibrated and overseen
- Objective records (milk production, protein, lactose, fat, SCC...)
- Semi-objective: pregnancy, heat, disease... (only as good as the reports)
- Subjective measures: udder composite........

Where does genetics come from?
- Sires of Sires 45%
- Sires of Cows 37%
- Dams of Sires 15%
- Dams of Cows 3%

Perspective:
- Three modern bulls:
  - Round Oak Rag Apple Elevation
  - Pawnee Farm Arlinda Chief
  - Penstate Ivanhoe Star
- Their lineage has dominated the sire list
  - Round Oak Rag Apple Elevation (51%)
  - Pawnee Farm Arlinda Chief (49%)
  - Penstate Ivanhoe Star (<1%, used to be> 10%)
Ivanhoe

- Linked to genetic disorders
  - BLAD (bovine leukocyte adhesion deficiency, immune disorder)
  - CVM (complex vertebral malformation: skeletal malformation leading to abortion)

Is this an issue

- Nearly all of genetic merit of Holstein population tied to 2 sire lines?
- How will this effect genetic progress going forward?
- Might this explain the drop in fertility in the Holstein breed in the US over the last 20 years?

Then the question of breeding for polled progeny

- The US, beef cattle breeders have been concerned about non-horned, polled cattle for years- very little polled gene remains in the breeding population
- Dairy cattle breeders have largely ignored polled gene
Polled gene

- Single allele for polled or horned
- Polled gene is dominant, therefore the heterozygote is polled
- Yet, only a few polled sires are in the top 20% of TPI sires in Holstein and Jersey breeds
- It might appear that polled gene is negatively correlated to TPI genes

But why consider polled

- Traditionally dairy managers simply dehorned cattle, up until recently, without anesthesia. Cost of dehorning regarded as trivial
- But, some public looks at dehorning as cruel and inhumane (in-boveine?)
- Breeding polled maybe an advantage-but at what current cost?

Review

- P=G+E
- G can be influenced by management and environment: clones do not always look alike
- Genetic progress is a function Of: (heritability, accuracy) variance and generation interval
- Understand what influences each variable (reliability, inbred, genomics, DHIA, )
- PTA is used in the dairy industry and is a measure of genetic merit that can be transferred to progeny
- Largely evaluated by progeny testing (need for good records- DHIA) and genomic analysis
- Negative correlation of traits-(Eg: milk and SCC, fertility & BCS)
**NET MERIT**

- Net Merit Dollars measures the expected lifetime profit that an offspring of an animal will provide over its lifetime.

Components of NM$’s are:

<table>
<thead>
<tr>
<th>Trait</th>
<th>Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>382</td>
</tr>
<tr>
<td>Fat</td>
<td>17</td>
</tr>
<tr>
<td>Protein</td>
<td>12</td>
</tr>
<tr>
<td>Health</td>
<td></td>
</tr>
<tr>
<td>Productive Life</td>
<td>1.0</td>
</tr>
<tr>
<td>Daughter Pregnancy Rate</td>
<td>0.2</td>
</tr>
<tr>
<td>Somatic Cell Score</td>
<td>0.07</td>
</tr>
<tr>
<td>Calving Traits</td>
<td></td>
</tr>
<tr>
<td>Sire Calving Ease</td>
<td>0.4</td>
</tr>
<tr>
<td>Sire Stillbirth</td>
<td>0.3</td>
</tr>
<tr>
<td>Daughter Calving Ease</td>
<td>1.6</td>
</tr>
<tr>
<td>Daughter Stillbirth</td>
<td>0.5</td>
</tr>
<tr>
<td>Conformation</td>
<td></td>
</tr>
<tr>
<td>PTA Type</td>
<td>0.99</td>
</tr>
<tr>
<td>Udder Composite</td>
<td>0.92</td>
</tr>
<tr>
<td>Foot &amp; Leg Composite</td>
<td>0.78</td>
</tr>
<tr>
<td>Stature</td>
<td>0.81</td>
</tr>
</tbody>
</table>

**RELIABILITY**

- The more information in the Animal Model, the greater the accuracy of a sire’s PTA.

- The Animal Model measure for this accuracy is called Reliability or REL, and is expressed as a percent.

- Determined by the total number of the bull’s relatives with records.
RELIABILITY

Is also determined on:
- the number of herds
- How sire's daughters are distributed among herds
- The number of lactations each daughter has completed
- Number of days in milk for records that are in progress

- Young sires 36%
  (with genomics: 70%-80%)
- Proven bulls 84%
  (first-crop daughters)
- Proven bulls 99%
  (second-crop daughters)

2010 Phenotypic Trend and Genetic Merit for Milk Production (Holstein)

<table>
<thead>
<tr>
<th></th>
<th>Phenotypic Trend</th>
<th>Genetic Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registered</td>
<td>27,912</td>
<td>3,894</td>
</tr>
<tr>
<td>Grade</td>
<td>27,610</td>
<td>3,841</td>
</tr>
</tbody>
</table>
Relative Progress in Milk Yield

Genetic Progress for Milk Yield (lb)

Number of Traits Selected for in Addition to Milk

1000 710 580 500 410 300 220 180

USDA Evaluations for Available:

Holstein Sires Sorted by Net Merit April, 2015
<table>
<thead>
<tr>
<th>Bull</th>
<th>PTA_Milk</th>
<th>PTA_SCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oneida</td>
<td>2,105</td>
<td>2.85</td>
</tr>
<tr>
<td>Veto</td>
<td>1,872</td>
<td>3.44</td>
</tr>
<tr>
<td>Difference</td>
<td>233</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

Oneida's daughters would produce 233 more lbs of milk and have a SCS of .59 less than the daughters of Veto if managed exactly the same.

<table>
<thead>
<tr>
<th>Bull</th>
<th>PTA_Milk</th>
<th>PTA_SCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foxy</td>
<td>2,105</td>
<td>2.85</td>
</tr>
<tr>
<td>Breed Avg. (2010)</td>
<td>0</td>
<td>3.0</td>
</tr>
<tr>
<td>Difference</td>
<td>2,105</td>
<td>-0.15</td>
</tr>
</tbody>
</table>

Foxy's daughters would produce 2,105 more lbs of milk and have a SCS of .15 less than the daughters of breed average cows managed exactly the same.


**Sire Summary Codes**

- **FMS**
  - Fluid milk dollars
  - Weighs PTA milk and fat, reflects the gross income per lactation the future mature daughters will earn in excess to hecalmates
- **CMS**
  - Predicted transmitting ability ebeose merit dollars
  - Reflects income per lactation daughters will receive if milk is priced according to it's value in cheese

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**Sire Summary Codes**

- **PTAT**
  - Predicted Transmitting Ability - Type
  - Expected difference in final score between daughters of the bull and breed average
- **TPI**
  - Type Production Index
  - Holstein:
    - 2 x PTA protein, 2 x PTA fat, 1 x PTA type, 1 x udder traits
  - Other breeds:
    - 3 x PTA, 3 x CY, 1 x PTAT

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**Sire Summary Codes**

- **Calving ease**
  - Percentage of difficult births in first calf heifers
  - Range 5 to 20%
  - Median 9%
- **Reliability**
  - Degree of confidence a breeder can place on PTA
  - Increases with number of daughters, number of bulls with daughters, number of records per daughter
  - Closer number is to 100%, the more reliable PTA
Sire Summary Codes

- **PPA**
  - Predicted Producing Ability
  - Cow’s ability to produce above or below the average of other cows
- **PI**
  - Pedigree Index
  - Estimate of animal’s genetic transmitting ability based on pedigree information
- **Parent Average**
  - Estimate of breeding average using sire and dam information

Sire Summary Codes

- **PL**
  - Productive Life
  - Predicted herd life for cows remaining in the herd
  - Reflects resistance to culling
- **SCS**
  - Somatic Cell Score
  - Transplant ability for somatic cell score
  - Lowly testable
- **NM$$**
  - Net merit index
  - Uses income and expenses to estimate expected lifetime profit daughters will provide

Selection Strategies

- Individual traits - milk, protein, stature, etc.
- Selection Indexes – multtrait indexes
  - TPI or PTI – production/type indexes
  - Productive Life (PL) – 1st crop daughters estimated from type and production traits, 2nd crop mostly direct from culling info
  - Others include SCS, FL composite, udder composite, body size composite
  - Net Merit $$ – additional net profit that a daughter will produce over her lifetime
    - Usually best index for profit of a commercial dairy
Summary

- Focus breeding strategies on traits that improve profitability the most and have the most opportunity for change.
  - Net Merit is probably the best selection index currently available for commercial herds – select bulls that are above the 90th percentile for Net Merit $S$
  - Registered bulls that derive a significant portion of income from cull cows are more complicated
- Call bulls from that group for calving ease issues or other major “flaws”
- Maintain collaring
- Sample groups of young sire on “groups” of unselected cows (all 3* service, etc.)
- Restrict young sire use to multiparous cows