Introduction to Genomic Selection

OUTLINE

1. What is different between pedigree based and genomic selection?
2. Selection tools
   - Selection Indexes
   - Genotyping resources
3. DNA-based markers and their use in dairy breeding programs

WHY USE SELECTION?

Estimated cost to raise a heifer is $2000-$3000
Second greatest expense for dairy after feed costs

To improve performance
- Nutrition
- Hygiene
- Health program
- Genetics

ACHIEVEMENT OF GENETIC CHANGE
IN RESPONSE TO SELECTION

Genetic Change = 
Accuracy of selection x Selection intensity x Genetic variation 

Generation Interval

EFFECT OF ACCURACY (RELIABILITY)

Accuracy depends on:
- Amount and type of information available
- With phenotypic selection, high accuracy occurs with high heritability
- Improving accuracy improves the response to selection
- In the dairy industry the term reliability (\% r) is often used for accuracy
**SELECTION INTENSITY**

How high the threshold is for animals that will be used in the breeding population

- High selection intensity increases the rate of response to selection

**GENERATION INTERVAL**

- The average age of the parent when their offspring are born
- Reducing the generation interval through assisted reproductive technologies or genomics increases the response to selection

**SELECTION PEDIGREE-BASED PTA**

**Predicted Transmitting Ability (PTA)**

- Estimates (predicts) the future offspring’s performance based on records obtained from:
  - Own performance
  - Relative’s performance (pedigree)
  - Past offspring’s performance
- Accuracy of prediction is typically poor until a large number of progeny have performance records

**SELECTION PREDICTION EQUATIONS**

The PTA measures the expected difference between the animal’s offspring and the mean of all offspring for that trait.

- Mean of the herd’s offspring = 25,000 pounds
- Mean of the cow’s offspring = 27,000 pounds
- PTA = +2000 lbs.

**SELECTION PEDIGREE-BASED PTA**

**Pros**

- Very effective with animals with large numbers of progeny
- Most effective with traits that are:
  - Easy to measure
  - Inexpensive to measure
  - Occur early in life
  - Moderate to high heritability

**Cons**

- Accuracy is low for most females throughout their lives
- Expensive and time consuming to “prove” bulls through extensive progeny testing
- Not effective for traits that are:
  - Difficult to measure
  - Expensive to measure
  - Occur late in life
**SELECTION**

**GENOMIC BASED PTA**

Use pedigree information **AND** information from thousands of DNA variants to predict performance of offspring.

**Cons**

- If the DNA variant isn't causal, prediction may not be accurate across breeds and will need to be routinely validated.

---

**IMPROVING ACCURACY**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Genetic Average</th>
<th>Traditional Parent Average</th>
<th>Difference Young Holstein Bulls1</th>
<th>2011 Difference Holstein Heifers2</th>
<th>Genomic Daughter Equivalents2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Meat (lb)</td>
<td>75</td>
<td>51</td>
<td>+42</td>
<td>+42</td>
<td>35.1</td>
</tr>
<tr>
<td>Fat (lbs)</td>
<td>75</td>
<td>35</td>
<td>+45</td>
<td>+48</td>
<td>26.0</td>
</tr>
<tr>
<td>Protein (percent)</td>
<td>75</td>
<td>50</td>
<td>+52</td>
<td>+46</td>
<td>26.6</td>
</tr>
<tr>
<td>Productive Life (years)</td>
<td>75</td>
<td>20</td>
<td>+64</td>
<td>+51</td>
<td>27.0</td>
</tr>
<tr>
<td>Somatic Cell Score</td>
<td>75</td>
<td>31</td>
<td>+43</td>
<td>+43</td>
<td>38.5</td>
</tr>
<tr>
<td>Daughter Pregnancy Rate (%)</td>
<td>71</td>
<td>27</td>
<td>+43</td>
<td>+42</td>
<td>146.3</td>
</tr>
<tr>
<td>Final Score</td>
<td>76</td>
<td>32</td>
<td>+44</td>
<td>+46</td>
<td>26.6</td>
</tr>
<tr>
<td>Sire Calving Ease</td>
<td>73</td>
<td>36</td>
<td>+18</td>
<td>+26</td>
<td>38.5</td>
</tr>
<tr>
<td>Daughter Calving Ease</td>
<td>73</td>
<td>36</td>
<td>+18</td>
<td>+26</td>
<td>38.5</td>
</tr>
</tbody>
</table>


---

**WHY ARE DAIRIES USING GENOMIC TESTS?**

- Increased (and improved) reporting of traits
- Improved customer confidence in genomic tests
- Ease of access
- Cost of testing is lower
- Implementation is increasing profitability and response to selection

---

**GENOMIC SELECTION**

**Pros**

- Prediction can be immediate (birth) rather than waiting for offspring to perform
- Dramatically increases rate of genetic change
- Best value when:
  - Selecting for traits that are difficult to measure
  - Selecting for traits that are expensive to measure
  - Selecting for traits that occur late in life
  - Animal has 0 or few offspring

---

**SINGLE NUCLEOTIDE POLYMORPHISMS**

DNA can be extracted from any tissue including blood, hair and semen.

---

**WHEN TO GENOTYPE**

**APRIL 11, 2018**
**USING GENOMIC SELECTION**

When to genotype?
- First 30 days
- Post-weaning (6 months)

Inform mating decisions
- Elite females – sexed semen, better bulls, ET donors
- Poorer females – beef bulls

**BREEDING OBJECTIVES**

Breeding objectives determine when to genotype
- What are your goals for your dairy?
- When do you want to sort your females?

**BEFORE WE GENOTYPE...**

Identifying goals and choosing priorities
- Identify replacements
- Identify females that won't produce replacements
  - Breed to beef bulls
- Identify elite females
  - Sexed semen
  - Assisted Reproductive Technologies
  - Breed to better bulls
- Reduce effects of early disease
- Reduce generation interval

**GENOTYPING EARLY**

First month
- Identification of replacements and elite females to sort heifers early for different levels of care
- Facilitates reducing generation interval by using assisted reproductive technologies
- Potential to further increase genetic progress

**AFTER WEANING OR AFTER CO-MINGLING**

Stratify females before breeding but with knowledge of resistance to BRD, scours, etc.
- Sort into breeding strategies by overall quality using selection indexes or to maximize complementarity with additional emphasis on specific traits
- Keep or cull

**WHO TO GENOTYPE**
**USING GENOMIC SELECTION**

Who to genotype?
- Identify replacements, sell or send other heifers to feedlot
- Rank females for mating decisions

**BREEDING OBJECTIVES ALSO INFLUENCE WHO IS GENOTYPED**

Identification of replacements, dams of future replacements or elite females
- Genotype more animals than you plan on keeping for replacements or elite females
- More you genotype, the choosier you can be for selecting your replacements
- Genotyping more animals improves accuracy of keeping the right individuals
- Genotyping more animals therefore results in faster genetic progress

**SELECTION INDEXES**

- PTAs of individual traits
- Predicted transmitting abilities (PTA) of dairy cattle are often summed into a selection index
- Selection indexes combine PTAs of various traits, weights them and gives you a single value to select by
- Weights can be based on economic value or the prioritization of what traits are the most important
- Examples: Total performance index (TPI), Net merit$ (NMS)

**WHAT INFORMATION DO WE GET?**

Predicted transmitting abilities on key traits and selection indexes

**NET MERIT$**

The NMS index is defined as expected lifetime profit as compared with the breed base for cows born in 2010

Updated in 2014 to include:
- New economic weights
- 2 more fertility traits - heifer conception rate (HCR) and cow conception rate (CCR)
- Grazing merit (GMS)
- Cheese merit (CMS)
- Fluid merit (FMS)
- Details may be found at [http://aipl.arsusda.gov/reference/nmcalc-2014.htm](http://aipl.arsusda.gov/reference/nmcalc-2014.htm)

Estimated that $8 million/year would be gained if all dairy breeders selected breeding stock using NMS (VanRaden and Cole, 2014)

**GRAZING MERIT DOLLARS**

Introduced in 2014 for cows in grazing herds

Fertility is of high importance as most grazing herds participate on a seasonal breeding and calving system

- Management (health & fertility) comprises 46%
- Production comprises 39% with focus on pounds of fat and protein produced
- 15% comes from conformation
Selection index developed by the **US Holstein Association** as a representation of their vision for improvement of the domestic and international Holstein population

Traits are weighted rather than multiplied by an economic value ($) as is done with NM$

**TOTAL PERFORMANCE INDEX**

**JERSEY PERFORMANCE INDEX**

- Selection index developed by the American Jersey Cattle Association with the overarching objective of increasing lifetime net income
- Developed from extensive evaluation of production, longevity, and health data to predict lifetime net profit from production, type, health, longevity and fertility traits

**NEOGEN – IGENITY® TESTING**

GGP HD150K $92-96
- 150k SNPs
- Reliabilities of 71-74%
- Supports Holstein, Brown Swiss, Ayrshire

GGP LD $42-46
- 42k SNPs
- Reliabilities of 68-72%
- Supports Holstein, Brown Swiss, Ayrshire, Jersey, Guernsey, Gyr, Girolando


**EXAMPLE IGENITY® REPORT ON KEY TRAITS**

<table>
<thead>
<tr>
<th>ID</th>
<th>GM$</th>
<th>NM$</th>
<th>Rank</th>
<th>NM$ USA %</th>
<th>Rank</th>
<th>Milk Yield</th>
<th>Fat lbs</th>
<th>Protein lbs</th>
<th>SCS</th>
<th>PL</th>
<th>DPR</th>
<th>DCE</th>
<th>IPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>635</td>
<td>627</td>
<td>1</td>
<td>99%</td>
<td>1102</td>
<td>49</td>
<td>30</td>
<td>2.84</td>
<td>5.8</td>
<td>2.7</td>
<td>5.8</td>
<td>2363</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>577</td>
<td>597</td>
<td>2</td>
<td>99%</td>
<td>1192</td>
<td>53</td>
<td>39</td>
<td>2.65</td>
<td>5.5</td>
<td>1.8</td>
<td>6.8</td>
<td>2322</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>360</td>
<td>375</td>
<td>4</td>
<td>98%</td>
<td>1431</td>
<td>26</td>
<td>28</td>
<td>2.95</td>
<td>3.4</td>
<td>0.9</td>
<td>5.9</td>
<td>2066</td>
<td></td>
</tr>
</tbody>
</table>

- **GM$** - grazing merit $
- **NM$** - net merit $
- **SCS** - somatic cell score
- **PL** - productive life
- **DPR** - daughter pregnancy rate
- **DCE** - daughter calving ease
- **Milk yield** - differences in pounds of milk for a 305 day lactation
- **Fat lbs** - differences in pounds of fat for a 305 day lactation
- **Pro lbs** - difference in lbs. of protein yielded for 305 day lactation
- **IPI** - Igenity production index (same as TPI)

**ZOETIS TESTING**

Clarifide® $39.50-42.50
- >20K SNPs
- Reliability 70-71%

Clarifide® $79-86
- 62K SNPs
- Reliability 72-75%
- Jersey, Brown Swiss

Clarifide® Ultra Plus $79-86
- Holstein
- Reliability 73%
- Includes Dairy Wellness Profit Index (DWP$)
- Includes Wellness Trait Index (WT$)

**PUTTING IT INTO PRACTICE**

- **SCE** - Sire calving ease
- **HCR** - Heifer conception rate
- **CCR** - Cow conception rate
- **DSB** - Daughter stillbirth
- **SSB** - Sire service stillbirth

**ZOETIS TESTING**

Clarifide® $39.50-42.50
- >20K SNPs
- Reliability 70-71%

Clarifide® $79-86
- 62K SNPs
- Reliability 72-75%
- Jersey, Brown Swiss

Clarifide® Ultra Plus $79-86
- Holstein
- Reliability 73%
- Includes Dairy Wellness Profit Index (DWP$)
- Includes Wellness Trait Index (WT$)
• Which will be the most profitable heifer?
• Which heifer will be the least profitable?

ACTUAL PROFITABILITY

SUMMARY

• When genotyping is done and what cattle are genotyped should reflect the goals of the dairy
• Genomic selection increases the genetic progress of the dairy herd and reduces financial risk
• Genomic selection can also be used for breeding and management decisions
• Genomic selection may be coupled with assisted reproductive technologies to further increase genetic progress
• Don’t use genomic selection if you aren’t going to use the information to make decisions

BREED DIFFERENTLY

Sexed Donor Cull Recipient
Semen Dam