Beef cattle improvement in the genomics era

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Outline

- Introduction to cattle breeding
- Genomic selection
- Practical questions for breeders
  - Dairy Industry as a genomic selection success story
  - Beef Industry as an “opportunity for improvement”
- What does the future hold
Genetic improvement

- Genetic change - use animals better than the average as parents of the next generation
- Key to genetic change: selection
Traditional Animal Breeding

• Selective breeding for economically important traits
• Traditionally based on phenotypic recording
  • Estimation of breeding values from phenotypic records and pedigrees
  • Knowledge of heritability of each trait
• Successful
  • but slow process especially for certain traits

Fed identical diets, kept in similar conditions for 56 days.

Strains: 1957 1978 2005
56-d weight: 905g 1,808g 4,202g
Impact of innovation in US

1977

7 cows today yield the beef of 10 cows in 1977

Mid 1940’s

Cows yield 4 times the milk of cows in the mid 1940s

Today

Today

Capper et al. 2009, Capper 2011
Slow/Difficult to improve traits

• Traits measured in **only one sex** (milk yield)
  • Need phenotypic records on relatives (progeny)

• Traits measured **late** in life (longevity) or **after death** (meat quality)

• Measuring the traits is **expensive** or **difficult** (feed efficiency, disease resistance)
Rate of genetic change

• Depends on 4 factors:
  • Selection **intensity**
  • **Accuracy** of genetic prediction
  • **Generation interval**
  • Amount of **genetic variation** in the trait
How to achieve high accuracy?

Historically:

• Number of records: large number of animals and high-quality phenotypic records

• Trait is highly heritable

Slow/Difficult to improve traits

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• Traits measured late in life (longevity) or after death (meat quality)

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MAS – marker assisted selection

• Since 1990s – DNA information can increase the rate of genetic improvement.

• Challenges:
  • The effect of individual markers (QTLs) on complex traits is small
  • A large number of markers (QTLs) are necessary to explain the genetic variation
  • Marker information in outbreeding species is limited – linkage phase between marker and QTL (gene) must be established for every population
Tenderness - calpain

• CAPN1-316 = marker for tenderness

• One of the SNPs in the GeneStar Tenderness test
  • GG was 1.10 kg tougher than GC (Pinto et al., 2010)
  • GG was 0.36 kg tougher than GC (Curi et al., 2010)
  • CC is 1.23 kg tougher than CG (UF multibreed pop., Casas et al., 2010)
Genomic Selection

• Trace all segments of the genome with markers
  • Divide genome in chromosome segments based on marker intervals
  • Capture all QTLs = all genetic variation
  • Marker density must be sufficiently high to ensure at least one marker for each QTL/gene with an effect on the trait
Principles of Genomic Selection

**Large Training Population**
- Phenotyped
- Genotyped

**Selection Candidates**
- Genotypes used to predict genetic merit

**Prediction equation**
Genomic breeding value = $w_1x_1 + w_2x_2 + w_3x_3 + \ldots$

**Training Pop**: many animals with phenotypes and genotypes

**Estimate effect of each marker, generate a prediction equation**

**Apply the prediction equation to a group of animals with genotypes**

**Selected breeders**
- Based on genomic breeding values

Not predictive in other breeds/lines

Adapted from Hayes and Goddard. 2009. Nature Reviews Genetics 10, 381-391
Dairy industry - as an example

- Dairy industry is well suited to whole genomic selection (different than beef)
  - High use of AI
  - Clear selection goal
  - One breed used extensively
  - Large number of high accuracy AI sires for training
  - Extensive, uniform collection of data on traits
  - Central evaluation (AIPL) receiving genotypes
  - Obvious way to increase rate of genetic change
  - AI companies funding the genotyping because they get a clear cost saving in terms of young sire program
Breeding value prediction in dairy

**Young Sire Parent Average**
- Birth
- Genetics inherited from sire and dam (half of sire and dam genetics)
- Accuracy: 0.20

**Young Sire Progeny Test**
- 5 years; $50,000 cost
- Genetics inherited from sire and dam (half of sire and dam genetics)
- Accuracy: 0.80

**Young Sire Genomic Selection**
- Birth; <<< $50,000 cost
- Genetics inherited from sire and dam (half of sire and dam genetics)
- Accuracy: 0.65
Benefits of genomic selection

• Genomic selection can help breeders identify superior individuals (higher genetic merit) at a young age
  
  • Selection **intensity**
  
  • **Accuracy** of genetic prediction **Increased**
  
  • **Generation interval** **Decreased**
  
  • Amount of **genetic variation** in the trait
How about the Beef Cattle Industry?

• Little use of AI
• Relatively few high accuracy sires for training
• Multiple competing selection goals – cow/calf, feedlot, processor – little data/value sharing between sectors
• Few/no records on many economically-relevant traits
• Many breeds, some small with limited resources
• Crossbreeding is important
• No one wants to pay, as value is not recovered by breeder
“The path to sustainable, profitable growth begins with creating more promoters [happy customers] and few detractors [unhappy customers]... It’s that simple and that profound.”


The cornerstone of prosperity for any industry depends on final consumer demand.
Challenges and Opportunities

**Challenge**: Beef’s competitive advantage is pressured by rising concerns about diet and health.

**Opportunity**: Strong “high-quality” branded beef programs
  - Consumers are willing to pay for assured quality

- Important to maintain and increase current consumers brand loyalty (meeting and exceeding quality expectations)

- Important to expand consumer base

- Improving quality – critical for beef industry

- **Tenderness** – the most important sensory attribute
Genomics as a management tool

• Data from project supported by FL Beef Council
• 200 animals from UF multibreed herd
  • genotyped with 150K SNP chip
  • impute 150K genotypes on another 200 animals
• 418 Brahman/Angus animals with 150K genotypes and WBSF
• Used in a discriminant analysis
  • Identify a subset of carcass and meat quality traits and markers with the highest predictive accuracy across tenderness classes
• 3 tenderness classes:
  • Tender1 (tender) if WBSF < 3.5
  • Tender2 (moder. tender) if WBSF between 3.5 - 4.5
  • Tender3 (tough) if WBSF > 4.5
### Best carcass traits, SNP, carcass+SNP

**Best carcass traits model**
- **Marb, REA**

<table>
<thead>
<tr>
<th>Error Estimates for tenderness classes</th>
<th>Tender</th>
<th>Moder.</th>
<th>Tough</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Rate</td>
<td>46.2</td>
<td>82.1</td>
<td>36.6</td>
<td>54.9</td>
</tr>
</tbody>
</table>

**Best SNP (marker) model**
- **17 SNP**

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</thead>
<tbody>
<tr>
<td>Error Rate</td>
<td>40.1</td>
<td>61.7</td>
<td>30.3</td>
<td>44.0</td>
</tr>
</tbody>
</table>

**Best carcass + SNP model**
- **Marb, LM, DP + 17 SNP**

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<tbody>
<tr>
<td>Error Rate</td>
<td>37.1</td>
<td>56.4</td>
<td>32.4</td>
<td>41.9</td>
</tr>
</tbody>
</table>

**Groups**
- **Group 1: tender** (*WBSF < 3.5*)
- **Group 2: moderately tender** (*3.5 > WBSF < 4.5*)
- **Group 3: tough** (*WBSF > 4.5*)
Future outlook / Summary Points

- Genomic information (SNPs)
  - Increase the accuracy of EPDs
  - Add “novel” traits to our suite of available EPD (feed efficiency, healthfulness, nutritional value, disease resistance, thermotolerance)

- Large resource populations with phenotypes are required for discovery and validation.

- Need breed specific prediction equations.

Genomics - technology to accelerate genetic progress.
Questions?
Challenges facing beef industry

• Beef’s competitive advantage is pressured by rising concerns about diet and health.

• Negative consumer perception regarding beef products is creeping into the marketplace and impacting buying behavior.

• The Consumer Climate for Red Meat Study (1985, Yankelovich, Skelly and White) reported a marked and significant shift in consumer preferences.
Industry’s efforts to identify shortfalls

• The National Cattlemen’s Association (NCA) initiated a “War on Fat” campaign (NCA, 1990) aimed at reduction of excess fat at the production level; it was the industry’s first unified step towards aligning production practices with some measure of consumer preferences.

• The first and second National Beef Quality Audit (NBQA 91 & NBQA 95) showed:
  • successful in attacking production of excess fat
  • new concerns about beef’s palatability and price/value relationships had developed.

• Low overall uniformity and consistency” was identified in 1991 and remained the number one concern in 1995 and 2000 (and second in 2005).
Industry’s challenges

- Unfavorable wellness/health perceptions of beef
- Product inconsistency
- Eroding palatability attributes
- Lack of preparation convenience;
- Its costs were disproportionately rising compared to its competitors.
- Meanwhile, the pork and poultry industries improved their respective perceptions among consumers while also becoming more and more efficient.
- Subsequently, the beef industry found itself with weakening perceptions of its price/value relationship in the mind of consumers (a critically important concept)