Heterosis
Importance to the Industry

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U.S. Beef Industry is Segmented

Seedstock → Cow-calf → Stocker

Dairy

Feedlot

Abattoir
Beef Industry Challenges

• “Sustainability”
  – Land use
  – Profit
  – Petroleum use
  – Animal welfare concerns
  – Social (antibiotic, growth promotants, etc.)
  – Climate
  – Lack of communication between sectors

• Who is (are) our consumer(s)?

• Heterosis, selection part of the solution
  – Improvements in production efficiency positively impact sustainability
Sire Selection in Two Steps

1. Pick the right breed(s)
   - PLANNED Crossbreeding
   - Breeding objectives
   - Considerations

2. Chose right individual in that breed
   - EPDs
   - Genetic risk management
   - Selection indexes
How Do I Choose a Breeding Program

• Are you profit or premium focused?
  – Why not both?

• Herd size
  – Efficient bull utilization/manage variation in marketing groups

• How do I generate replacement heifers?

• How do I market calves?

• Constraints
  – Environment
  – Management
Making the Case for Crossbreeding

1. Why crossbreed?
2. What is heterosis?
3. How does it work for me?
4. Breed Complementarity at work...
Why Crossbreed?

- Profit
- Headache
Crux of Straight-breeding

Do the benefits of selection for economically important/convenience traits within breed (straight-breeding) outweigh the improvement of lowly heritable traits via heterosis (especially maternal)?

Selection should be for **BOTH** additive and non-additive genetic merit.
Having Your Cake and Eating it Too

• Commercial cattlemen SHOULD care about BOTH additive and non-additive effects.
  – Selection index/EPDs
  – Hybrid vigor or heterosis

• Seedstock producers SHOULD focus on additive genetic merit, and putting it in a package that helps clientele exploit non-additive effects.
### Heritability and Heterosis: Inversely Related

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability</th>
<th>Heterosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproduction</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>(fertility)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>(growth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>(carcass)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Heterosis

• Hybrid Vigor
• Superiority of a crossbred animal as compared to the average of its straightbred parents
• More divergent parental lines = more heterosis
• NOT available from within breed matings
• Extensively researched in cattle (Google Scholar >13,000 manuscripts)
The Power of Crossbreeding

• Heterosis
  – Especially maternal heterosis

• Breed Complementarity
  – Selection of breeds for core traits that fill the other breed(s) shortcomings
What Are the Benefits of Heterosis?
Table 2. Estimates of biological type heterosis (SE) (British x British, British x Continental and Continental × Continental) for birth, weaning and yearling weight (Model 1)

<table>
<thead>
<tr>
<th>Covariate</th>
<th>BWT², kg</th>
<th>WT205D², kg</th>
<th>WT365D², kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>B × B</td>
<td>0.47 (0.37)</td>
<td>6.43 (1.80)**</td>
<td>17.59 (3.06)**</td>
</tr>
<tr>
<td>B × C</td>
<td>0.75 (0.32)*</td>
<td>8.65 (1.54)**</td>
<td>13.88 (2.63)**</td>
</tr>
<tr>
<td>C × C</td>
<td>0.73 (0.54)</td>
<td>5.86 (2.57) *</td>
<td>9.12 (4.34) *</td>
</tr>
<tr>
<td>Maternal heterosis</td>
<td>0.41 (0.31)</td>
<td>0.34 (1.84)</td>
<td>3.44 (2.66)</td>
</tr>
</tbody>
</table>

¹B = British, C = Continental.

²BWT = adjusted birth weight, WT205D = adjusted weaning weight, WT365D = adjusted yearling weight.

*P < 0.05.

**P < 0.01.
An emerging hypothesis...

• For many years the source of heterosis has been thought to be increased ‘heterozygosity’
  – The inverse of linebreeding/inbreeding
  – Inbred animals less ‘fit’ across environments, crossbreds more ‘fit’

• Genomics and sequence data provide a new look at potential source of heterosis or dominance effects
  – Recovery of gene function in crossbreds from parents homozygous for LOF mutations.
Recovery of Gene Function in Crossbreds

Sire

Dam

Progeny

Knowledge for Life
Benefits of Heterosis

- Heterosis increases production 20 to 25% per cow in *Bos taurus* x *Bos taurus* crosses; 50% in *Bos indicus* x *Bos taurus* crosses in subtropical regions.
- More than half of this effect is dependent on use of crossbred cows.

Jenkins, MARC
### Advantages of the Crossbred Cow

<table>
<thead>
<tr>
<th>Trait</th>
<th>Observed Improvement</th>
<th>% Heterosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longevity</td>
<td>1.36</td>
<td>16.2</td>
</tr>
<tr>
<td>Cow Lifetime Production:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. Calves</td>
<td>0.97</td>
<td>17.0</td>
</tr>
<tr>
<td>Cumulative Wean. Wt., lb.</td>
<td>600</td>
<td>25.3</td>
</tr>
</tbody>
</table>

Adapted from Cundiff and Gregory, 1999.
# Advantages of the Crossbred Calf

<table>
<thead>
<tr>
<th>Trait</th>
<th>Observed Improvement</th>
<th>% Heterosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calving rate</td>
<td>3.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Survival to weaning</td>
<td>1.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Birth weight</td>
<td>1.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>16.3</td>
<td>3.9</td>
</tr>
<tr>
<td>ADG</td>
<td>0.08</td>
<td>2.6</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>29.1</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Adapted from Cundiff and Gregory, 1999
Impact on Profit

Profit = Revenue - Costs

Heterosis Impact
The Dollars of Heterosis

100 cows, 80% Weaning Rate, 575 avg. weaning weight, 10 year horizon

Calf Survival to Weaning (6%) = 48 hd.
Weaning wt. (4%) = +18,400 lb.

Weaning wt. per cow exposed (23%) = +105,800 lb.

...or the equivalent of 18 more 575 lb. calves/year

Heterosis is worth ~$150/cow/year

($1.50/lb for 5-6 cwt calves)

Decreases breakeven by $0.28/lb...straightbred would have to generate an additional $198 per head to be equivalent
Impact of Increased Reproductive Rate

• Increase % Calf Crop Weaned
• Increase revenue
  – Let’s assume a 7% increase, 83-90%, 100 cows
  – 7 hd. of 500 lb calves, $145/cwt, grosses $5,075
  – Equivalent to increasing revenue by $61.44/hd
  – Decrease breakeven by $11.27/cwt
• No matter how you sell calves, pay wt. drives the bus (#head * avg. wt)
How Valuable is the Improvement?

• Heifer Pregnancy
  – **Easy**: Heterosis: +7% FSCR, +5% HP (45 d)
  – **Difficult**: Selection: +8% (avg. vs top 1% HP RAAA)

• Longevity
  – **Easy**: Heterosis: +16% (~1.4 years)
  – **Difficult**: Selection: +9% (avg. vs top 1% STAY ASA)
    • 9% fewer replacements-~$20,000 cost savings per 100 cows...that’s $200 per cow/lifetime
Retained Heterosis

- Mating of crossbred animals leaves you with 0 heterosis... **WRONG**
- Heterosis is retained in future generations
- Related to the probability of alleles from different breeds pairing together
  - Note that expected and realized heterosis may differ due to the relationship of breeds
  - Heterozygosity and heterosis are not linearly related
One Bull to Do It All...

Antagonisms
Retained Heterosis
Breed Complementarity
Selection tools/trait focus
Separate Maternal and Terminal Mating Decisions

More Flexibility

Making Shorthorns Great Again-Kansas City
Suggested Mating System Goals

1. Optimize the utilization of calf and maternal heterosis.
2. Utilize breed complementarity to match cows to their environment and their progeny to market targets.
3. Minimize variation in progeny phenotypes by stabilizing breed inputs.
4. Use Adv. Repro tech to help structure mating system (i.e. AI, gender sort semen)
Breeding Programs

- Terminal
- F1, Hybrid, or Composite Seedstock
- Rotational 2, 3, 4 breeds
  – if your operation is (very) large enough
  ♦ Retained Heterosis
  ♦ Stabilization of Breed Percentages
## Systems, Benefits, Constraints

### Table 7. Summary of crossbreeding systems by amount of advantage and other factors.

<table>
<thead>
<tr>
<th>Type of System</th>
<th>% of Cow Herd</th>
<th>% of Marketed Calves</th>
<th>Advantage (%)</th>
<th>Retained Heterosis (%)</th>
<th>Minimum No. of Breeding Pastures</th>
<th>Minimum Herd Size</th>
<th>No. of Breeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Breed Rotation</td>
<td>A*B Rotation</td>
<td>100</td>
<td>100</td>
<td>16</td>
<td>67</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>3-Breed Rotation</td>
<td>A<em>B</em>C Rotation</td>
<td>100</td>
<td>100</td>
<td>16</td>
<td>67</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>2-Breed Rotational/ Terminal Sire</td>
<td>A*B Rotational</td>
<td>50</td>
<td>33</td>
<td>20</td>
<td>86</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>T x (A*B)</td>
<td>50</td>
<td>67</td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>100</td>
<td>100</td>
<td>21</td>
<td>90</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Terminal Cross with Straightbred Females</td>
<td>T x (A)</td>
<td>100</td>
<td>100</td>
<td>8.5</td>
<td>0e</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td>Terminal Cross with Purchased F1 Females</td>
<td>T x (A*B)</td>
<td>100</td>
<td>100</td>
<td>24</td>
<td>100</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td>Rotate Bull every 4 years</td>
<td>A*B Rotation</td>
<td>100</td>
<td>100</td>
<td>12-16</td>
<td>50-67f</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>A<em>B</em>C Rotation</td>
<td>100</td>
<td>100</td>
<td>16-20</td>
<td>67-83f</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td>Composite Breeds</td>
<td>2-breed</td>
<td>100</td>
<td>100</td>
<td>12</td>
<td>50</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>3-breed</td>
<td>100</td>
<td>100</td>
<td>15</td>
<td>67</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>4-breed</td>
<td>100</td>
<td>100</td>
<td>17</td>
<td>75</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td>Rotating Unrelated F1 Bulls</td>
<td>A<em>B x A</em>B</td>
<td>100</td>
<td>100</td>
<td>12</td>
<td>50</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>A<em>B x A</em>C</td>
<td>100</td>
<td>100</td>
<td>16</td>
<td>67</td>
<td>1</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>A<em>B x C</em>D</td>
<td>100</td>
<td>100</td>
<td>19</td>
<td>83</td>
<td>2</td>
<td>Any</td>
</tr>
</tbody>
</table>
Figure 1. Two-breeds rotation.

Figure 2. Three-breeds rotation.
Figure 3. Two-breed rotational/terminal sire.

Pasture A
young cows and heifers

X

Market steers and non-replacement heifers

Pasture B
young cows and heifers

X

X

Pasture C
older cows

Market all
**Figure 4.** Terminal cross with purchased F_{1} females.

*purchased replacement heifers*

**Figure 6.** Composite breeding system.

*Pasture A*

Market steers and non-replacement heifers

**2, 3, 4 Breed composites**
Figure 7. Rotating F₁ bulls.

**Strategy 1**
A x B bulls mated to A x B cows.

**Strategy 2**
A x B bulls and A x C bulls mated to cows.

**Strategy 3**
A x B bulls and C x D bulls mated to cows.
Crossbreeding Done RIGHT!

• Build a plan – set attainable goals
• Considerations
  – Marketing end points
  – Replacement females (cows must have heterosis)
  – Environment
  – Management
• Stick to it!
Systematic Sire Selection

- Set Goals
- Assess Cow Herd
- Assess Resources
- Breed Selection
- Bull Selection
  - Reproduction
  - Structure
  - Performance
  - Visual Appraisal

http://www.nbcec.org/producers/sire.html
Thank You!

Questions