Meat quality and thermotolerance in *Bos Indicus* influenced cattle

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Animal Genomics

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Beef cattle in the world

> 50% cattle in the world – maintained in hot and humid environments

- including ~ 40% of beef cows in US
• Approximately **80%** of global beef production is *Bos Indicus* based.

*Bos indicus* germplasm:
• Critical role in US and worldwide beef production
• Particularly when used as part of a well-structured crossbreeding program

• Adapted to heat and humidity
• Resistant (or at least tolerant) to internal and external parasites
• In crossbreeding systems produce improved cattle:
  • Fertile
  • Gain well
  • Long lived
Two areas of interest

Meat Quality

- Top priority for beef industry
  - Great power to influence demand
  - Can be improved
- Very important for *B. indicus* crosses
  - Routinely penalized for relatively low marbling score.
  - Routinely penalized for perceived inadequate tenderness

Thermotolerance

- Climatic stress - major limiting factor of production efficiency
- Genomic tools can help select
  - Animals with superior ability for both thermal adaptation and food production
  - Energy-efficient, sustainable approach to meet the challenge of global climate change.
Meat quality
Meat Quality

USDA grading system
- Based on marbling and maturity
- Limited in predicting eating quality
  - Tenderness

Genomic Tests
- Developed on B. Taurus data
- Limited prediction in B. Indicus -influenced
  - Need to be breed specific
## Tenderness by USDA Quality Grade

<table>
<thead>
<tr>
<th></th>
<th>5.6%</th>
<th>47.1%</th>
<th>32.1%</th>
<th>10.8%</th>
<th>3.4%</th>
<th>1.2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>Standard</td>
<td>Select</td>
<td>Choice -</td>
<td>Choice</td>
<td>Choice +</td>
<td>Prime</td>
</tr>
<tr>
<td>(%)</td>
<td>5.6%</td>
<td>47.1%</td>
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</tr>
</tbody>
</table>

*UF MAB (N = 1,366)*
**Tenderness by USDA Quality Grade**

<table>
<thead>
<tr>
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<th>Choice</th>
<th>Choice +</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6%</td>
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<td>32.1%</td>
<td>47.1%</td>
</tr>
</tbody>
</table>

**UF MAB (N = 1,366)**
Variation in WBSF – by breed

Numbers

WBSF, kg
Variation in WBSF – by breed

- UF Angus
- UF Brahman
Genetic tests
Tenderness
Genomics Tests

SNP – genetic marker

..GACGCTCTCTCGTGG..
..GACGCTCTCTCGTGG..

3 possible genotypes

UF Angus, n = 153

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Mean (WBSF, kg)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT</td>
<td>3.96</td>
<td>124</td>
</tr>
<tr>
<td>TC</td>
<td>3.89</td>
<td>26</td>
</tr>
<tr>
<td>CC</td>
<td>3.69</td>
<td>23</td>
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</tbody>
</table>

UF Brahman, n = 241

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Mean (WBSF, kg)</th>
<th>n</th>
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</thead>
<tbody>
<tr>
<td>TT</td>
<td>4.43</td>
<td>93</td>
</tr>
<tr>
<td>TC</td>
<td>4.41</td>
<td>119</td>
</tr>
<tr>
<td>CC</td>
<td>4.73</td>
<td>29</td>
</tr>
</tbody>
</table>
Combination of markers in calpastatin

```
<table>
<thead>
<tr>
<th>Combination</th>
<th>WBSF, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG-CG</td>
<td>3.77</td>
</tr>
<tr>
<td>TA-TA</td>
<td>4.13</td>
</tr>
<tr>
<td>TA-TG</td>
<td>4.15</td>
</tr>
<tr>
<td>TA-CG</td>
<td>4.32</td>
</tr>
<tr>
<td>CG-CG</td>
<td>4.75</td>
</tr>
</tbody>
</table>
```

- TG-CG: n = 16
- TA-TA: n = 356
- TA-TG: n = 66
- TA-CG: n = 178
- CG-CG: n = 39

Significance levels:
- a
- ab
- b
- c
Thermo-tolerance
In response to heat stress, cattle will regulate:

**Heat Production**
- Modulating basal metabolic rate
- Changing: feed intake, growth, lactation, activity

**Heat Exchange**
- Blood flow to the skin
- Evaporative heat loss through sweating & panting

**Goal:** Develop genomic tools to select for superior ability for both thermal adaptation and food production.
Breed effect on body temperature

Critical heat stress: ≥ 84
Major heat stress: 79 - 83
Moderate heat stress: 75 - 78
Minimal heat stress: ≤ 75
Breed effect on body temperature

Critical heat stress ≥ 84
Major heat stress 79 - 83
Moderate heat stress 75 - 78
Minimal heat stress ≤ 75

Body temp every 15 min by day - REPEATED with cov structure type = ARH(1)
Breed effect on body temperature

- **Angus**
  - Body Temp (°C) observed every 15 min by day
  - REPEATED with cov structure type = ARH(1)

- **Critical heat stress**
  - ≥ 84

- **Major heat stress**
  - 79 - 83

- **Moderate heat stress**
  - 75 - 78

- **Minimal heat stress**
  - ≤ 75

Graph showing body temperature changes over 24 hours with different breeds.
Breed effect on body temperature

Body Temp (°C)

≥ 84  Critical heat stress
79 - 83  Major heat stress
75 - 78  Moderate heat stress
≤ 75  Minimal heat stress

vagtmp every 15 min by day - REPEATED with cov structure type = ARH(1)
Factors important in thermotolerance

Coat
Hair
Sweat
Glands
Other
Skin Prop.
Factors important in thermotolerance

Coat
Hair

Sweat
Glands

Other
Skin Prop.

Long Hair Length
Long Hair Diameter
Short Hair Length
Short Hair Diameter
Factors important in thermotolerance

- **Coat**
  - Long Hair Length
  - Short Hair Length

- **Hair**
  - Long Hair Length
  - Short Hair Length

- **Sweat Glands**

- **Other Skin Prop.**
  - Fraction of Brahman genes

Significant quadratic effect of percentage Brahman composition.
Factors important in thermotolerance

Coat Score

Sweat Glands

Other Skin Prop.

Angus Sweat Glands

Brahman Sweat Glands
Factors important in thermotolerance

Significant linear effect of percentage Brahman composition

Coat Score

Sweat Glands

Other Skin Prop.
Factors important in thermotolerance

Coat Score

Sweat Glands

Other Skin Prop.

Skin Thickness (stratum corneum, stratum spinosum and basale)

Distance top of SG to skin surface

Distance bottom of SG to skin surface

Epidermis

Dermis

Sweat gland (SG)

Sebaceous gland

Skin Histology
**Take-home points**

### Meat Quality
- The USDA grading system (marbling and maturity) - limited in predicting eating quality (*tenderness*).
- Existing genomic tests, developed mostly on *Bos Taurus* data, are not predictive in our **Brahman** influenced cattle populations.

### Thermotolerance
- Selection for production ignoring *adaptability* = animals more sensitive to heat stress.
- Variation in **coat** and **skin** properties = allows selection for increased thermotolerance without affecting production.

### Population Specific Genomic Tools
Acknowledgments

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- Sheri Holmes
- Bobby Yates
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- Dayne Johns, etc.

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- UF ANS Hatch Project
- Seminole Tribe of Florida
- Brangus Breeders Association
- Florida Beef Council
- Florida Cattlemen’s Association
UF Angus vs Brangus tenderness/quality grade

UF Angus
(N = 222)

UF Brangus
(N = 216)
UF Angus vs Brangus tenderness/quality grade

UF Angus
(N = 222)

UF Brangus
(N = 216)
Sweat glands

**Table:**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>F Value</th>
<th>Pr &gt; F</th>
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</thead>
<tbody>
<tr>
<td>Breed</td>
<td>5</td>
<td>13.42</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>SweatGlandArea</td>
<td>1</td>
<td>18.40</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**Graphs:**

- **Sweat Gland Area (µm²):**
  - 100%A, 75%A, Brangus, 50%A, 25%A, 0%

- **Distance top SG to skin (µm):**
  - 100%A, 75%A, Brangus, 50%A, 25%A, 0%

- **Body Temp (°C) under High THI:**
  - 100%A, 75%A, Brangus, 50%A, 25%A, 0%

**Legend:**
- Red: Angus
- Orange: Brahman
Factors important in thermotolerance

Coat

- Hair
  - Score 1: Excessively Smooth
  - Score 2: Fairly Smooth

Sweat Glands

Other Skin Prop.

<table>
<thead>
<tr>
<th>Coat score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. excessively smooth</td>
</tr>
<tr>
<td>2. fairly smooth</td>
</tr>
<tr>
<td>3. long coat</td>
</tr>
<tr>
<td>4. woolly</td>
</tr>
<tr>
<td>5. excessively woolly coat</td>
</tr>
</tbody>
</table>

Long Hair Length
Long Hair Diameter
Short Hair Length
Short Hair Diameter
Factors important in thermotolerance

Coat Score

Sweat Glands

Other Skin Prop.
Factors important in thermotolerance

Coat Score

Sweat Glands

Other Skin Prop.

Significant linear effect of percentage Brahman composition
Thermotolerance measurements

• Vaginal **temperature** 15 min over 5 days
• Environmental data: temperature, humidity, **THI**
• **Sweating** rate
• **Coat**: color, coat score, hair length & diameter
• **Temperament**: chute and exit score
• Body **condition** score
• **Skin** biopsies: for histology & gene expression
• **Weight gain** over the summer/fall
• Rump fat and rib fat ultrasound
• Subsequent **pregnancy** status
• **250K** genotypes
Conclusion and future work

• Critical to identify genes and gene pathways for thermotolerance independent of production traits.

• Ultimate goal: cattle with high productivity and resistant to heat stress
  ▪ Genomic selection within indicine-influenced breeds.
  ▪ Gene editing for rapid incorporation into non-adapted breeds.

• Approach: GWAS for all traits (gene networks) combined with gene expression.
Conclusion and future work

• **Reaction norm** – good approach to describe **phenotypic plasticity** of core body temperature in response to environmental heat stress.

• Cattle with different **Brahman** percentage vary in their phenotypic plasticity.

• The **phenotypic plasticity** has a genetic component ($h^2 \sim .24$)

Programs to utilize the genetic component to improve **phenotypic plasticity** can be implemented.
Take-home points

• **Brahman** cattle – critical role in US and worldwide beef production.

• Genetics of **thermotolerance** – will allow for improved adaptability in Brahman crosses.

• **Meat quality** – great improvements in tenderness

• Need **breed specific genomic** tool for accurate prediction.
Breed-specific genomic tools

- To meet consumer expectation, the average **tenderness** needs to be **improved** and the variation in meat tenderness must be **controlled/managed**

- To be effective - genomic tools need to be developed in the **target** populations

Large resource populations with phenotypes are required for discovery and estimation.
Thermotolerance

• **Heat stress** - negative impact on US and global livestock productivity.
• > **50%** cattle in the world – maintained in hot and humid environments
• When cattle experience heat stress:

  - Feed intake
  - Milk production
  - Growth
  - Reproduction