The Science Behind the Grade
The Science Behind the Grade

How biology and physiology impact production, performance, and carcass quality and acceptance.

Dr. Jennifer N. Martin
Assistant Professor
Center for Meat Safety & Quality
Envision a high-quality beef experience
Beef Quality

Intrinsic Traits
- Palatability Traits (tenderness, juiciness, flavor)
- Safety
- Nutrition
- Appearance

Extrinsic Traits
- Price
- Production strategy
- Socio-cultural values (welfare, sustainability, etc.)
Focus on Palatability

Palatability Traits

• Tenderness
• Flavor
• Juiciness

What do we know about palatability?

• Tenderness is **essential** for consumer acceptance
  – >90% of steaks are considered tender or very tender
• Flavor may be equally important to tenderness
  – 58% of consumers say flavor is **more important** than tenderness
  – 43% of consumers say tenderness is **more important** than juiciness
Focus on Palatability

- Select: 29%
- Small: 62%
- Modest: 82%
- Moderate: 88%
- Slightly Abundant: 99%
- Moderately Abundant: 98%

If marbling is highly associated with a positive eating experience... 

...let’s just produce all Prime beef
U.S. Quality Grade Improvement

Fed Cattle Grading Percentage

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2019</th>
<th>Change</th>
<th>% Change</th>
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<tbody>
<tr>
<td>Prime</td>
<td>2.8%</td>
<td>8.6%</td>
<td>5.8 pts</td>
<td>+207%</td>
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<tr>
<td>Upper 2/3 Choice</td>
<td>13.8%</td>
<td>23.4%</td>
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<td>Certified Angus Beef®</td>
<td>15.6%</td>
<td>35.1%</td>
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<td>Lower 1/3 Choice</td>
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<td>48.2%</td>
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<tr>
<td>Choice</td>
<td>52.9%</td>
<td>71.6%</td>
<td>18.7 pts</td>
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<tr>
<td>Select</td>
<td>36.5%</td>
<td>16.8%</td>
<td>-19.7 pts</td>
<td>-54%</td>
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</table>

Source: USDA, CattleFax

May 2019: 8% Prime

May 2020: 11-12% Prime

USDA Prime and Choice Production

The market continues to reach new record-high quantities of Prime and Choice beef.
Producing High Quality Beef is an Art...  
...and a balance

National Beef Quality Audit Summaries

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<td>679</td>
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<td>Fat thickness, in</td>
<td>0.59</td>
<td>0.47</td>
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<td>0.51</td>
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<td>HCW, lbs</td>
<td>760.6</td>
<td>747.8</td>
<td>786.8</td>
<td>793.4</td>
<td>824.5</td>
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<td>LM area</td>
<td>12.9</td>
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<td>13.4</td>
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Trend of greater high-quality carcasses has been met with trend of increasing Yield Grade and HCW
Balancing Quality with Yield

<table>
<thead>
<tr>
<th>YG-1</th>
<th>+$3.79/cwt</th>
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<tr>
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<th>Par</th>
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<td>%</td>
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<tr>
<td>Prime</td>
<td>1.78</td>
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<tr>
<td>Choice</td>
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<th>YG-4</th>
<th>-$11.64/cwt</th>
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<td>%</td>
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<td>Choice</td>
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<td>Other</td>
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Producing High Quality Beef is an Art...

...and a science

In order to balance eating quality and yield, we must understand...

• The science of muscle, fat, and skeletal development
• The variables influencing carcass performance and eating quality
Building High Quality Beef
Starts at the Cell
Ends at the Rail
From the Cell to the Rail

Myocytes

Mesenchymal Stem Cells

Adipocytes

Fibroblasts
Science of Skeletal Development

High quality cattle begin with good skeletal structure
• Similar to the foundation of a house
• Bones serve as levers for skeletal muscles

Skeletal structures form prenatally
• Bone formed from mesoderm layer
• At birth, bone content is high (2:1) → decreases as animal grows
• Nutrition, use, hormones, and management can influence post-natal skeletal development and bone growth
  • Calcium and functional use influence bone growth
  • Castration and estrogen exposure inhibit bone growth
Science of Skeletal Development

Post-Natal Skeletal Changes
  • Bone growth occurs longitudinally
    • Longitudinal growth occurs at the epiphyseal plate--ossification
    • Amount of bone growth depends on:
      • Rate of new cell production
      • Size of cells before ossification

Why Does Skeletal Development Impact Beef Quality?
  • Skeletal system creates foundation for muscle development
  • As bones grow longitudinally $\rightarrow$ muscles grow
  • Large frame size usually attributed with faster rate of lean meat growth (tend to be later maturing)
  • Large-framed cattle produce leaner beef
Science of Muscle Development

Muscle development begins in early gestation
- 1\textsuperscript{st} two months $\rightarrow$ primary muscle cells develop
- 2 through 8 months $\rightarrow$ secondary muscle cells $\rightarrow$ majority of skeletal muscle
- Number of skeletal muscles cells is largely set by month 8 of pregnancy
- Skeletal muscle isn’t priority for energy partitioning (brain, heart)
- After birth, muscle growth is hypertrophic (growth in size)

What does this mean?
- Prenatal factors influence skeletal muscle development
- Management of cows mid-gestation correlated with muscling
  - Poor nutrition during gestation = light muscling, low yield
Science of Muscle Development

Postnatal Muscle Changes

• At birth, focus is on small muscles associated with the skeleton
  • *Necessary for biological functionality*
• After birth, substantial changes in muscles not associated with the skeleton
  • Reflection of use, location, nutrition, etc.

Differences in Muscle Fiber Type

• Primarily Type I fibers at birth
• Transition to glycolytic metabolism
• Changes influenced by:
  • Use
  • Breed-type
  • Nutritional plane

<table>
<thead>
<tr>
<th>Trait</th>
<th>Type I</th>
<th>Type IIA</th>
<th>Type IIX</th>
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<tr>
<td>Metabolism</td>
<td>Oxidative</td>
<td>Oxidative &amp; Glycolytic</td>
<td>Glycolytic</td>
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<tr>
<td>Speed</td>
<td>Slow</td>
<td>Medium</td>
<td>Fast</td>
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<tr>
<td>O2 Requirement</td>
<td>Aerobic</td>
<td>Aerobic</td>
<td>Anaerobic</td>
</tr>
<tr>
<td>Size</td>
<td>Small</td>
<td>Small</td>
<td>Large</td>
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<tr>
<td>Lipid Content</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Myoglobin</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Fatigue Resistance</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Mitochondrial Activity</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Color</td>
<td>Red</td>
<td>Intermediate</td>
<td>White</td>
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<tr>
<td>Example</td>
<td>Diaphragm</td>
<td>Psoas major</td>
<td>Chuck/Round</td>
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</table>
Science of Muscle Development

Muscle fiber type and metabolism impact a variety of beef quality factors:

- Ultimate pH Decline
- Marbling (Type I Fibers ↑ Marbling)
- Tenderness (cross sectional area, use)
- Water Holding Capacity
- Color

![Graph showing pH decline over hours postmortem]
Science of Fat Development

Lipid cells develop in late gestation and early postnatal period
  • Overlap between adipogenesis and secondary myogenesis
  • Lipid cell development follows a sequential order:
    • Visceral → subcutaneous → intermuscular → intramuscular

Adipose cells are clustered in connective tissue or within/between muscle bundles
  • Intramuscular adipocytes exist between primary/secondary muscles bundles (perimysium)
  • Lipid-storing ability of intramuscular adipocytes lower than subcutaneous adipocytes

Given the value of marbling, significant efforts to understand intramuscular fat
  • Fibro-adipogenic progenitors → the foundation for intramuscular fat development
Science of Fat Development

- Retinoic acid, Inflammation, TGFβ, IGF-1, FGFs, etc.
- Vitamin A restriction, PPARγ agonist, Corn-based diets

- FAP commitment into preadipocytes and then adipocytes
- Adipocyte hypertrophy

- FAP proliferation

- Intramuscular adipocyte development

- Conception
- Mid-gestation
- Birth
- 250 days
- Harvest

- Embryonic fibroblasts
- Fibro/adipogenic cells (FAPs)
- Preadipocytes
- Adipocytes

Li et al., 2020
Science of Fat Development

**Subcutaneous Fat**
- Develops early
- More mature
- Acetate Required

**Intramuscular Fat**
- Develops later
- Less mature
- Glucose required

Zhao et al., 2019
Building High Quality Beef Starts at the Cell Ends at the Rail
Balancing Postnatal Changes

As animal matures, muscle growth slows and is replaced by fat deposition.

Fat deposition is energy inefficient:
- Especially IMF
Producing High Quality Beef is an Art... 
...a Science 
...a Balance
Managing Variables that Impact Quality

**Pre-Harvest Factors**
- Breed or breed-type (*Bos indicus* vs. *Bos Taurus*)
- Prenatal Nutrition
- Age of animal
- Stress prior to harvest
- Production systems
- Performance technologies (i.e. Beta-agonists, implants, etc.)

**Post-Harvest Factors**
- In-plant practices (chilling, temperature, etc.)
- Aging method (wet vs. dry aging)
- Aging length
- Packaging
- Cooking/Preparation
Producing High Quality Beef is Essential

Consumers demand a high-quality eating experience.

U.S. Consumer Expenditures
Beef, Pork and Broiler

Twenty years of Spending Growth!

Broiler up $27 B
Pork up $30 B
Beef up $62 B

Source: USDA

Billion $
As price increases, demand for high-quality and consistency will also increase...

...so what?
Building High Quality Beef
Starts at the Cell
Ends at the Rail

Understand the Science
Respect the Art
Perfect the Balance
The Science Behind the Grade

How science affects the grade

Dr. Bucky Gwartney
International Marketing Specialist
USDA – Agricultural Marketing Service
Science and the Grade Application

• Quality grade—characteristics of the meat that predict the palatability of the lean

• Yield grade—indicates the yield of closely trimmed, boneless retail cuts expected to be derived from the major wholesale cuts (round, sirloin, short loin, rib, and chuck)
USDA Quality Grade

Adapted from Smith et al., 1987. Journal of Food Quality 10:269-286
Quality Grade Determination

• Sex Classification

• Maturity evaluation based on evidences of skeletal maturity and color and texture of ribeye muscle (between 12\textsuperscript{th} & 13\textsuperscript{th} rib). Only if over 30 months.

• Marbling and Firmness of Ribeye Muscle (between 12\textsuperscript{th} & 13\textsuperscript{th} rib)
Quality Grade Determination

• Sex Classification – Bulls vs Steers vs Heifers

  • Intact males (Bulls) deposit less marbling but are higher muscled
  • Castrated males (steers) deposit more marbling but are less muscular
  • Females (heifers) tend to be a little fatter and lighter than steer carcasses
Quality Grade Determination

• Sex Classification

• Maturity evaluation based on evidences of skeletal maturity and color and texture of ribeye muscle (between 12th & 13th rib). Only if over 30 months.

• Marbling and Firmness of Ribeye Muscle (between 12th & 13th rib)
Skeletal Maturity

- Sacral Vertebrae
- Lumbar Vertebrae
- Thoracic Vertebrae
- Rib bones
- Chine Bones

- Skeletal ossification occurs from the posterior end (rear) to the anterior end (head) of the carcass
Factors Potentially Influencing Physiological Maturity

- Gender
- Sex condition
- Breed type
- Implant program
- Diet
Skeletal Maturity

Physiological maturity determined by evaluating the size, shape and ossification of the bones and cartilages, the color & texture of the lean of the ribeye.

All maturity indicating factors are considered – composite evaluation

Factors seldom develop to the same degree – limitless number of potential combinations to consider
Quality Grade Determination

• Sex Classification

• Maturity evaluation based on evidences of skeletal maturity and color and texture of ribeye muscle (between 12th & 13th rib). Only if over 30 months.

• Marbling and Firmness of Ribeye Muscle (between 12th & 13th rib)
Marbling

• Fat within the muscle
  • Intramuscular fat

• Evaluated on the ribeye between the 12th & 13th ribs
Marbling

• Influences
  • Chill
  • Bloom
  • Lighting
Conditions or Defects Preventing or Lowering a Grade

**Blood Splash**

- When a carcass is not dressed and prepared properly at harvest, blood pressure within the carcass can spike and capillaries in the muscle tissue can rupture.
- Carcasses can have a “small” amount of blood splash & still grade. The “small” amount is based on the “Slight” marbling card.
Conditions or Defects Preventing or Lowering a Grade

• **Calloused**
  - Result of steatosis; fatty tissues spread into areas of the muscle creating a callous section; strenuous muscle exertion.
  - The maximum amount of calloused to still grade is a small amount (less than \( \frac{1}{2} \) inch)
Conditions or Defects Preventing or Lowering a Grade

• **Dark Cutters**
  • Dark Cutting characteristics are determined in percentage, from 10 to 100%.
  • Dark Cutting beef affects overall quality grade.
  • Each percentage dark relates to the discount amount you will assign to the carcass.
  • Up to 1% of beef carcasses are dark cutters.
What is Dark Cutting Beef?

- Dark, firm, and dry is the name of the condition
  - Dark in color because of light absorption
  - Firm because muscle proteins are pulled together more tightly
  - Dry in appearance due to more water held in the muscle
- Caused by a variety of factors including:
  - Aggressive activity
  - Estrus
  - Stress – long term
  - Growth Promotants
  - Weather
- Most of the sugars in the muscle are used up by the live animal during stress
- Minimal sugars left for postmortem muscle metabolism

Figure Source: *Principles of Meat Science, 4th Edition*
USDA Yield Grade
Yield Grade Factors

- Thickness of fat over the ribeye (backfat)
- Ribeye area
- Hot Carcass Weight
- Percentage of kidney, pelvic, heart fat (KPH)
Yield Grade Factors

Thickness of fat over the ribeye (backfat)

Remember this is the second area where fat is deposited
Yield Grade Factors

Ribeye Area

This is a measurement of the muscle growth and mass
Yield Grade Factors

Hot Carcass Weight

This is where we relate how well a carcass is muscle in relation to its overall weight
Yield Grade Factors

Percentage of kidney, pelvic, heart fat (KPH)

This is a measurement of the internal fat deposits, one of the first areas for fat development.
Percentages of Retail cuts for the various YG

<table>
<thead>
<tr>
<th>Yield Grade</th>
<th>Percent Boneless, Closely Trimmed Retail Cuts from the Round, Loin, Rib &amp; Chuck</th>
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<tbody>
<tr>
<td>1.0</td>
<td>&gt; 52.3%</td>
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<tr>
<td>2.0</td>
<td>52.3-55.0%</td>
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<tr>
<td>3.0</td>
<td>50.0-47.7%</td>
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<tr>
<td>4.0</td>
<td>47.7-45.4%</td>
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<tr>
<td>5.0</td>
<td>&lt;45.4%</td>
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FY2020 Beef Grading Summary

FY 2020 Quality Grade Percentages

- Prime
- Select
- Standard

Percentage
FY2020 Beef Grading Summary

FY 2020 Yield Grade Percentages

- YG 5
- YG 4
- YG 3
- YG 2
- YG 1

Percentage
Thank you for Participating

For more information on this webinar series and the USDA Cattle and Carcass Training Centers, visit: