Packaging & Processing

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51st International Congress of Meat Science and Technology 2005

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51st International Congress of Meat Science and Technology 2005

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2005

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51st International Congress of Meat Science and Technology 2005

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Current Research in Meat Color: A Review

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Scope of the Review:

1. Suggestions from other scientists

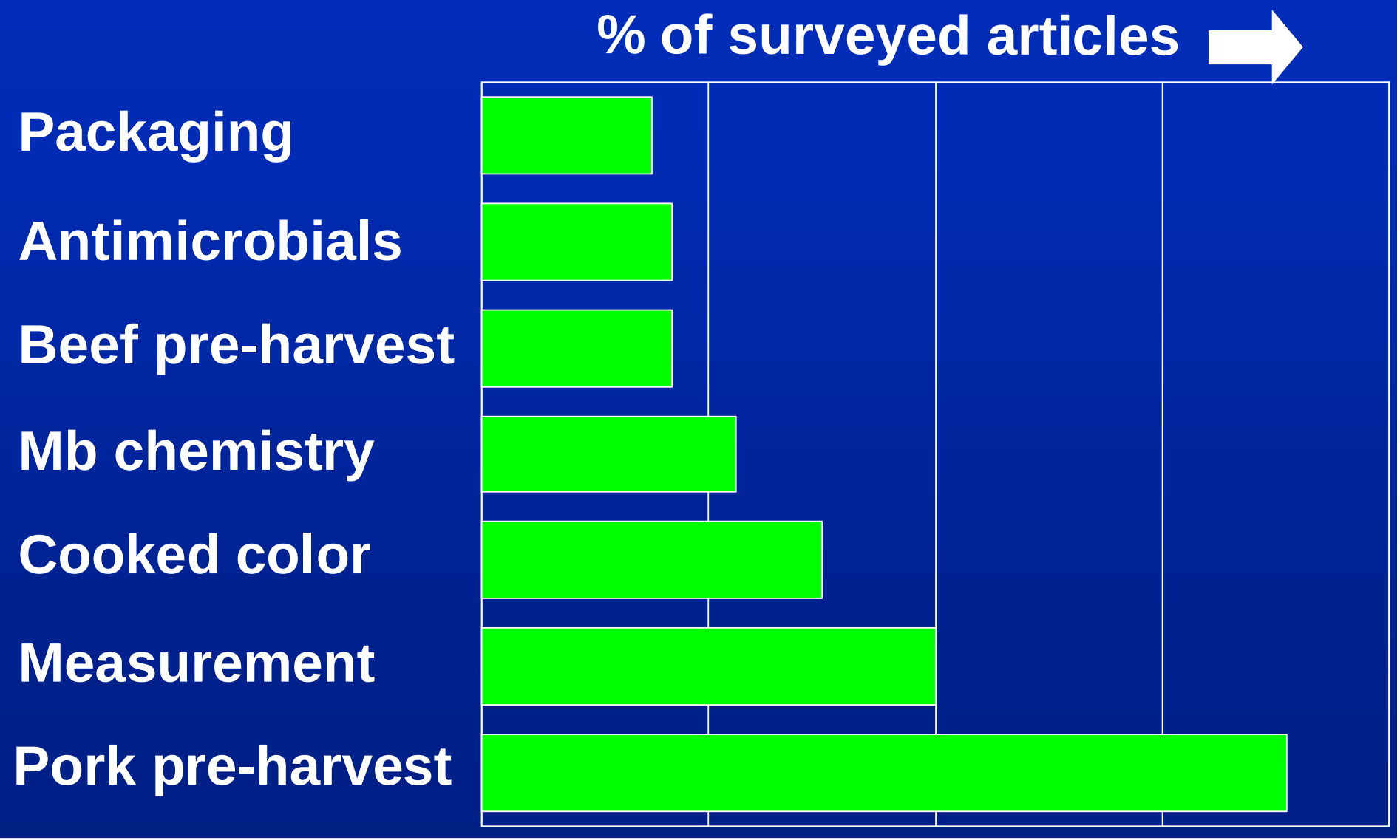
2. Principally 4 journals, 1999 - 2004:
   - Meat Science
   - Journal of Animal Science
   - Journal of Food Science
   - Journal of Muscle Foods

Scope of the Review:

3. Over 250 papers considered

4. Papers had to be:
   - Principally "Fresh Meat"
   - "Meat Color" objectives

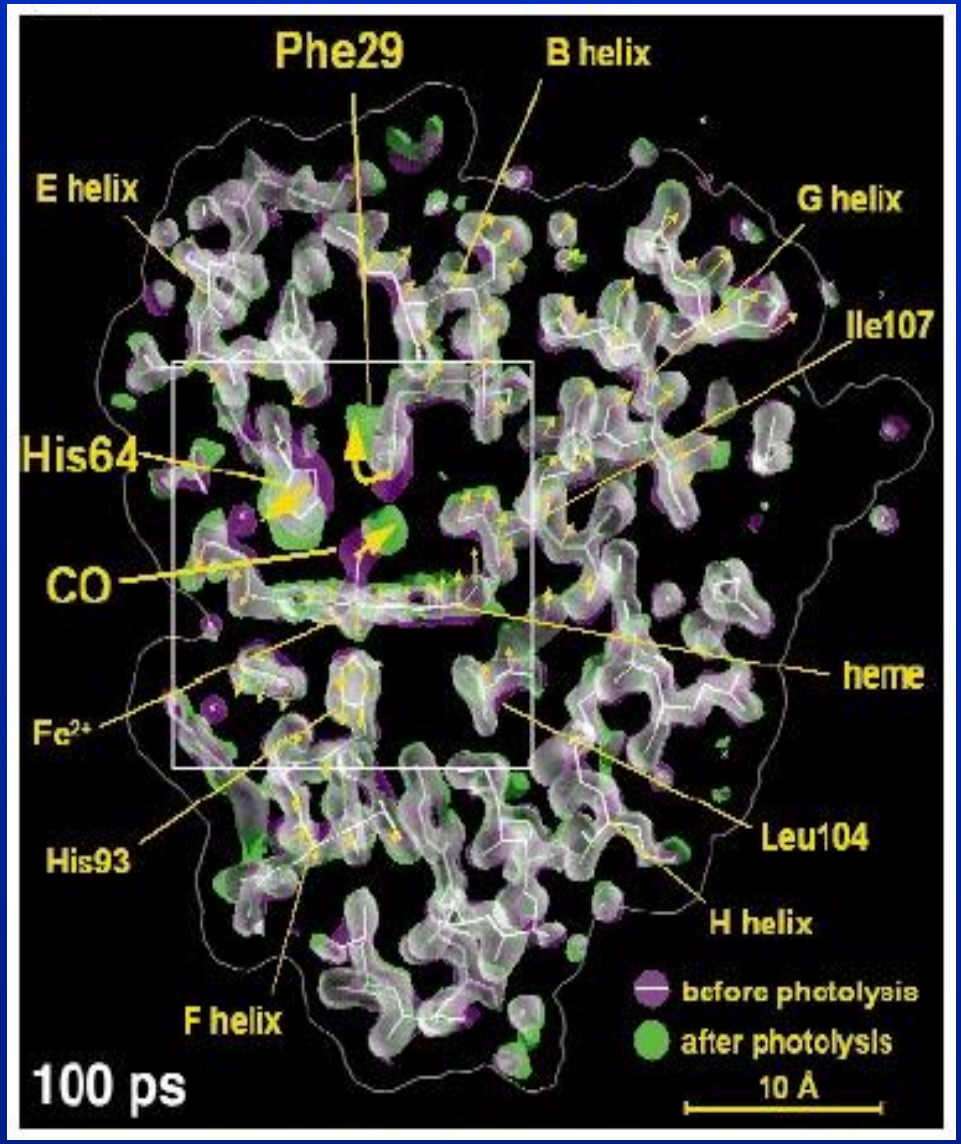
Scope of the Review:



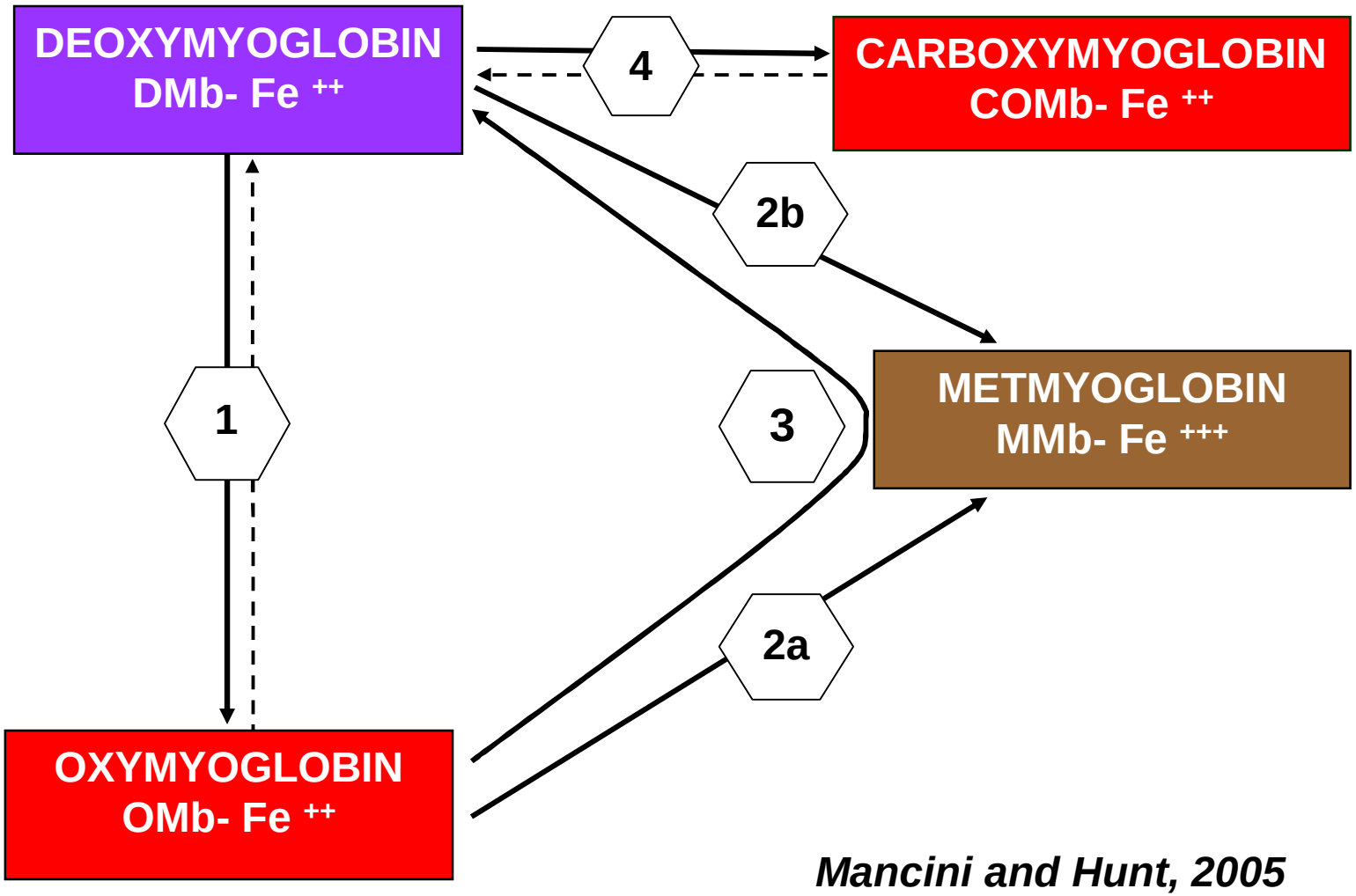
Meat Color is:

1. A critically important attribute
2. One of the most frequent quality issues
3. Complex
4. Sometimes confusing
5. Often studied as “just another variable”

Myoglobin Chemistry



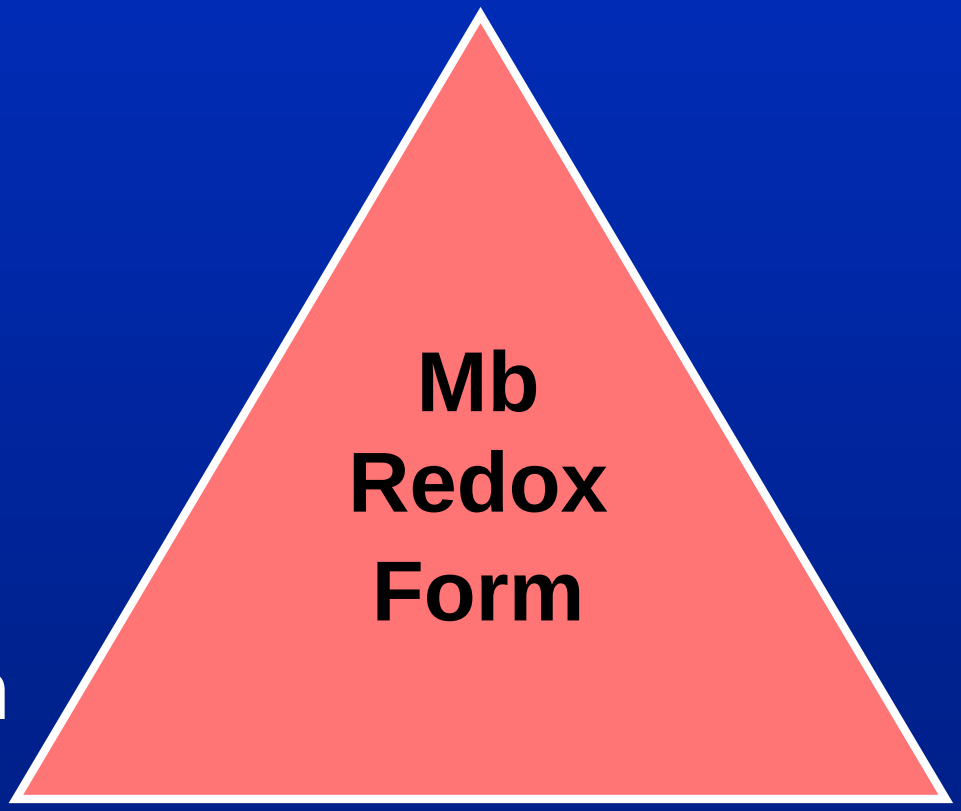
Visible Myoglobin Chemistry



Mancini and Hunt, 2005

Pigment Chemistry

Postmortem Dynamics of NADH



Pigment Reduction Systems

Oxygen Utilization

Reducing Systems vs. NADH

- **Not straightforward**
- **NADH more important than MRA in beef**

  Bekhit et al, 2003
- **MRA less important in lamb color stability**

  Bekhit et al, 2000
- **Location of the MRA in muscle is critical**

  Bekhit et al, 2004

Chilling and MRA

- Slow chilling damages MRA
- Muscle location effects:

Superficial SM

Deep SM

Sammel et al, 2002a,b

OMb Stability

- **Aldehydes decrease Mb redox stability**
  - ***4-hydroxy-2-nonenal***

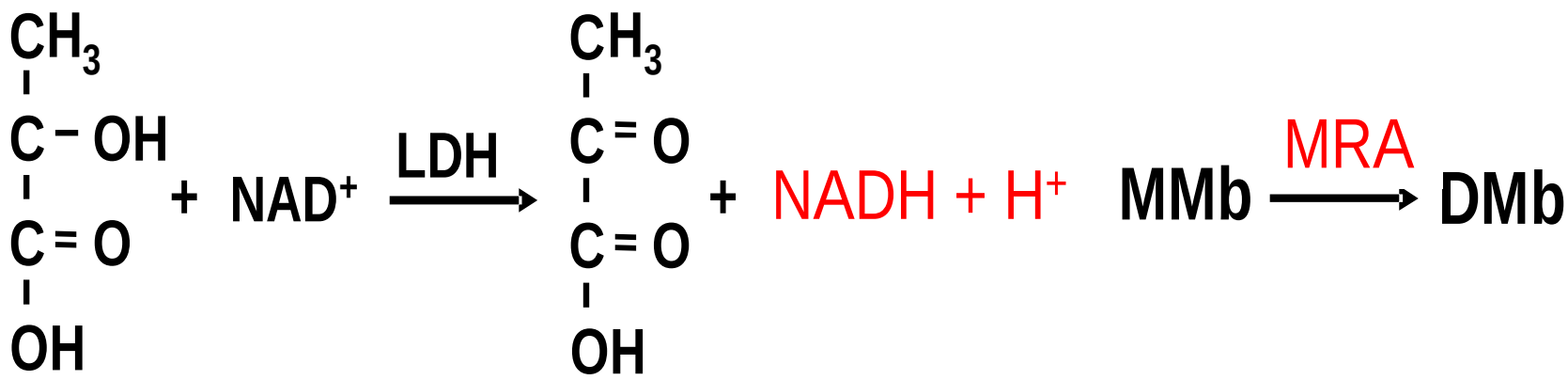
    Alderton et al, 2003; Faustman et al, 1999; Lynch & Faustman, 2000; and Lee et al, 2003

- **Peroxynitrite induced OMb instability**
  - **Due to direct iron oxidation**
- **Glutathione improved OMb stability**

  Connolly et al, 2002

  Tang et al, 2003

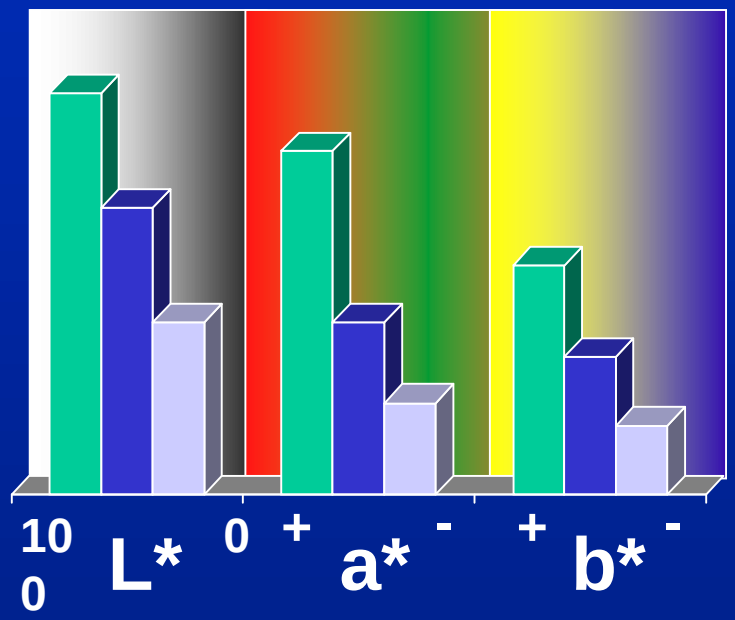
Proposed Mechanism: Fresh Meat Color Stabilization via Added Lactate



Lactate **Pyruvate**

Mancini et al, 2004
Kim et al, 2005

New Approaches for Color Measurement



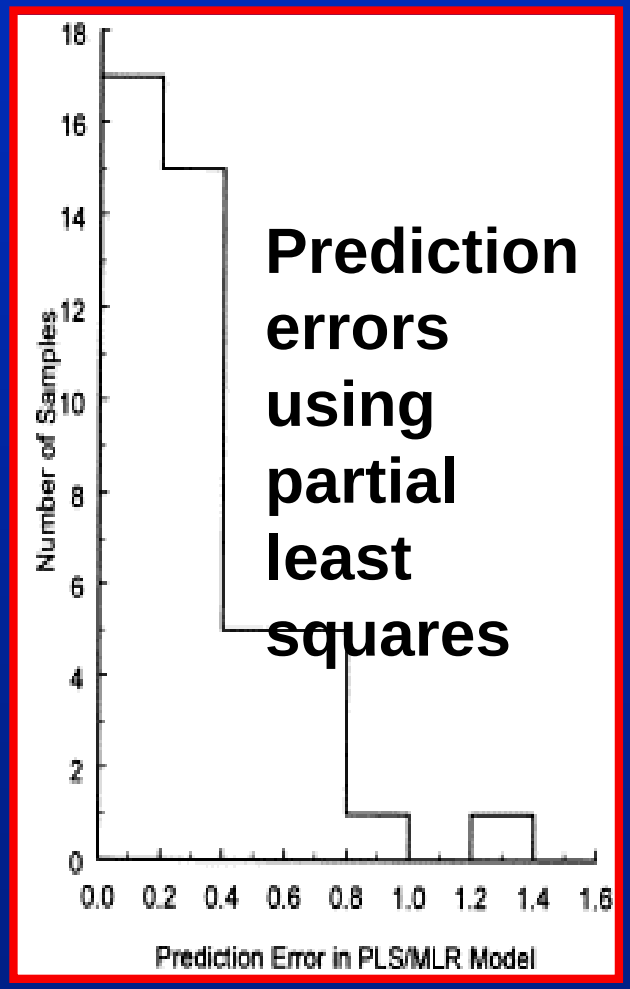
Visual:
The Gold Standard?

Researchers tend to Misuse Color Methodology

Computer Vision / Image Analysis

- Digital image analysis
- Combined with:
  - Neural network or
  - Statistical modeling
- Predicted pork loin visual color

Lu et al, 2000
Ringkob 2002



Prediction errors using partial least squares

Measurement of Surface OMb

Historically have used:

- **Isobestic wavelenghts for DMb and MMb**
- **OMb determined by difference from 100%**

OMb can be quantified directly using:

- **Ratio of 610nm / 525nm**

Mancini et al, 2003

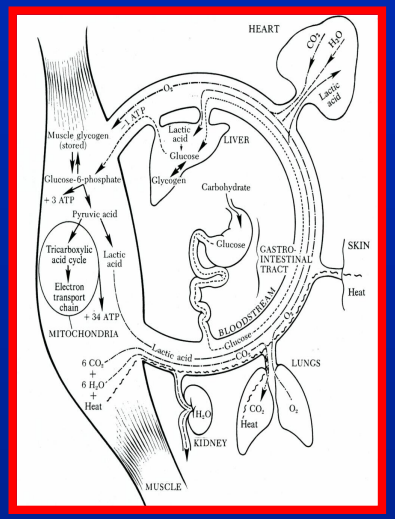
Updated Krzywicki Equations

New wavelengths

Mb Form	Old nm	New nm
MMb	545	503
DMb	565	557
OMb	572	582

Tang et al, 2004

Pre-harvest: Beef



Pre-harvest Beef Color

Forage vs. grain based diets

- **Promote oxidative metabolism**
- **Limit glycogen storage**
- **Increase muscle pH and darkness**

  Vestergaard et al, 2000

- **Decrease a* and color stability**
- **More 18:3 FA and less α-tocopherol**

  Lynch et al, 2002

Pre-harvest Beef Color

Forage vs. grain based diets

- **Decreases subcutaneous fat**
- **Increases postmortem chilling**
- **Slows pH decline**
- **Subcutaneous fat & inst color correlations**

  L* (0.63), a* (0.60), b* (0.67) pH (-0.82)

Bruce et al, 2004

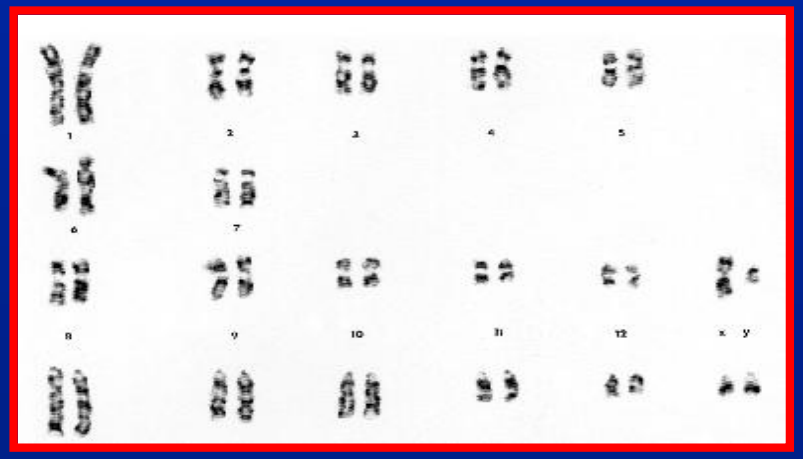
Pre-harvest Beef Color

Environment – Loose housing vs. Tie stall

- **Increased:**
  - **Pigmentation**
  - **Slow-contracting fibers**
  - **Vascularization**
  - **Pyruvate oxidation** *Vestergaard et al, 2000*

- **α- and β-red fiber diameter correlate with a* (0.32, 0.30)** *Ozawa et al, 2000*

Pre-harvest: Pork



Quantitative Trait Loci

Genomic regions accounting for phenotypic variation in pork color were:

- **Detected for:**
  - **L*, a*, and pigment**
- **Not detected for:**
  - **b*, hue angle, or chroma**

de Koning et al, 2001
Ovilo et al, 2002

Alleles for the Napole (RN) Gene

- Breed affects Mb content & color
- Previous alleles: RN^- and rn^+
- New mutant allele: V199I at PRKAG3 = rn*

Genotype	pH	FO Probe
RN^- / RN^-	Lowest	Greatest
rn+ / rn+	Intermediate	Intermediate
rn+ / rn* rn* / rn*	Highest	Least

Lindahl et al, 2004a,b

Alleles for the Napole (RN) Gene

RN-	rn+
Redder, greater a*	Less red
More yellow	Less yellow
Faster pH decline	Slower pH decline
Greater bloom	Less bloom

Color differences attributed to Mb redox state and pH effects on OCR and MRA

Lindahl et al, 2004a,b

Vitamin D Supplementation

- Decreased loin chop L* and increased a*

  Wiegand et al. 2002

- May benefit pork for export markets

- Possible mechanisms:
  - via slowing postmortem pH decline
  - ⬆ oxidative metabolism by ⬆ intracellular Ca^{++}

  Wilborn et al. 2004

Magnesium Supplementation

- ↑ Ca^{2+} uptake
- ↑ Ca^{2+} ATPase activity in normal pigs
- Competition between Mg and Ca

Magnesium influences muscle via altered energy metabolism

Lahucky et al. 2004

Magnesium Supplementation

- Inconsistent results
- Benefits depended on stress susceptibility
- Little quality improvements when pigs are not stressed beyond routine slaughter

Apple et al. 2000, 2001
Geesink et al. 2004

Glycolytic Potential

- Positively correlated to L* values
  - r = 0.23 *Hamilton et al, 2003*
  - r = 0.33 *Moeller et al, 2003*
  - ⬆Glycolytic potential = ⬆Paleness
    Meadus & MacInnis, 2000
  - L* increases 0.99 units for every standard deviation in antemortem glycolytic potential
    Hamilton et al, 2003b

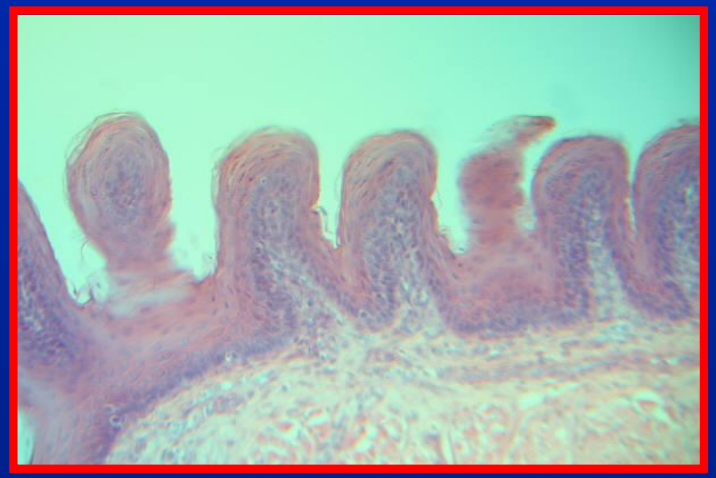
Glycolytic Potential

- Diets low in digestible carbohydrates
  - Reduce muscle glycogen
  - Improve pork color

Rosenvold et al, 2001b

Reducing glycolytic potential and free glucose may improve pork muscle color

Antimicrobials



Antimicrobials

- Researchers often:
  - Evaluate only microbial growth
  - Fail to consider affects on color

- Antimicrobial technologies are ideal if:
  - They minimize microbial growth
  - They have no affect or improve color

Antimicrobials and Ground Beef

- Organic acids (lactic or acetic)
- 0.5% cetylpridinium chloride and/or
- 10% trisodium polyphosphate
  - Promise as antimicrobial, but
  - ⬇pH and ⬆lightness
  - Decreases redness and OMb stability

Pohlman et al, 2002 a,b,c, Jiminez-Villarreal et al, 2002, and Stivarius et al, 2002a,b

Modified Atmosphere Packaging

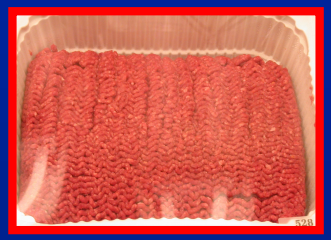
Modified Atmosphere Packaging

- Most Common Systems
  - High oxygen (70 to 80% O_2)
  - “No” or “ultra-low” oxygen
  - 0.4% CO in “low” oxygen

- Topic of the following speaker

Carbon Monoxide in MAP

- Used in Norway for years, phasing out
- 2002 - US approved as GRAS for fresh meat
  - CO limited to 0.4%
  - Two current systems
    - CO in Master Bag, but removed at retail
    - CO in MAP at retail



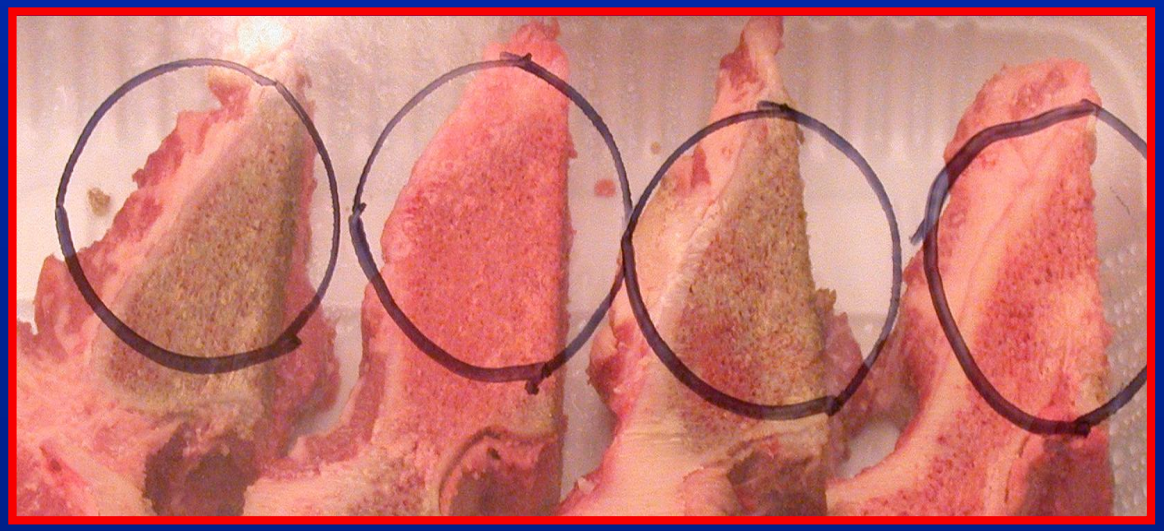
- "Cold Smoke" system in fish

Carbon Monoxide in MAP

Current Issues involving CO:

- Basic COMb chemistry not well defined
- Quantitation of COMb vs. OMb
- Muscle differences
- CO penetration into the meat
- Meat / gas ratio
- COMb heat denaturation – Persistent pink

Bone Marrow Discoloration



Bone Marrow Discoloration

- Change in color on the surface of cut bones from bright-red to gray, tan, or black

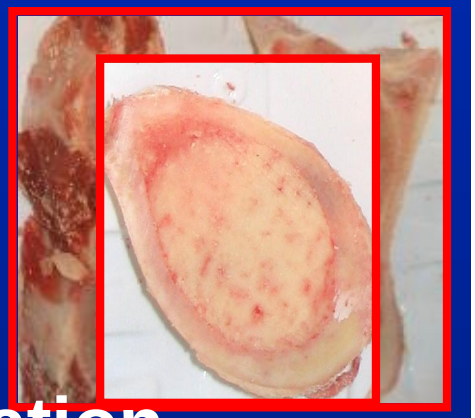
- A major obstacle facing high-oxygen MAP case-ready packaging

- Decreases product shelf life

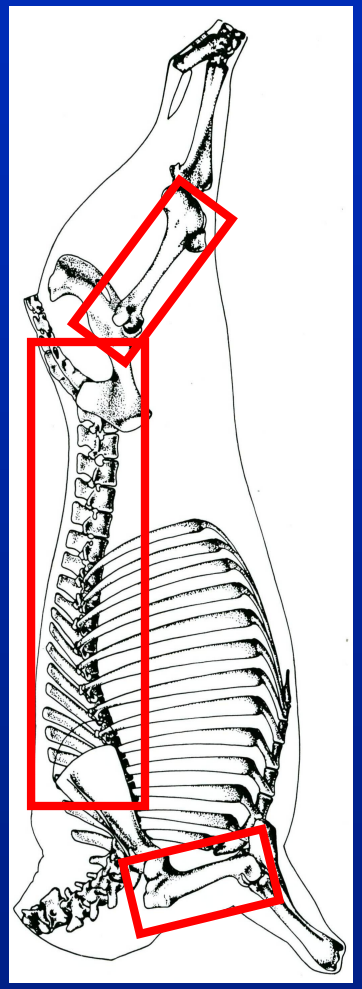
Marrow Types

Two types of marrow:

1. Red or erythropoietic (vertebrae and ribs)
   - Discolors



2. Yellow or fatty (long bones)
   - Little or no discoloration



Grobbel et al, 2004

Bone Marrow Discoloration

Marrow color: likely due to hemoglobin redox

Key was maintaining ferrous hemoglobin

- **Ascorbic acid**
- **Ultra-low oxygen**
- **0.4% CO MAP**

Mancini et al, 2004

Factors Involved in Marrow Color

Hemoglobin redox

Reducing agents

Packaging atmosphere

Marrow color

Greater Importance

Lesser Importance

Lipid antioxidants

Metal content

Lipid oxidation

Cooked Color

Cooked Color

Issues:

- **Normal cooked color development**
  - **Red to Pink to Tan/Brown Color**
- **Premature Browning**
  - **Brown at unsafe temperatures**

55°C

- **Persistent Pink Color**
  - **Pink at safe temperatures**

77°C

Cooked Color

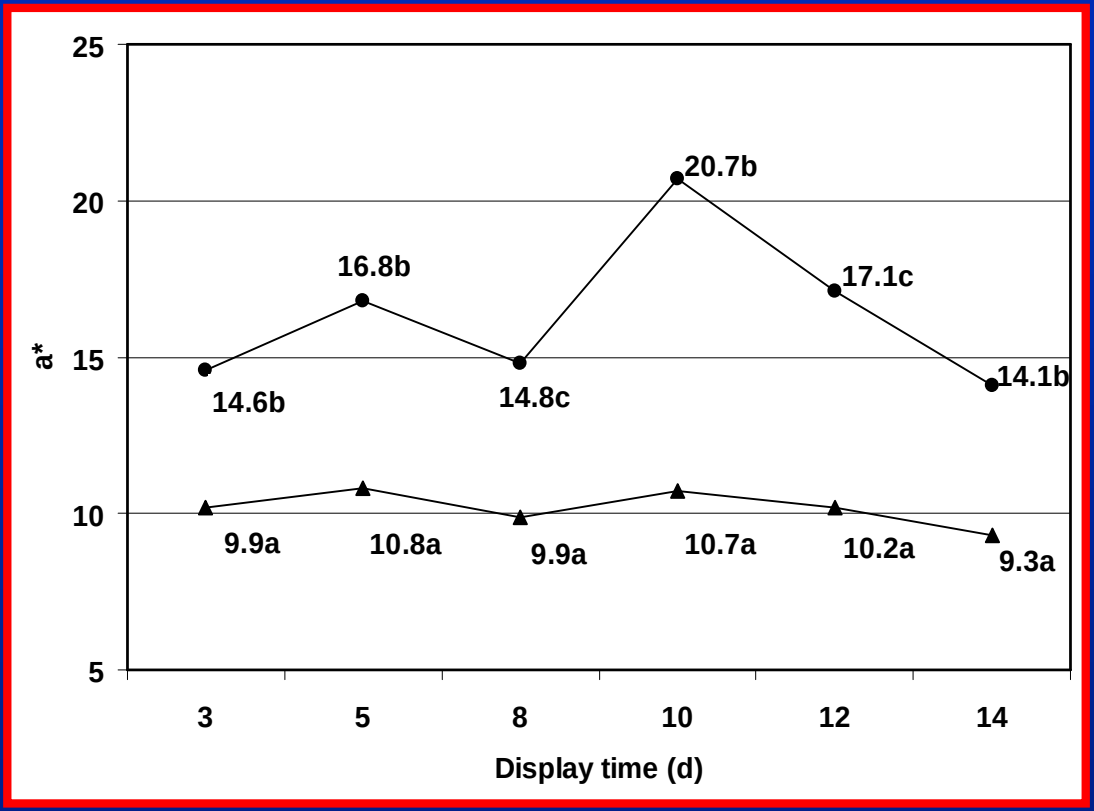
Interactive Factors:

- pH
- Redox pigment form
  - MMb and OMb → PMB
  - DMb and COMb → Normal or PPC
  - MAP Influence – → SAFETY ISSUES
- Endpoint temperature
- Cooking time
- Cooking rate

Premature Browning and Hi O_2 MAP

More pink

No pink



No-O_2 MAP

Hi-O_2 MAP

Seyfert et al, 2004

Cooked Color - MAP

Erythorbate:

- **Increases total reducing activity**
- **Usage will inhibit PMB**

Suman et al, 2005

Muscle source:

- **PMB: *Psoas* > *Longissimus***

Suman et al, 2004

Cooked Color - MAP

Carbon monoxide:

- **May affect consumer acceptance**
- **More stable than DMb** *Ballard, 2004* *John et al, 2004*
- **Inhibits PMB** *John et al, 2004*
- **Great need for understanding**
  - **Thermal denaturation**
  - **Chemical binding and penetration**

Summary

Summary

- Fundamental concepts still unanswered
- Need more myoglobin chemistry research
- Future areas of ***MEAT COLOR RESEARCH:***
  - Need a “practical” method for OCR
  - Relationship between MRA and OCR
  - Genetics / Quantitative trait loci
  - Proteomics
  - Color vision analyses
  - Nanotechnology

?

Thanks for Listening