PRACTICAL APPLICATIONS TO IMPROVE FRESH MEAT COLOR

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Consumers expect high quality meat, which should have desirable flavor, tenderness, and juiciness.

**MEAT QUALITY**

**Consumers judge freshness and wholesomeness of meat.**

**First factor**

**Palatability**
- affects consumers’ repeated purchase of meat.
PRACTICAL APPLICATIONS TO IMPROVE FRESH MEAT COLOR

1. POST - HARVEST FACTORS & STRATEGIES

2. PRE - HARVEST FACTORS & STRATEGIES
1. POST-HARVEST FACTORS

1. TEMPERATURE
High pre-rigor temperature (42°C) significantly reduced the retail color display life of chilled lamb loins.

Effects of electrical stimulation (ES) and different pre-rigor temperatures (15 and 38°C) on L* (lightness) values of beef *M. longissimus*. 

(Kim et al., 2014)
INFLUENCE OF CARCASS CHILLING TEMPERATURE ON MEAT COLOR

**SSM:** Fast chilling

**DSM:** Slow chilling

**Graphs:**
- **Temperature (°C) vs. Post-mortem Hour (h):**
  - DSM in red
  - SSM in blue

- **pH vs. Time postmortem (h):**
  - DSM in red
  - SSM in blue
HIGH TEMPERATURE & RAPID pH DECLINE CONDITIONS RESULT IN MYOGLOBIN DENATURATION

Two-toned color development

High Temp & fast pH decline conditions

Protein denaturation: myoglobin denaturation

SSM

DSM
MORE DISCOLORATION OF DSM DURING RETAIL DISPLAY

<table>
<thead>
<tr>
<th></th>
<th>DSM</th>
<th>SSM</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td>46.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.9</td>
</tr>
<tr>
<td>a*</td>
<td>32.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.5</td>
</tr>
<tr>
<td>b*</td>
<td>24.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.5</td>
</tr>
<tr>
<td>Hue</td>
<td>37.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Means in a row with different subscripts (a-b) are different (P < 0.05)

(Kim et al., 2010)
LESS EXTENT OF MU-CALPAIN AUTOLYSIS AND PROTEOLYSIS IN DSM

Kim et al. (2010b) Meat Sci. 86: 883-887
DSM HAD GREATER STAR PROBE VALUES (TOUGHER) THAN SSM

Means having different letters within each day are different ($p < 0.05$).
Implementation of efficient chilling techniques to prevent protein denaturation should improve consistency and quality of fresh beef cuts.
Increase in the storage temperature from the ideal storage temperature of -1.5°C to 2°C significantly decreased the color stability of lamb loins.

Long term T abuse: 2°C for 7wks
Short term T abuse: -1.5°C for 6 wks + 1 wk at 2°C.

(Rosenvold & Wiklund, 2011)
IMPACT OF ELEVATED DISPLAY TEMPERATURES FOR A SHORT-TIME PERIOD ON MEAT COLOR

A short-term temperature abuse for 6 hours resulted in about 17% reduction in $a^*$ (redness) values of beef muscle.

(Kim, 2014)
I. POST- HARVEST FACTORS

1. TEMPERATURE

2. AGEING, FREEZING & THAWING

(Photo from Cryovac Inc.)
MEAT QUALITY CHANGE DURING CHILLED-STORAGE

- Substantial meat quality improvement (tenderness, juiciness and/or flavour) through endogenous enzymatic protein degradation.

Long-term chilled storage during shipping (6 to 8 weeks)
EFFECT OF CHILLING STORAGE PERIODS ON COLOR STABILITY OF LAMB LOINS

Meat color stability decreases with increasing chilling storage periods.

Significant economical issue! $$$

(Kim et al. Unpublished data)
CONVENTIONAL IDEAS ON FRESH VS. FROZEN MEAT

Consumer perception

<table>
<thead>
<tr>
<th></th>
<th>High Quality</th>
<th>Tender</th>
<th>Juicy</th>
<th>Prep Variety</th>
<th>Flavor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>67%</td>
<td>62%</td>
<td>62%</td>
<td>61%</td>
<td>65%</td>
</tr>
<tr>
<td>Frozen</td>
<td>22%</td>
<td>24%</td>
<td>20%</td>
<td>34%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Meat quality:
Fresh (chilled never frozen) > Frozen
EFFECT OF AGEING/FREEZING ON WATER-HOLDING CAPACITY (WHC) OF LAMB LOINS

Ageing/freezing significantly improved WHC of loins

abc Different letters indicate significant difference (P < 0.05)

(Kim et al. 2012)
EFFECT OF AGEING/FREEZING ON SHEAR FORCE VALUES OF LAMB LOINS

Ageing-then-freezing significantly improved tenderness of loins

Shear force (KgF)

Storage Treatment

A1wk A3wk A9wk A3F6wk F9wk

abc Different letters indicate significant difference (P < 0.05)

(Kim et al. 2012)
### Consumer evaluation of cooked meat after 9 wk storage

<table>
<thead>
<tr>
<th>Specie / muscle</th>
<th>Chilled</th>
<th>Aged-frozen</th>
<th>Statistical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamb</td>
<td>LD</td>
<td>53%</td>
<td>47%</td>
</tr>
<tr>
<td><strong>Overall acceptability</strong>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>7.1</td>
<td>7.3</td>
<td>NS</td>
</tr>
<tr>
<td>LD</td>
<td>7.8</td>
<td>7.1</td>
<td>NS</td>
</tr>
<tr>
<td>Venison</td>
<td>LD</td>
<td>9.7</td>
<td>9.6</td>
</tr>
</tbody>
</table>

*Unstructured continuous line scale with 0= dislike extremely and 15 = like extremely was used for beef and venison consumer sensory evaluation

(Wiklund et al, 2009; Wiklund et al. 2010)
EFFECT OF AGED/FROZEN ON COLOUR STABILITY OF LAMB LOINS

Aged/frozen improved color stability of loins during retail display.

Discoloration scores

Display days

(F9)

(A2F7)

(A3F6)

(A9)

(Kim et al. 2013)
I. POST- HARVEST FACTORS

1. TEMPERATURE

2. AGEING, FREEZING & THAWING

3. PACKAGING
COLOR TRIANGLE

Vacuum pack: very stable (weeks)

MMb

Oxidation

OMb

Overwrap-PVC: short colour life (2-3 days)
HIGH-OXYGEN MODIFIED ATMOSPHERE PACKAGING (HIOX-MAP) SYSTEM

HiOx-MAP (80% $O_2$ + 20% $CO_2$) allows
1) more oxygen to penetrate into meat, consequently forming a higher percentage of oxymyoglobin and a brighter cherry red meat colour

(Photo courtesy of Dr. D.H. Kropf, Kansas State University)
HIGH-OXYGEN MODIFIED ATMOSPHERE PACKAGING (HIOX-MAP) SYSTEM

HiOx-MAP (80% O₂ + 20% CO₂) allows
1) longer color shelf-life
2) CO₂ in the package preventing microbial growth
   - High solubility in both muscle and fat tissue
   - At ↓temp, ↑solubility of CO₂, hence is more effective in retarding microbial growth (10 to 14 days).
HiOx-MAP (80% O₂ + 20% CO₂) are likely to increase the incidence of oxidative changes in the meat, and thus it may negatively affect meat quality characteristics.
EFFECTS OF HIOX-MAP ON MEAT QUALITY

Muscle selection: LD, SM, AD (N=10) @ 1 d p.m.

Trim & cut a steak (2.54 cm)

HiOx-MAP

VAC

Displayed for 9d at 1°C

(Kim et al. 2010)
Influence of different packaging types on surface redness

Means having different letters are different ($p < 0.05$).

SEM = 1.11

(Kim et al. 2010)
HIOX-MAP INCREASED LIPID OXIDATION OF BEEF STEAKS

Means with different letters are different ($p < 0.05$). (Kim et al. 2010)
HIOX-MAP INCREASED OFF-FLAVOR OF BEEF STEAKS AFTER DISPLAY FOR 9D

\[ \text{Off-flavor} \]

\[ \text{MAP} \]

\[ \text{VAC} \]

\[ \text{SEM} = 0.06 \]

\[ ^{ab} \text{Means with different letters are different (} p < 0.05 \text{).} \]

(Kim et al. 2010)
HIOX-MAP DECREASED MEAT TENDERNESS

**Sensory Tenderness**

![Bar chart showing sensory tenderness for LL, SM, and AD muscles. The chart indicates that MAP samples have higher tenderness compared to VAC samples.]

**Sensory Chewiness**

![Bar chart showing sensory chewiness for LL, SM, and AD muscles. The chart indicates that MAP samples have lower chewiness compared to VAC samples.]

**A. SDS-PAGE**

- CL-MHC
- MHC

**B. Western blot of X-linked MHC**

- LV D1
- LM D1
- LV D9
- LM D9

(SEM = 0.68 for Sensory Tenderness, SEM = 0.33 for Sensory Chewiness)

(Kim et al. 2010)
2D-DIAGONAL-PAGE TO DETERMINE ANY INTERMOLECULAR X-LINKED PROTEIN

First dimension
SDS-PAGE

Non-reducing condition

Reducing condition

Second-D SDS-PAGE

VAC
MAP

Non-reducing condition

Reducing condition

Intermolecular disulphide bonds
HIOX-MAP RESULTED IN PROTEIN POLYMERIZATION

Cross-linking of MHC with Titin?

(Kim et al. 2010)
PREMATURE BROWNING (PMB):
Mb denatures at a temp. lower than necessary to destroy pathogens (71°C).

Could be a major food safety concern!!!

(Photo courtesy of Curwood, Bemis Company Inc.)

(Photos courtesy of Dr. Cornforth, Utah State Univ.)
IMPACTS OF HIOX-MAP ON MEAT QUALITY

Oxidative conditions

Myoglobin oxidation

Lipid oxidation

Protein oxidation: protein polymerization formation

Premature browning

Color

Flavor

Juiciness

Tenderness
THE KEY IS TO PREVENT OXIDATION – O2

1) Different packaging condition (e.g. Ultra LoOX-MAP or CO-MAP)
- Ultra LoOx-MAP substantially minimized an incidence of oxidation during retail display and thus maintained lamb meat quality attributes.

(Kim et al. 2013)
Ultra LoOx-MAP substantially minimized oxidation during retail display time thus improved color/Flavour/Aroma of long-term stored meat.

(Kim et al. 2013)
CO-MAP

- CO-MAP contains 0.4%CO/30%CO2/69.6%N2 with oxygen impermeable film.
- FDA approved CO-MAP (0.4%; GRAS for retail packages)

Beef patties packaged in either PVC or CO-MAP (0.4% CO) displayed for 7 days at 2°C.

A false perception that CO-MAP can mask the discoloration of spoiled meat due to bacterial growth.

Use/Freeze by Date!

(Dr. Cornforth presentation at MIRC, 2007)
FRESH CASE® SYSTEM – NITRITE CONTAINING FILM

A

- Outer layer
- Barrier
- Sealant layer

Package Interior (Meat Product Surface)

Invisible Sodium Nitrite Crystals

B

CON
NO2

Siegel (2010)
ANOTHER WAY IS TO IMPROVE MRA

1) Different packaging condition (e.g. Ultra LoOX-MAP or CO-MAP)
2) Injection enhancement
LACTATE INJECTION ENHANCEMENT

• Commonly used in fresh and processed meat products with phosphate as an antioxidant – Value added products

• Lactate ion decreases oxidation by scavenging free radicals such as superoxide anion (O$_2^-$) and ·OH.

(Groussard et al., 2004)
1) Strong antioxidant capacity (Kim et al., 2009)
2) Increased MRA by replenishment of NADH through lactate-LDH coupling reaction (Kim et al., 2006)
Lactate/phosphate enhancement decreased lipid oxidation of beef steaks packaged in HiOx-MAP

Means having different letters are different ($p < 0.05$).

(Kim et al. 2010)
Lactate/phosphate enhancement improved tenderness values for LD and SM in HIOX-MAP

Means having different letters are different ($p < 0.05$).

(Kim et al. 2010)
II. PRE-HARVEST FACTORS

1. FEEDING EFFECT
14 week old lambs (n =124) were randomly allocated to 7 different forage treatments for 12 weeks until slaughter: (Clover 12wk, Clover 11wk, Clover 9wk, Lucerne, Chicory, Plantain and Ryegrass)

Paired loins from each carcass stored for 9 weeks @ -1.5°C

Packaged in either HiOx-MAP (80% O2/20% CO2) or LowOx-MAP (20% CO2/80% N2)/displayed for 7 days

To test,
1) Forage effect
2) Packaging effect

-Color stability: Minolta/Sensory color panel
-pH
-TBARS
-Sensory eval.

(Kim et al. 2013)
EFFECTS OF FORAGE TYPES ON DISCOLORATION OF LONG-TERM CHILLED LOINS DURING DISPLAY UNDER HIOX-MAP

(Kim et al. 2013)
Acceptable color was maintained after 7d display under LoOx-MAP

(Kim et al. 2013)
II. PRE-HARVEST FACTORS

1. FEEDING EFFECT

2. GENDER/CASTRATION

Ewe  Ram  Wether  Cryptorchid
Different gender/castration status influences meat quality attributes?

- Meat from entire (ram) lambs is unsatisfactory?
OBJECTIVES

1) To determine effects of different gender or castration status on color and lipid oxidation stability of long-term chilled lamb meat.

2) To evaluate the influence of different muscle types on color stability of lamb meat during retail display.

(Kim et al. 2014)
EFFECTS OF GENDER/CASTRATION/MUSCLE TYPE ON COLOR STABILITY OF LAMB MUSCLES

Color stability: Ram > Cryptochid > Wether > Ewe

(Kim et al. 2014)
EFFECTS OF GENDER/CASTRATION/MUSCLE TYPE ON MYOGLOBIN CONTENTS OF LAMB MEAT

Color stability: ST > LD > BF > SM
EFFECTS OF GENDER/CASTRATION/MUSCLE TYPE ON MYOGLOBIN CONTENTS OF LAMB MEAT

Myoglobin contents (mg/ml)

- Ewe
- Wether
- Ram
- Cryptorchid

Myoglobin contents (mg/ml)

- LD
- SM
- BF
- ST

Myoglobin
- Dark/red
- Susceptible to oxidation

(Kim et al. 2014)
Effects of gender/castration status on lipid oxidation stability of long-term chilled loin during display under HiOx-MAP

![Graph showing effects of gender/castration status on lipid oxidation stability.](image)

**Lipid oxidation & Discoloration (Myoglobin oxidation)**

abc Means with different superscripts differ ($P < 0.05$).
SUMMARY: IMPLICATION & FURTHER STUDIES?

1. Temperature control (Carcass chilling – Storage – Display)
2. Ageing, Freezing & Thawing (Aged/Frozen meat)
3. Developing novel packaging systems
4. Enhancement
5. Antioxidant property through feeding strategy (e.g. Ryegrass/Plantain + Se/Vit-E supplementation?)
6. Animal (breed, gender/castration) & muscle differences
7. Genetically select lambs with high MRA/color stability?

PURDUE UNIVERSITY
IMPLICATIONS: FUTURE RESEARCH

- Identify fundamental inter-relationship & biochemical mechanism.
- Develop innovative methods to control variation in fresh meat quality attributes.
SUMMARY: STRATEGIES TO IMPROVE MEAT COLOR

**Producer**
- Animal productivity
- Genetic influence on meat quality attributes
- Feeding & growth rate effects on muscle fiber type and meat quality
- Gender/castration
- Animal welfare

**Meat Processor**
- Optimized carcass chilling technology
- Pre-rigor hot-boned meat processing
- Innovative chilling/freezing/thawing methods
- Novel packaging

**Retailer**
- Enhancement technology
- Modified atmosphere packaging & other innovative packaging methods
- Display condition

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**Purdue University**

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### Meat pH

- MRA
- DMb
- MMb
- OMb

1. Oxidation
2. Reduction

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**Color**

**Flavor**

**Tenderness**

**Juiciness**
ACKNOWLEDGEMENTS

• National Cattlemen’s Beef Association
• Iowa Beef Industry Council
• Purac Inc.
• Meat Industry Association, New Zealand
• Ministry of Science and Innovation, New Zealand
• AgResearch CoreFund, New Zealand

Colleagues & Mentors
Thanks To Our Sponsor

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CRYOVAC Diversey