FACTORS & CONDITIONS IMPACTING FRESH MEAT COLOR

American Meat Science Association

Numerous factors affect meat color. Traits of the muscle itself, biochemical reactions within the meat, live animal attributes and many external and environmental factors may contribute to meat color and changes to color. Understanding how each factor contributes to or influences changes and stability of color are important for managing meat color to meet consumer expectations. Packaging materials, environment around the package and the atmosphere within a package are also factors influencing fresh meat color. Consumer quality preferences (and therefore market value) for meat are generally placed upon several attributes which include color.

Basics of Meat Color

Color of meat revolves around the primary red pigment in meat, myoglobin, responsible for storing oxygen in cells. The molecule can exist in four chemical states (deoxymyoglobin, oxymyoglobin, carboxymyoglobin and metmyoglobin) which dictates the observed color. Factors that influence interconversion between these chemical states and /or the stability of the chemical state provide the opportunity for some control of the observed color.

Factors Impacting Meat Color

Intrinsic to the Muscle

Color and stability of the meat color are influenced by pigment concentration, and by cellular level reactions involving oxidation, reduction, and oxygenation of the color pigments. Two key mechanisms in muscle are:

- **Oxygen Consumption Rate (OCR)** – The respiration rate of muscles over time during display, which competes with the myoglobin for enough oxygen to keep the muscle in the oxymyoglobin state. Also produces intermediates needed for metmyoglobin reducing activity. (Muscles with lower OCR are generally more stable.)
- **Metmyoglobin Reducing Activity (MRA)** – The system in muscle that converts metmyoglobin back into deoxymyoglobin (without oxygen) and oxymyoglobin (with oxygen) through a series of reactions until the reductants are depleted. (Muscles with higher MRA are generally more stable.)

These intrinsic mechanisms differ across muscles because each muscle has differing locomotion purposes within the live animal dictating the amount of oxygen and energy needed to conduct the movement. In the transition from muscle to meat, these mechanisms continue to function, contributing to the timing of color interconversions and ultimate meat color. Additional factors influence these mechanisms, and their rates include:

- pH
- Temperature
- Protein denaturation during muscle to meat conversion
- Biochemical intermediates available to modulate meat color
- Quantity of unsaturated fatty acids

Antemortem

- Gender
- Genetics
- Animal age (Myoglobin loses its affinity for oxygen as age increases)
- Diet energy density
- Time on feed
- Seasonality
- Stress

Postmortem

- Rate of temperature decline in muscle (impacted by)
- Carcass weight
- Method of immobilization (electrical, atmosphere)
- Chilling rate
- Scalding/singing
- Processing temperatures
- Temperatures of storage and transport
- Application of antimicrobial interventions
- Packaging methods
- Time
- Extent of exposure to oxygen
- Antioxidant concentrations

Scan for complete Meat Color Measurement Guidelines

Packaging

The color state of fresh meat within a package is influenced by many aspects of the packaging system, which includes the chemical and physical properties of trays, films, lids and bags. Other considerations include the atmospheric environment and the use of other components such as soaker pads or oxygen scavengers.

Package Characteristics

The specific composition of the packaging materials determines potential exposure to oxygen and the rate of exposure. Oxygen is the key component dictating chemical state of the color pigment and managing the interaction of meat with the oxygen is a way to achieve or maintain a specific color state. Consideration must be given to the following components:

- Film permeability – transmission rates for water vapor, oxygen and other gases:
  - high permeability maintains oxy-heme pigments
  - extremely low permeability encourages deoxyheme
- Film thickness – influences rate of transmission
- Tray or container type (rigid or foam)
- Other components – soaker pads, oxygen scavengers
- Headspace or excess space in package
- Barrier to light

Table 1 shows the relationship between oxygen concentration and partial pressure which both influence the color state of the myoglobin pigment. Conditions resulting in low partial pressure (1-25mm Hg) encourage oxidation and pigment browning.

Partial Pressure Explained

In a mixture of ideal gases, each gas has a partial pressure, which is the pressure that the gas would have if it alone occupied the volume. The total pressure of a gas mixture is the sum of the partial pressures of each individual gas in the mixture.

Common Package Types and Atmospheric Considerations

The atmosphere within a package or around the package can both impact observed color. Common packages for fresh meat are:

Overwrap tray – Film permeability, tray type and temperature in the display case are key factors determining color.

Vacuum Package – Even with high levels of vacuum pulled, significant oxygen may remain in the environment and impact MMb (MMb is metmyglobin) formation. The OCR will impact removal of residual oxygen from a vacuum package.

MAP (modified atmosphere packaging) – Predetermined gas mix within an impermeable film and tray aid in maintaining a desirable color by controlling the oxygen concentration (via vacuum and by displacement.)

Gas mixtures – Carbon dioxide is well known for its antimicrobial effect in MAP. However, nitrogen and carbon dioxide are essentially neutral in their effects on pigment forms and therefore their presence in a MAP headspace will not affect color.

Summary of considerations to maintain a red color desired by consumers:

- Oxygen concentration (and vacuum)
- Modifying gas composition
- Partial pressure
- Display temperature

Concentration and partial pressure of oxygen in environments with differing percentages of oxygen

Trait	Oxygen (%, ppm or pressure) values				
Oxygen concentration[1] in meat's atmosphere, %	o	5	10	15	Air, 20.9
Oxygen concentration, ppm	o	50,000	100,000	150,000	209,000
Approximate partial pressure of oxygen, mm Hg	o	38.0	76.1	114.1	159.2

[1]Metmyoglobin (MMb) forms by oxidation between 1% and 3% oxygen (1,000 and 3,000 ppm).

References

King, D. A. & Hunt, M. C. & Barbut, S. & Claus, J. R. & Cornforth, D. P. & Joseph, P. & Kim, Y. H. & Lindahl, G. & Mancini, R. A. & Nair, M. N. & Merok, K. J. & Milkowski, A. & Mohan, A. & Pohlman, F. & Ramanathan, R. & Raines, C. R. & Seyfert, M. & Sørheim, O. & Suman, S. P. & Weber, M., (2023) "American Meat Science Association Guidelines for Meat Color Measurement", Meat and Muscle Biology 6(4): 12473, 1-81. doi: https://doi.org/10.22175/mmb.12473

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