# CHEMISTRY OF FRESH MEAT COLOR

Color of muscle foods revolves around myoglobin, the primary red pigment in meat, responsible for storing oxygen in cells. However, ultimate *perceived* color as seen by the human eye is affected by many additional internal and external factors. Understanding the chemical states of myoglobin is important for managing and controlling color and, ultimately, meeting consumer expectations. The more myoglobin content meat contains the darker red it will appear in color. Myoglobin content is higher in beef and lower in poultry with lamb and pork having intermediate amounts.

## Basic Principles of Fresh Meat Color and Color Stability

- Myoglobin is a large, water soluble protein with a heme group containing a centrally located iron atom.
- One specific binding site on the central iron (Fe) atom (Figure 1) can reversibly bind oxygen, carbon monoxide, and water.
- Color of meat exists in four chemical states: deoxymyoglobin, oxymyoglobin, carboxymyoglobin and metmyoglobin (Figure 2).
- Meat color is determined by: (Table 1)
  - the specific molecule at that binding site
  - the valence (oxidation) state of the iron
  - availability or concentration of oxygen
- Color can be "managed" by controlling conditions that impact the above three factors.
- Meat color is not due to presence of blood.

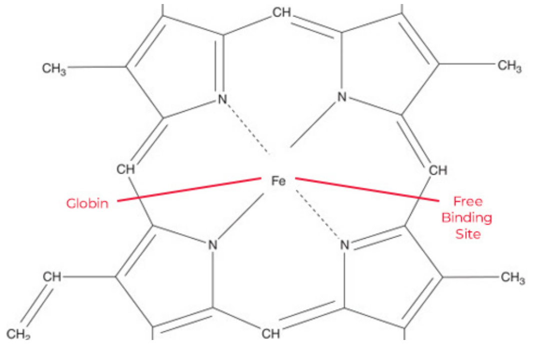


Figure 1. Heme group within myoglobin molecule

## Factors Influencing Fresh Meat Color Interconversions

The factors that influence myoglobin oxygenation (blooming) in meat, the red state most recognized by consumers, include:

- time postmortem
- temperature
- pH
- competition for oxygen by muscle cell mitochondria

Higher oxygen levels lead to a thicker layer of oxymyoglobin on and immediately below the meat's surface. Reaction 2 in Figure 2 is unlikely to occur because, thermodynamically, oxymyoglobin is resistant to oxidation to metmyoglobin.

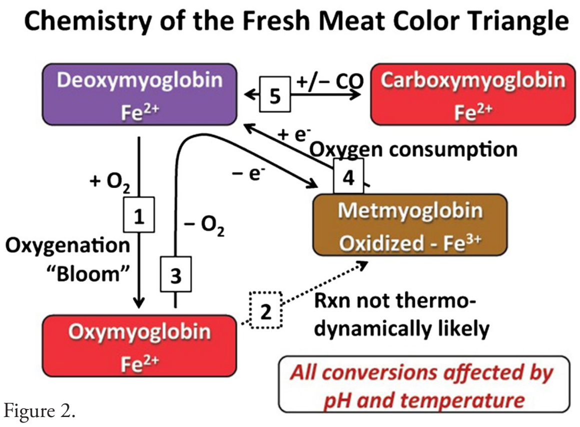


Figure 2.

| Chemical Form of Myoglobin | Compound on Free Binding Site | Iron State | Color | Other Conditions |
|---|---|---|---|---|
| Deoxymyoglobin | None | $Fe^{++}$ (Ferrous) | Purple | Very low oxygen (i.e., intact muscle, vacuum package) |
| Oxymyoglobin | O2 | $Fe^{++}$ (Ferrous) | Red | Exposure to air (i.e., film overwrap tray) |
| Carboxymyoglobin | CO | $Fe^{++}$ (Ferrous) | Red | Oxygen concentration dependent |
| Metmyoglobin | H20 | $Fe^{+++}$ (Ferric) | Brown | 1-3% oxygen (i.e., leaking vacuum package) |

Table 1. Chemical States and Conditions of Fresh Meat Color

The *visual* change of meat color is slightly different than the chemical pathways. The human eye may not actually see some of these chemical states because they happen quickly and below the meat surface. Specifically, brown metmyoglobin is usually seen forming *directly* from bright red oxymyoglobin. Thus, it is sometimes difficult to put the principles shown in Figure 2 into practice, especially when troubleshooting meat color problems. Figure 3 shows the chemical states that are visually seen during practical observation.

### "Visual, Practical" - Fresh Meat Color Triangle

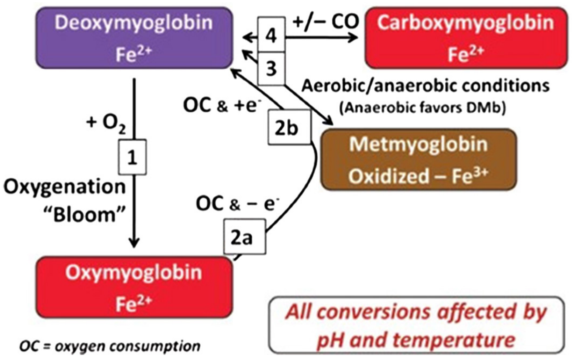


Figure 3.

## Common Questions

1. **If deoxymyoglobin is formed, why does the surface color change directly from red to brown, with no purple intermediate?**

   The purple deoxymyoglobin formation is obscured by the overlying red oxymyoglobin layer during the early part of storage or display and later by the increasing thickness of the metmyoglobin layer. Furthermore, in the surface oxymyoglobin layer, the small amounts of deoxymyoglobin formed are rapidly converted back to oxymyoglobin due to high concentration of oxygen near the surface.

2. **How does metmyoglobin change to purple deoxymyoglobin after sufficient vacuum (anaerobic) storage?**

   The thin brown metmyoglobin layer develops because of vacuum removal of some, but not all, oxygen. The low oxygen level at the meat surface favors browning. The purple deoxymyoglobin becomes apparent only after the overlying red oxymyoglobin and brown metmyoglobin levels disappear. Oxymyoglobin levels go to near zero mainly because of muscle mitochondrial oxygen consumption.

## Factors Influencing Color Stability

The stability, or ability of fresh meat to stay in a color state is also determined by:

- **Animal age** – Myoglobin loses its affinity for oxygen as age increases
- **Muscle cut** – Each muscle has a varying locomotion purpose leading to a different cellular activity which impacts other factors.
- pH
- Temperature
- **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
- **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
  - Muscles with lower OCR are generally more stable

**Scan for complete Meat Color Measurement Guidelines**

**References**

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2. McKenna, D. R., P. D. Mies, B. E. Baird, K. D. Pfeiffer, J. W. Ellebracht, and J. W. Savell. 2005. Biochemical and physical factors affecting discoloration characteristics of 19 bovine muscles. Meat Sci. 70:665-682. doi:10.1016/j.meatsci.2005.02.016

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