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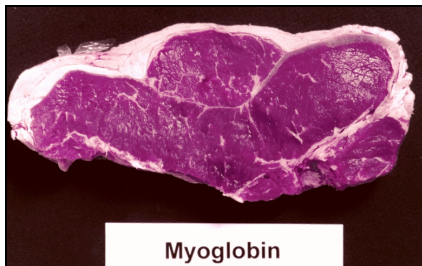
Montana State University and Saskatchewan Food Product Innovation Program
University of Saskatchewan

Basic Meat Color

The first impression consumers have of any meat product is its color and thus color is of utmost importance. The color of meat may vary from the deep purplish-red of freshly cut beef to the light gray of faded cured pork. Fortunately, the color of meat can be controlled if the many factors that influence it are understood.

Fresh and cured meat color both depend on myoglobin, but are considerably different from each other in terms of how they are formed and their overall stability.

Myoglobin is a water-soluble protein that stores oxygen for aerobic metabolism in the muscle. It consists of a protein portion and a nonprotein porphyrin ring with a central iron atom. The iron atom is an important player in meat color. The defining factors of meat color are the oxidation (chemical) state of the iron and which compounds (oxygen, water or nitric oxide) are attached to the iron portion of the molecule.



Fresh cut meat surface. The meat pigment is myoglobin.

Because muscles differ greatly in activity, their oxygen demand varies. Consequently different myoglobin concentrations are found in the various muscles of the animal. Also, as the animal gets older there is more myoglobin. A greater myoglobin concentration yields a more intense color. Muscle pigment concentration also differs among animal species. For example, beef has considerably more myoglobin than pork or lamb, thus giving it a more intense color.

Meat Color Reaction

Immediately after cutting, meat color is quite dark - beef would be a deep purplish-red. As oxygen from the air comes into contact with the exposed meat surfaces it is absorbed and binds to the iron. The

surface of the meat blooms as myoglobin is oxygenated. This pigment, called oxymyoglobin, gives beef its bright cherry red color. It is the color consumers associate with freshness.



Striploin steaks allowed to bloom to oxymyoglobin.

Myoglobin and oxymyoglobin have the capacity to lose an electron (called oxidation) which turns the pigment to a brown color and yields metmyoglobin. Thus, myoglobin can change from a dark purple color to a bright red color simply from oxygenation or to a brown color by losing electrons. The pigments myoglobin, oxymyoglobin and metmyoglobin can be changed from one to the other, depending on the conditions at which the meat is stored. After cooking, a brown pigment called denatured metmyoglobin is formed, which normally cannot be changed to form another pigment.

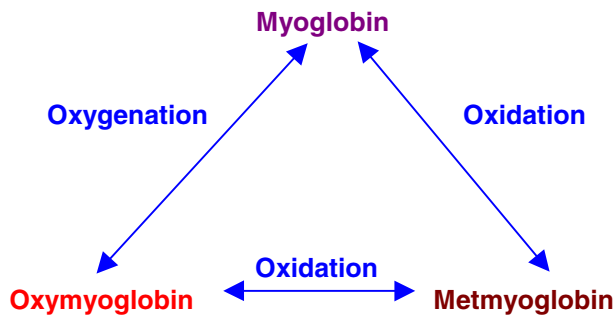


Striploin steak that has been stored and metmyoglobin has formed

Oxymyoglobin, commonly known as the fresh meat color, is the most desirable color for fresh meats. Maintaining this color requires that the meat surface be free from any contamination which would cause a chemical reaction resulting in the formation of the brown pigment metmyoglobin. Also, oxygen must be available at a sufficient concentration in order to combine with the myoglobin to form oxymyoglobin. This reaction is reversible and dependent on the availability of oxygen, active enzymes and reducing compounds in the muscle.

Vacuum packaged fresh meat has a dark, purplish red color because the oxygen has been removed from the package and reducing enzymes have converted the meat pigment back to myoglobin. Once the meat is taken out of the vacuum package it will recover its bright red color, albeit for a shorter time period than its unvacuum packaged counterpart.

The change from myoglobin to oxymyoglobin and vice versa usually occurs quite readily. Similarly, the reaction that produces the brown meat metmyoglobin occurs quite easily, but the reverse of this is more difficult. In raw meat there is a dynamic cycle such that in the presence of oxygen the three pigments myoglobin, oxymyoglobin and metmyoglobin are constantly interconverted, all three forms are in equilibrium with one another.



Interconversion of meat pigments. Myoglobin when oxygenated is bright red in color and called oxymyoglobin. Both myoglobin and oxymyoglobin can lose an electron (oxidize) to form metmyoglobin

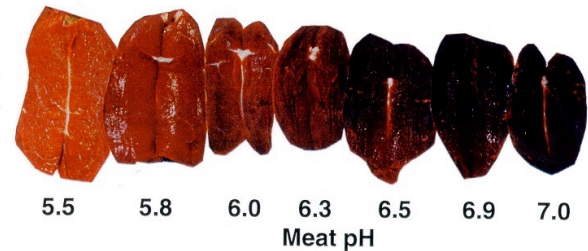
Metmyoglobin is associated with chilled meat that has been stored too long (*ie* reducing enzyme activity available to reduce metmyoglobin to myoglobin has been exhausted), but also appears when oxygen partial pressure is low, such as when meat pieces are stacked one on top of another. Oxygen partial pressure can also be reduced when aerobic bacteria use up the oxygen and it is unavailable to react with the myoglobin.

Effect of Meat pH

The rate and extent that muscle pH declines postmortem are both variable and have a great impact on the color of meat and meat products. The normal pH decline in muscles is from approximately 7.0-7.2 down to near pH 5.5-5.7 over about 24 hrs. With this pH decline, whole tissue is the characteristic color of the species. If the pH declines to the normal pH of 5.5-5.7 within 45 min or less, the muscle will appear very pale and soft (PSE). A very low ultimate pH (<5.4) will also result in a paler color. If the pH does not drop much postmortem, the meat

will be dark with a dull, dry surface (DFD). As the ultimate pH increases, the meat gradually becomes darker. This darkening of color becomes noticeable when the muscle pH exceeds 5.7.

BEEF:
Example of how meat colour is affected by ultimate pH



Effect of ultimate meat pH on the color of beef.
Picture supplied by Arie Graffhuis, MIRINZ Food Research

The color changes observed with PSE and DFD meat are mostly due to structural changes in muscle. Some of the changes are due to the rate of myoglobin oxygenation. The changes in pH affect the charge on the proteins making up the muscle. These changes alter the spacing between the fibres of the meat, and the change in structure affects how light is reflected and absorbed, and thus affects the visual appearance.

Color Stability of Fresh Meat

High ultimate pH can affect the color stability of fresh meat because it affects enzyme activity and the rate of oxygenation. Reducing enzymes are necessary to convert metmyoglobin back to oxymyoglobin. The high ultimate pH has a dry surface and this inhibits the penetration of oxygen into the meat and thus slows down the oxygenation process.

The length of time the meat has been stored postmortem affects the color stability of the meat or meat product. Increased time from slaughter results in reduced color stability because co-factors necessary for the reduction of metmyoglobin are depleted as postmortem time increases. A similar problem is seen if frozen meat is used. Products made with frozen meat will be darker initially and will not maintain the fresh color for as long as products made from meat which has never been frozen.

Both storage time and temperature have a great effect on color stability. Color acceptability decreases as storage time increases; however, the length of time the color is acceptable is greatly affected by storage temperature. Fresh meat and meat products should be stored at temperatures of -1.5°C (29.3°F) to give maximum color shelf-life and safety of products.

Particle Size Reduction and Mixing

Air is incorporated into meat products during the grinding process or mixing in of ingredients. The more air that is incorporated, the more stress is put upon the natural reducing systems of meat which help maintain oxymyoglobin stability and keep metmyoglobin formation in check. Longer mixing times and smaller meat particles results in shorter color shelf-life for meat products. Use of vacuum mixers helps to improve color stability, but will not completely bring the stability back to what would be expected in whole muscle products.

Cooked Meat Pigment

During the cooking process, myoglobin is denatured. All of the pigment is not affected at the same time or to the same extent and this is why you get reddish color at different end point temperatures when cooking. The cooked pigment is denatured metmyoglobin. It is brown and is easily recognized in cooked meat products. Certain meat conditions can result in protection of the myoglobin.

The ultimate pH of the muscle is one of these conditions. The ultimate pH of meat or meat products will affect how the meat color changes during cooking. If the meat has a high pH, it will have to be cooked to higher end-point temperatures to get the same visual degree of doneness as one with normal pH. Frequently, complaints of this hard to cook defect are associated with a high pH of the meat or meat product. This meat appears raw in color, dark red to purple, long after appropriate cooking temperatures have been reached.



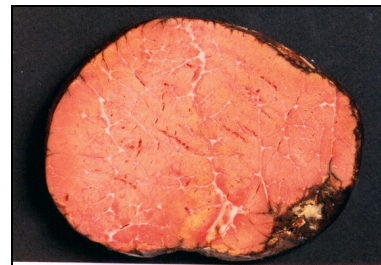
**Denatured
Metmyoglobin**

**Cooked beef roast. The myoglobin is denatured and oxidized to form denatured metmyoglobin.
Cured Meat Color**

Curing of meat has been done for centuries for the preservation of meat products. Today cured products are made for their unique flavour and texture. Cured products have a pink pigment that is relatively stable. To form this pigment, sodium nitrite is either rubbed onto the surface or injected into the meat with a needle injector. The nitrite, when added to water forms nitrous acid and nitric oxide, and

which penetrate the meat and combine with the myoglobin to form nitric oxide myoglobin. This pigment is not stable until after cooking when the final cured pigment, nitrosylhemochrome, is formed. The cooked pigment is more stable, but is still sensitive to oxygen presence, temperature and light. This is why most cured products are vacuum packaged in special UV protective films.

Many problems can occur in the curing of meat products that can result in the development of strange colors. One of the most common is the oxidation of the pigment to form a green or grey color. This is usually caused by metal contamination from moulds or smoke sticks. This sometimes happens if the moulds are old or they have be welded improperly with solder that contains copper or iron.



Nitrosylhemochrome

Cured cooked meat pigment.

Pinking of Uncured Cooked Products

Sometimes a pink color can form in uncured cooked meat products. This can be caused by many factors and should not be confused with the hard to cook phenomena caused by high meat pH.

Cooked beef or other meats can become contaminated with the curing salt nitrite from contact with a cured product, incomplete cleaning of utensils used with cured products or water contaminated with nitrites. It takes only small amounts of nitrite to develop cured meat color. Although 50 parts per million are necessary to maintain the pink color in cooked ground beef, pink color can show up with levels as low as 5 parts per million - that is 5 milligrams per kilogram of beef.

The cured meat color can be on the surface if the contamination occurs during the cooking process but will be throughout the meat product if it occurred earlier.

A pink color can also be formed in slow cooked meat products that have not been contaminated with nitrite. It is caused by specific conditions that promote interaction of natural meat pigments and nitrogen containing constituents of meat. This color

is actually desired in products such as Texas barbecue.

Surface pinking, also termed “pink ring” can occur if gas ovens or barbecue grills are used to cook meat products. Incomplete burning of the gas or contaminates in the gas result in the formation of nitrogen dioxide and nitric oxide. Nitric oxide is the active form of nitrite that yields the pink color. In roast beef this is generally considered a serious color defect because consumers might associate it with undercooking.



Pink ring around cooked pork. From Cornforth, D.P., J. K. Rabovitser, S. Ahuja, J. C. Wagner, R. Hanson, B. Cummings, and Y. Chudnovsky. 1998. *J Agric. Food Chem.* 46:255-261.

Naturally occurring nitrates found in water and vegetables can be converted to nitrites during thermal processing and can cause a pink color to form. Carrots and cabbage are examples of vegetables that have naturally occurring nitrates that can contribute to pinking of cooked meats. This occurrence is rare because nitrates take longer periods of time to be converted to nitrites which in turn yield nitric oxide that forms the color pigment necessary for the pink color. This color is usually seen in slow cooked soups or stews.

Another cause of pink color is the presence of carbon monoxide (CO). Carbon monoxide combines with natural pigments in meat to produce a dark red color in raw and cooked meat. Minute amounts of the gas may come from dry ice, or carbon dioxide freezer tunnels used in hamburger production and it will affect color. Carbon monoxide, which has a greater affinity for myoglobin than oxygen, binds almost irreversibly to the raw color pigment. However, this occurrence is relatively rare. Researchers have shown that if CO is used in modified atmosphere packages a dark red color develops and it remains after cooking.

Iridescence in Processed Meat Products

Iridescence is a common problem in sliced roast beef and ham products. The dominant color is frequently green and consumers sometimes confuse this with green myoglobin pigments associated with

microbial growth. The iridescence of meat products is produced by a combination of the angle of incidence of the light on the muscle fibres and the wetness of the surface. If the fibres are pulled slightly out of alignment during slicing, the light strikes the fibre at an angle scattering light which appears as the rainbow or greenish color on the surface of the meat. Addition of phosphate seems to exacerbate the problem by increasing the amount of water that is retained by the product.

Color is the single most important factor of meat products that influences consumer buying decision and affects their perception of the freshness of the product. Knowing the factors that affect color is important to understanding problems when they occur. Everyone dealing with meat products should have a working knowledge of the color. We hope this article has helped!

About the Authors

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