Enhancing Meat Color Stability

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Meat color stability is affected by numerous decisions and circumstances that begin with live animal selection and breeding, and include nutrition, environment, handling, holding conditions before slaughter, stun/bleed variables, chilling protocol, aging, holding time and conditions (especially temperature), fabrication conditions, time from fabrication to packaging, successful packaging, type of packaging; storage, distribution and handling of product, display conditions and handling by customers. The above apply to fresh, chilled, frozen and to cured products. Enhancements to chilled non-cured meat can markedly influence color stability. Cured meat is additionally affected by added ingredients, physical manipulation conditions, time and temperature protocols for smoking and heat processing and post-cook chilling and packaging. Those who troubleshoot color stability problems tend to concentrate on the most recent events but color could be affected in many places in the livestock to product to consumer chain.

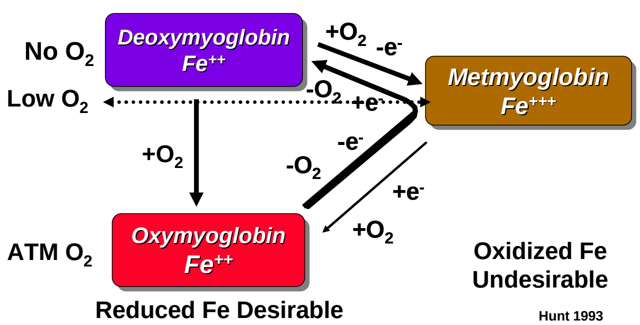

Figure 1. Fresh meat color triangle.

Meat color basics will be reviewed. First, understanding the meat color triangle is very important. Muscle tissue appearance is determined by the chemical state of muscle pigments (Figure 1). In the absence of oxygen, pigment is in the deoxymyoglobin state, which has a dark, purplish-red color (Kropf, 2000). On exposure to air, the pigment is rapidly oxygenated to form oxymyoglobin, the bright red that consumers have been taught to expect and find attractive. Deoxymyoglobin and oxymyoglobin, which are both in the reduced state, can oxidize to metmyoglobin, which has a dull brown color associated with deterioration of quality. Metmyoglobin is more stable and is slowly converted to deoxymyoglobin by enzyme-mediated reactions termed metmyoglobin-reducing activity. Muscle tissue that is deficient in the enzymes that mediate metmyoglobin reduction or in reduced cofactors necessary for reduction is unable to reconvert metmyoglobin, which then persists. Muscles vary widely in metmyoglobin-reduction activity, and it dissipates during storage of muscle. Those that tend to have a high activity, such as the longissimus dorsi, are more color-stable in air, their red color persisting for 3 or 4 times as long as unstable muscles of low metmyoglobin-reduction activity.

Partial oxygen pressure (PO_2) plays an important role in determining which chemical state of heme pigments, primarily myoglobin, is favored at any muscle location (Figure 2). Formation of undesirable brown met forms of heme pigments occurs most rapidly at intermediate PO_2 with peak activity at 4 mm but ranging from 1.4 to about 25 mm PO_2. Thus, partially oxygenated heme pigments discolor faster than completely deoxygenated or with a higher level of oxygenation.

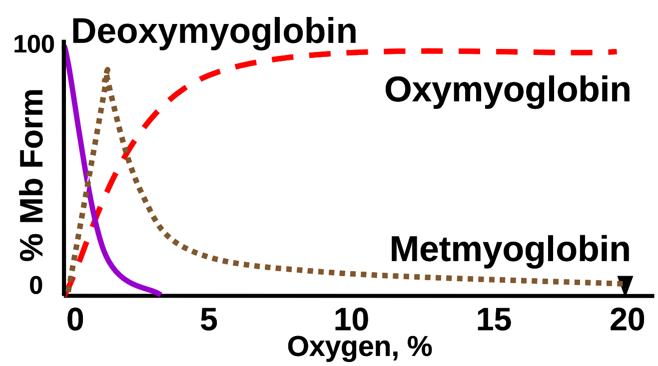

Figure 2. Partial oxygen pressure and myoglobin form.

Color stability is more achievable if myoglobin remains as deoxymyoglobin until bright red or bright pink is required to satisfy meat purchasers. Unnecessary and uncontrolled pigment changes are costly in terms of losing ability to return to deoxymyoglobin and shorten color life. Using fresh rather than tired raw material to produce a cured product also contributes to improved meat color stability.

When the new cut surface is formed, oxymyoglobin quickly forms at the surface and gradually penetrates more deeply as oxygen diffuses into the muscle, resulting in the gradual blooming. The depth of oxygen penetration into

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muscle is dependent on oxygen diffusion, which is influenced by temperature as well as pH. Although oxygen diffusion is more rapid at a higher temperature, net oxygen penetration is greater at temperatures close to 0°C, where activity of enzymes that use oxygen is minimal. At higher temperatures, respiratory enzymes use more oxygen and limit its penetration into muscle. Respiratory enzyme activity is favored by higher pH, consequently high-pH muscle utilizes more oxygen, and so less oxygen diffuses into muscle. The result is a darker colored muscle, which has only a very thin layer of oxymyoglobin on the surface; consequently the color is primarily that of the subsurface deoxymyoglobin. High partial oxygen pressure in the gaseous environment surrounding the muscle will cause the oxymyoglobin layer to move into the muscle more rapidly and more deeply. Relatively fresh muscle with a good supply of reducing capability will have two pigment layers, oxymyoglobin on the surface and deoxymyoglobin at deeper locations. For intact muscles, oxygen diffuses more deeply with increasing time after initial exposure to air for several days, depending on the mini-environment surrounding the muscle and the supply of reducing capability of the muscle. When reducing mechanisms of muscle approach depletion, a third layer of pigment, brown metmyoglobin, forms between the oxymyoglobin and deoxymyoglobin layers. The brown area has the intermediate PO_2, which favored its formation. The oxymyoglobin layer becomes thinner and the metmyglobin layer becomes thicker and moves closer to the surface. Ultimately both visual observers and reflectance instruments begin to see the brown discoloration. Color stability can be influenced by:

Live Animal Selection - Stress resistant may favor slower pH decline, less oxidative meat.

Nutrition - Vitamin E (tocopherol) feeding creates more color stability, even for higher unsaturated fat diets, and longer aging, and influences pork and turkey in a similar direction (Liu and others, 1995; Buckley and others, 1995).

Environment - Severe conditions may cause dark cutters. A sudden temperature rise during cool spring days can affect pigs and turkeys and cause more oxidative, discoloration-prone muscle.

Handling - Cattle and pigs are vulnerable to hot temperature and to mixing of animal groups. Hauling at night advocated, also keeping animal groups intact. Conditions that distract/startle animals can cause stress (Faustman and Cassens, 1990).

Holding Conditions - Pigs should be rested before slaughter, allowed to cool, have access to water for 3 to 4 hours after unloading. Too short or no holding encourages PSE and too long (over 6 hours) may increase DFD.

Stun/bleed Variables - Effective stunning including proper placement, appropriate current for electrical and stun application time influence quality. Bleeding quickly after stunning is also essential. Carbon dioxide may be good system.

Dressing/chilling - More rapid chill translates to color stability as low temperature slows pH decline, pigment oxidation and facilitates a deeper oxymyoglobin front.

Aging - While longer aging (14 to 28 days) encourages faster discoloration, a ripening time of five to seven days facilitates blooming and lengthens display life.

Fabrication/Enhancement/Packaging - Minimize light exposure and time from fab to packaging.

Added Ingredients - Those that may improve color stability (Miller, 1998) include sodium, potassium or calcium lactate; ascorbic acid or sodium isoascorbate, carnosine, anserine, phenolic antioxidants, rosemary and its extractives, and other plant source materials. Those that may diminish color stability are alkaline phosphates, salt, water contaminants, ascorbic acid or sodium isoascorbate, organic acids, and heavy metals.

Packaging (Kropf, 2000) - High-oxygen MAP systems often have atmospheres of 20% carbon dioxide and up to 80% oxygen, produce and maintain a desirable red color in beef for up to 9 days and depress metmyoglobin formation by driving oxygen deep under the surface of meat. Ground beef in a similar treatment was stable for 6 days. Pork loin chops in high oxygen had acceptable saturation indices and display color for 8 to 12 days. Odor, not color may limit this system. Carbon monoxide has been used in beef MAP systems to maintain a bright cherry-red color (Sorheim and others, 2001). Carbon monoxide binds strongly to myoglobin and hemoglobin, forming stable bright-red compounds. Beef loin eye steaks at 4°C in a 0.4% carbon monoxide, 60% carbon dioxide, and 40% nitrogen system, compared with a high-oxygen (80%) system or vacuum packaging, were brighter red and had better display color stability. This does not mask microbial deterioration and is approved as a master pack system in the U.S.A.

In ultra-low oxygen MAP, a slight amount of residual oxygen frequently occurs due to small pockets of air not removed initially by evacuation or flushing. These frequently cause major discoloration, reduced color stability, or blooming ability problems. Initial oxygen concentrations >0.15% (1,500 ppm) seriously compromised color stability of beef and lamb. Pork was affected by residual oxygen concentrations >1.0%. Oxygen scavengers are needed to get residual oxygen low enough and fast enough as muscle scavenging of oxygen is inadequate and slow. For cured product, nitrogen gas is used with a goal of diluting residual oxygen to 0.5% or less.

Lighting (Faustman and Cassens, 1990; Kropf, 1998) - Time and intensity of meat product exposure to light during processing, storage and distribution should be minimized. Display lighting is essential for marketing but its effect on discoloration by temperature elevation, photochemical oxidation and sub-optimal color rendition can be minimized by selecting fluorescent lamps of 2900 to 3750° Kelvin and using least intensity which is compatible with effective display. Color display at 32°F is effective in enhancing display life. Ultra-violet is detrimental to meat color, especially shorter wavelengths (Bertelsen and Skibsted, 1987) but packaging can block this effect.

Temperature - Cold at proper times is absolutely essential to minimizing product value loss. A comprehensive ground beef study (Mancini, 2001) gives display life as influenced by storage time and by temperature of storage and display. Coarse ground beef in chubs stored and displayed at 32°F benefits dramatically and is cost effective. The least product price discounting or loss saved $283 per week for a store selling 2000 lbs. ground beef per week. This information led to the "32° Makes a Difference" program by a major packer. In a companion study, half of meat display temperatures were at 39°F or warmer. Audits International (1999) surveyed actual retail temperatures for refrigerated foods including fresh meat, prepackaged lunchmeat and deli counter meat. Data from primary shoppers of over 1000 households geographically dispersed across the country showed one in two refrigerated product temperatures were over 41°F, one in four were over 45°F, and 1 in 17 were over 50°F. All types of cases had product above 41°F with frequency of this occurrence ranging from 27% for fresh meat to 71% for the deli counter. Mean and maximum temperatures reported were 43.6 and 66°F for prepackaged lunch meat, 44.8 and 64°F for deli counter meat and 39.2 and 58°F for fresh meat, with the worst 10% above 50°F for prepackaged lunch meat and deli counter meat.

Product temperatures rise about 8 to 10°F during a typical summer shopping excursion. The worst 5% of shopping conditions showed product temperatures increased 15 to 20°F on the way home from shopping. This data is very alarming and indicates that the entire meat product marketing chain needs to minimize problem temperatures. Shopper education should emphasize proper handling of meat and other perishables.

Consumers judge acceptability of meat largely on appearance, mostly color, of exposed muscle. Dull and/or discolored fat, purge or bone cut surfaces detract from meat cut appearance but their good appearance cannot compensate for discolored muscle. Longer storage (Warren and others, 1992) can result in greenish pork fat. Feeding cattle diets high in some unsaturated fat can result in "dirty" looking discolored spots, possibly more pronounced with high oxygen.

Black vertebra have been caused by ultra-chill in pork. Freezing poultry may cause black bones. Bones on beef cuts are more black in high oxygen packages but also noted in polyvinylchloride film packages, always in the bone marrow or porous bone structure. Antioxidant or vitamin C treatment may diminish this problem.

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