Scientific Contributions

The Science of Meat Color

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Consumers judge retail meat products on their visual appearance at the point of purchase. Consumer acceptability and willingness to purchase retail meat products is highly dependent upon their subjective appraisal of a product's visual attractiveness. Products with desirable color presented in a bright, clean retail case connote freshness. Due to the importance of color in purchasing decisions, the basic science of meat color should be understood by the merchandiser.

The color of any object is caused by the reflection of specific light wavelengths. Roses reflect red wavelengths, while carrots reflect orange. The muscle protein myoglobin is the major contributor to reflected color in meat products. The quantity of myoglobin present in meat determines the relative shade of red (light or dark) displayed by that product. Myoglobin quantity varies by animal age, animal species, as well as physical activity of the muscle. Different species (beef, lamb, pork or poultry) contain various levels of myoglobin with beef and lamb having the most, followed by pork and then poultry. As an animal grows older, the myoglobin concentration in muscle cells increase. This difference in myoglobin concentration as influenced by age can be demonstrated by comparing the color of veal and beef. Muscles with higher degrees of physical activity have greater amounts of myoglobin. The best example of this is the comparison of turkey thigh and breast meat.

Myoglobin can reflect several different color wavelengths. To understand why this occurs, the role of myoglobin in the living animal must be understood. It is a complex protein similar to hemoglobin. Myoglobin is found internally in the muscle cell while hemoglobin is found in blood. The purpose of these two proteins is to bind and transport oxygen molecules. Oxygen is taken into the lungs and passes from the lungs to the bloodstream where it attaches to the hemoglobin molecule in the red blood cell. It is then carried by the hemoglobin to all parts of the body via the circulatory system. Small capillaries carry oxygen-rich hemoglobin to the muscle cell membrane where the oxygen molecule is transferred across that membrane and attaches to the myoglobin molecule. Myoglobin then transports oxygen throughout the muscle cell to produce energy.

Myoglobin has the ability to bind with several other chemical compounds other than oxygen. These include: water, nitrite (cured meat color), or the binding site can remain free of any compound. *The compound that is bound to the myoglobin molecule has a marked effect on meat color and the common ones are shown in Table 1.*

All three myoglobin states (deoxy-, oxy- and met-) are simultaneously present in fresh meat. The predominant state determines the reflected color of the product. Myoglobin in freshly cut meat placed in a retail package can bind to and release oxygen or water multiple times, thus readily converting between the oxy- and deoxy- states. The rate and ability of myoglobin to bind decreases over time. Eventually it loses this ability to bind

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Table 1. Effect of myoglobin state on meat color

State of Myoglobin	Compound bound to Myoglobin	Reflected Color	Example
Oxy-Myoglobin	Oxygen (O_2)	Beef: Bright cherry red Lamb: Reddish pink Pork: Greyish pink Poultry: Light pink to dull red	Meat in retail display
Deoxy-Myoglobin	Water (H_2O)	Purple	Vacuum packaged meat
Meat-Myoglobin	Nothing	Brown	Associated with old meat
Nitrosyl-Myoglobin	Nitrite (NO) Irreversible	Pink	Cured meat-hotdogs, ham

oxygen and converts to met-myoglobin. Met-myoglobin reflects a brown color and is detrimental to the product's consumer appeal, typically resulting in economic losses due to price markdowns or product discards.

MEAT COLOR

What can be done to maximize the color of fresh red meat and increase the product's consumer appeal? Fresh meat will inevitably discolor when exposed to oxygen; however there are several key management items which can be controlled to maximize the products' display life.

Cold Chain Management

Maintaining cold temperatures slows product discoloration in three ways:

-Lower temperatures slow the oxidation reaction (alternate binding of oxygen and water) and delays the formation of met-myoglobin. Optimum product storage temperature is between 30-34 degrees F. Testing at Cargill's R&D Center indicates that ground beef stored at 50 degrees F converts to met-myoglobin up to four times faster than product stored at 32 degrees F.

-Lower temperatures will also slow bacterial growth. While typical spoilage bacteria do not directly cause meat to discolor, high levels of bacterial activity will compete with myoglobin for oxygen, which can lead to localized discoloration.

-Lower temperatures also slow natural enzymatic reactions which also compete for available oxygen.

Cold chain management starts in the slaughter facility and continues to the consumer's kitchen. Any breaks in the cold chain will reduce the product's color life.

Good Sanitary Practices

Proper sanitation reduces bacterial contamination risks.

Product Age

Myoglobin loses its oxygen-binding ability over time, even when packaged in a vacuum bag. For optimum color display of product, use proper rotation and follow

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your supplier's recommendations for storage temperatures. Cargill recommends that fresh meat be stored at 32 degrees F. Ground meats should be used within 18 days. Whole muscle cuts should be used within 45 days. Aging whole muscle cuts in a vacuum bag at 32 degrees F for 14 to 21 days will not significantly affect the color performance.

Lighting

Exposure to light will initiate and accelerate the formation of met-myoglobin. Because exposure to light is necessary to display products, minimizing exposure time to light through good retail case management and proper product rotation are essential to controlling measures to maximize display time.

Consumer retail purchasing decisions are made very quickly and are highly dependent upon product appearance. Utilizing your knowledge of the basic science of meat color to guide product management decisions can improve sales and reduce markdowns and discards.

Table 2. Cargill's Plant Microbiological Information (based on data from 6 plants)

Product	Test Performed	Frequency	Average Results
Ground Beef (Age is 48 hours or less)	Aerobic Plate Count	6 per day	7400 cfu/g
	Coliforms	6 per day	80 cfu/g
	Generic E. coli	6 per day	30 cfu/g

Listed are plant level results. Retail level counts will be higher because they have aged more. Coliform and E. coli are done using standard 3M petrifilm. General counts are used to establish control criteria for slaughter-dressing.