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Summary with Implications

The objective of this study was to determine the impacts of myoglobin oxygenation level and frozen storage duration on frozen beef color. Strip loins were wet-aged for 4 or 20 days and were fabricated into steaks that were assigned a myoglobin oxygenation level (highly oxygenated, lowly oxygenated, or deoxymyoglobin) and packaging film (impermeable or permeable). Steaks were then frozen for 0, 2, 4, or 6 months of storage and analyzed for various beef color measurements. Highly oxygenated steaks had greater a values (redness) and percent oxymyoglobin compared to the other treatments. Frozen storage beyond 4 months and oxygen impermeable packaging tended to have detrimental effects on beef color. Highly oxygenated steaks that are aged for 4 d displayed superior red color for extended storage with few undesirable effects.*

Introduction

Meat color is the number one factor influencing consumer purchase decisions. Typically, fresh beef can be associated with three different myoglobin states: deoxymyoglobin (purplish color associated with intact beef), oxymyoglobin (bright red cherry color associated with beef that has been exposed to oxygen), and metmyoglobin (brownish color prominent once beef has become oxidized). The emerging market of frozen meat highlights the need to understand beef surface discoloration and the optimal color parameters of freezing beef to retain a superior, bright red cherry color. Improving understanding of beef surface discoloration and the ideal parameters to freeze beef color, could lead to an increase in revenue for the beef industry. Therefore, the objectives of this study were to determine the impacts of oxygenation level and frozen storage duration on frozen beef color.

Procedure

Thirty-six USDA Choice strip loins were aged for 4 d or 20 d. For each loin, 0.5 inch steaks were fabricated and randomly assigned to a myoglobin oxygenation level [deoxymyoglobin (DeOxy; fabricated and immediately packaged), low oxygenation (LoOxy; oxygenated in air for 30 m, allowing it to bloom), and high oxygenation (HiOxy; packaged for 24 h in a modified atmosphere packaging mixture of 80% O_2 and 20% CO_2)]. Steaks were then vacuum packaged in oxygen permeable film or impermeable film and immediately frozen (-4°F). Following either 0, 2, 4, or 6 months of frozen storage, steaks were removed from the packaging and immediately analyzed (while frozen) for oxygen penetration, instrumental color (L*, a*, b*), delta E, percent oxymyoglobin, metmyoglobin, and deoxymyoglobin (via spectrometer), redness ratio (calculated as 630nm/530nm via spectrometer), subjective discoloration, and lipid oxidation. A one inch cut from the lateral end of the steak was made to measure oxygen penetration using a Westward caliper measuring the penetration depth of the bright red cherry oxymyoglobin color from the surface of the steak. Instrumental color was measured via colorimeter measuring L* (darkness to lightness), a* (greenness to redness), and b* (blueness to yellowness); delta E was measured as the magnitude of difference in the L*, a*, b* color space from the initial fabrication day till the designated frozen storage period. Delta E was calculated using the formula $\Delta E=((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$. Percent oxymyoglobin, metmyoglobin, and deoxymyoglobin were determined using a portable spectrometer (Quality Spec® Trek Malvern Panalytical) using the isobestic wavelengths and redness ratio was calculated as 630nm/530nm using the portable spectrometer. Subjective percent discoloration was evaluated by a panel of five trained panelists using a percentage surface scale where 0% meant no discoloration and 100% meant complete surface discoloration. Lipid oxidation or thiobarbituric acid reactive substance values (TBARS) were established via the amount of mg of malonaldehyde per kg of muscle tissue.

All data were analyzed as a split-split plot design with age as the whole-plot, frozen storage as the split-plot and a three by two factorial of oxygenation level and packaging film as the split-split plot. Frozen storage period was analyzed as an incomplete block design with each loin containing two random storage periods. Loin was considered the experimental unit. The data were analyzed using the PROC GLIMMIX procedure of SAS with the LS MEANS statement. Statistical significance was determined at $P < 0.05$.

Results

The HiOxy steaks had greater oxygen penetration (bright red cherry color depth) and greater a* values (Figure 1), when compared to DeOxy and LoOxy regardless of packaging film ($P<.0005$). Conversely, DeOxy steaks exhibited the lowest a* values (lowest redness) regardless of packaging film ($P<.0005$). This was expected since the HiOxy steaks were exposed to greater concentrations of oxygen allowing oxygen to bind to the heme ring and produce a bright red color typical of oxymyoglobin. The HiOxy steaks that were aged for 4 d had greater a* values than DeOxy and LoOxy at all frozen storage times ($P=.0118$). In addition, HiOxy 20 d steaks had the highest delta E values (10.79), compared to all other treatments at six months of frozen storage ($P=.0057$). Increasing frozen storage time

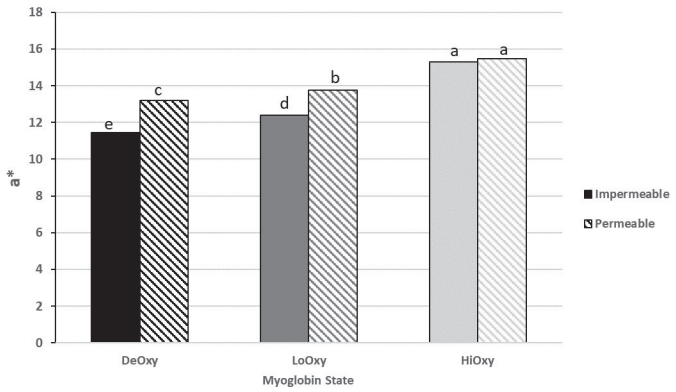

Figure 1. Instrumental color values for a* (redness) of steaks in either a deoxymyoglobin (DeOxy), low oxygenated (LoOxy), or high oxygenated (HiOxy) state and impermeable or permeable packaging.
[a, b, c, d, e] Different superscripts indicated differences among treatments (P<0.05).

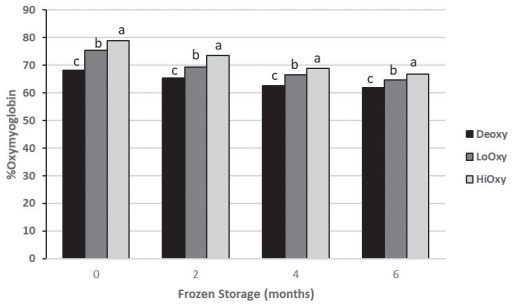

Figure 2. Instrumental color values for percent oxymyoglobin of steaks in either a deoxymyoglobin (DeOxy), low oxygenated (LoOxy), or high oxygenated (HiOxy) state compared within frozen storage period.
[a, b, c] Different superscripts indicated differences within frozen storage period (*P*<0.05).

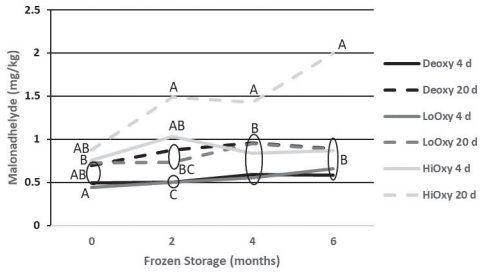

Figure 3. Lipid oxidation (TBARS) values of steaks in either a deoxymyoglobin (DeOxy), low oxygenated (LoOxy), or high oxygenated (HiOxy) state and either aged for 4 or 20 d compared within frozen storage period.
[a, b, c] Different superscripts indicated differences within frozen storage period (*P*<0.05).

led to an increase in delta E values for the HiOxy steaks ranging from 3.88 to 10.79 representing a noticeable difference in visual color (*P*=.0057). Delta E is used to measure the change in total color over time. Therefore, a larger delta E value would represent a larger change in color during frozen storage.

Percent oxymyoglobin (Figure 2) and redness ratio values were highest for HiOxy steaks within each frozen storage period (*P*<.0002). The HiOxy and LoOxy steaks had similar percent oxymyoglobin when in permeable packaging film that allowed the oxygen to pass through the film. The DeOxy steaks had the lowest percent oxymyoglobin and HiOxy steaks had the highest percent oxymyoglobin within each aging and frozen storage period (*P*<.01). Conversely, HiOxy steaks had the lowest percent metmyoglobin and DeOxy steaks had the highest percent metmyoglobin when packaged in impermeable film that inhibited oxygen passage through the film (*P*<.0001). Lowest percent metmyoglobin values were from the 4 d HiOxy steaks at 2, 4, and 6 months of frozen storage (*P*=.0188).

The HiOxy 20 d steaks had the greatest percent discoloration compared to 4 d aging and more discoloration than all other myoglobin treatments at 6 months of storage (*P*<.0001). Lipid oxidation, indicating the amount of rancidity, increased with frozen storage time (*P*=.0169). The HiOxy steaks aged for 20 d exhibited the greatest TBARS values (Figure 3) at 2, 4, and 6 months of frozen storage (*P*=.0224). The HiOxy 4d steaks and LoOxy steaks were similar in discoloration and lipid oxidation.

The HiOxy steaks exhibit a brighter and deeper cherry red color compared to the DeOxy steaks. The HiOxy steaks were superior or similar in various beef color measurements when compared to LoOxy steaks. However, as frozen storage was extended, HiOxy steaks started to display more detrimental effects compared to the LoOxy steaks. Based on the results, HiOxy steaks that are aged for 4 d give a superior red color for extended storage with few undesirable effects. However, it is not advised to freeze deoxygenated steaks and expect a bright red cherry color through frozen storage.

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