

Project Summary

Evaluation of Factors Relating to the Black Bone Condition in Packaged Beef Retail Cuts and Ways to Decrease the Incidence

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Background

A condition, commonly termed “black bone,” is typically associated with meat cuts packaged in high-oxygen modified atmosphere packaged (MAP) systems, as well as cuts packaged in polyvinyl chloride film (PVC). Black bone has been identified in both beef and pork.

Several researchers have suggested various causes of black bone condition. One is that the discoloration occurs when bone is cut and hemoglobin is released to the surface of the cut bone where it will accumulate. Over time and through exposure to air, hemoglobin on the surface of the bone turns from red to brown to black.

Another possibility is that lipid oxidation may also be a factor in the development of the discoloration. Bone marrow more closely resembles adipose tissue rather than muscle or liver tissue. The amount of lipid content varies among bones and their location, which might explain why rates of discoloration differ among bones.

As more and more beef is being sold as case-ready, it is important to determine the cause of this problem and develop ways to prevent it. Consumers may perceive bone discoloration as unwholesome and it might affect their overall perception of a fresh meat product. As a result, Kansas State University researchers conducted two experiments to 1) evaluate the effects of various packaging systems on the development of discoloration in several different bones from beef carcasses. The second project evaluated the effects of ascorbic acid and rosemary on the development of black bone in beef lumbar vertebrae, and the two compounds’ ability to prevent such discoloration.

Methodology

In Experiment One, thirty-six beef humerus, ribs, scapulas and thoracic vertebrae from U.S. Select or U.S. Choice carcasses were obtained from a commercial processing facility and cut into one-inch thick sections four days after harvest. The bone pieces were packaged in one of three package types:

- High-oxygen (80% oxygen/20% carbon dioxide) modified atmosphere package
- Ultra-low-oxygen (70% nitrogen/30% carbon dioxide) modified atmosphere package
- Polyvinyl chloride film overwrap

Packages were displayed under continuous fluorescent lighting for five days to simulate conditions found in a retail meat case. Instrumental color scores were taken ($L^*a^*b^*$) on the first, second and fourth day of display to determine the amount of graying discoloration on each bone surface.

Ten trained visual panelists also scored bone marrow color once each day for five days beginning on the first day. High-oxygen MAP and PVC packages were scored using the following seven point scale:

- 1) Bright reddish-pink to red

- 2) Dull pinkish-red
- 3) Slightly grayish-pink or grayish-red
- 4) Grayish-pink or grayish-red
- 5) Moderately gray
- 6) All gray or grayish-black
- 7) Black discoloration

Ultra-low oxygen MAP were scored with the following seven point scale:

- 1) Bright purplish-red or purplish-pink
- 2) Dull purplish-pink or purplish-red
- 3) Slightly grayish purple or pink
- 4) Grayish-purple or grayish-red
- 5) Moderately gray
- 6) All gray or grayish-black
- 7) Black discoloration

Myoglobin and hemoglobin pigment concentrations were also measured, as well as total iron and phosphorus content and 2-thiobarbituric substances (TBARS), which are a measure of oxidation.

Experiment Two

During Experiment Two, twelve beef lumbar vertebrae from U.S. Select or U.S. Choice carcasses were selected, cut into one-inch thick sections and packaged into one of the same three package systems used during Experiment One.

Prior to packaging, the bones were treated with one of the following antioxidant treatments:

- 1) Untreated controls
- 2) 1.25 or 2.5 percent ascorbic acid (L-ascorbic acid)
- 3) 0.1 or 0.2 percent rosemary or a combination treatment of 0.15 percent Origanox (Rad Natural Technologies) plus 0.3 percent ascorbic acid

Similar to the first experiment, the packages were displayed under continuous fluorescent lighting to simulate a retail display case. Additionally, the following measurements were made:

- Instrumental color measurements
- Visual color measurements by a trained panel
- 2-Thiobarbituric acid reactive substances

Findings

Experiment One

Overall, the ribs, scapulas and thoracic vertebrae turned darker (grayish-black) in PVC and high-oxygen MAP during five days of display. These bones turned dark in color within a 24 hour period of time. The humerus bones remained acceptable in color throughout five days of display. The researchers hypothesized that the difference in bone marrow composition played a role in the differences in discoloration rates.

In PVC and high-oxygen MAP, humerus bone marrow did not develop the black bone condition and had much more desirable visual color scores—approximately a three-score advantage on a

seven-point scale. Rib, scapula and thoracic vertebra bones packaged in PVC and high-oxygen MAP had undesirable discoloration, with a significant proportion of them being described as being black bone. In ultra-low oxygen MAP, mean visual color scores were acceptable throughout display.

All four bones became darker to varying degrees during the display period for all three packaging types. Much of the darkening occurred within the first day of display. However, this darkening was much more extensive in the ribs, scapulas and thoracic vertebrae than for the humerus. Furthermore, the darkening was much more extensive for bones packaged in PVC and high-oxygen MAP than for ultra-low oxygen MAP.

Humerus bones had dramatically higher L^* values than rib, scapula, and thoracic vertebrae, which was in agreement with visual color scores. The L^* values were similar for all three packaging systems and did not show differences like those found with visual color scores.

The humerus had lower a^* (less red) values than the other bones. The a^* values for ribs, scapulas and thoracic vertebrae decreased over time, which corresponds to lowered visual color scores. Additionally, a^* value changes from bones packaged in ultra-low oxygen MAP were smaller, matching much smaller visual color score changes for the same packaging type.

Ratios of a^*/b^* and chrome showed that bones discolored during display, but discoloration was noticeably less for bones packaged in ultra-low oxygen MAP and for humerus bones in PVC and high-oxygen MAP.

Oxidation was measured using 2-thiobarbituric acid reactive substances (TBARS) and was considerably lower for humerus bone marrow than for rib and thoracic vertebra bone marrow and did not change over display time. Ultra-low oxygen MAP resulted in the least change in TBARS during the four days of analysis. Thoracic vertebrae marrow had TBARS values significantly higher on the fourth day of display as compared to the first, for PVC and high-oxygen MAP.

Humerus marrow had less total iron and hemoglobin than rib and thoracic vertebrae for all three packaging systems. Phosphorus was lower in thoracic vertebra than in humerus and rib bone marrow. Rib bone marrow had more myoglobin than thoracic vertebra bone marrow. Myoglobin was undetectable in humerus bone marrow. The much higher total iron and hemoglobin in ribs and thoracic vertebrae likely corresponds to the development of the black bone condition.

Experiment 2

Control lumbar vertebrae darkened dramatically in PVC and high-oxygen MAP. However, lumbar vertebrae bone discoloration in ultra-low MAP was much less extensive. In general 0.1 and 0.2 percent rosemary treatments were not effective in preventing discoloration in PVC and high-oxygen MAP. The 2.5 percent ascorbic acid treatment was most effective in preventing discoloration and maintaining initial color in both PVC and high-oxygen MAP. The 1.25 percent and combination of 0.15 percent Origanox and 0.3 percent ascorbic acid were able to maintain desirable color scores through mid display in PVC and high-oxygen MAP, but not after five days of display. Although antioxidant treatments are not needed as much in ultra-low oxygen MAP,

the 1.25 percent ascorbic acid treatment was as effective as the 2.5 percent ascorbic acid treatment in preventing discoloration.

In contrast to visual scores, changes in L* values during display were minor across packaging systems, whereas a* values were similar to visual color score trends. Furthermore, lumbar vertebrae treated with ascorbic acid had higher or no change in a* values over display time.

Ratios of a*/b* and chrome show that the ascorbic acid treatments were very effective in preventing discoloration. In general, discoloration tended to be greater in bones held 14 days after harvest than those held six days.

In all three packaging systems, bones held 14 days after harvest had higher oxidation levels than those bones held six days. Overall, ascorbic acid treatment was most effective in minimizing TBARS, or oxidation changes throughout display.

Implications

Black bone occurred in ribs, scapulas and thoracic vertebrae when packaged in PVC and high-oxygen MAP. Bones packaged in ultra-low oxygen MAP had minimal discoloration and/or black bone development. Based on this research, black bone condition is not an issue in humerus bones.

Results from this project indicate that ascorbic acid treatments, particularly the 2.5 percent application, were very effective in preventing black bone discoloration and were superior to other treatments.

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