PE4.32 Premature browning in color-stable beef muscle 121.00

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***Abstract* - Earlier studies investigated the effect of high-oxygen modified atmosphere packaging (MAP) on premature browning (PMB) in beef muscles with intermediate color stability. However, information on the influence of high-oxygen MAP on PMB in color-stable beef muscles is scarce. Therefore, our objective was to determine the impact of high-oxygen MAP on the tendency of color-stable beef muscle to undergo PMB. Color-stable beef muscle (Longissimus lumborum; LL), from 16 (n = 16) carcasses (USDA Select grade) were fabricated into 1.92-cm steaks. Steaks were individually packaged either in high-oxygen MAP (HIOX; 80% O_2 + 20% CO_2) or in vacuum (VP), and stored for 9 days at 2°C in darkness. At the conclusion of storage, steaks were cooked to an internal endpoint temperature of either 66°C or 71°C, chilled in ice for five minutes, sliced parallel to the cooked surface, and internal cooked color was determined. LL steaks in HIOX demonstrated lower redness (*a** value) and were more susceptible to PMB at 66°C than those in VP. These findings suggested that retailing beef color-stable muscles in HIOX will increase the incidence of PMB. On the other hand, VP could be used as effective packaging strategy to minimize the occurrence of PMB in color-stable beef muscles.**

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***Index Terms* — Cooked color, Longissimus lumborum, Modified atmosphere packaging, Premature browning.**

I. Introduction

The characteristic dull-brown color of cooked beef products is due to heat-induced denaturation of myoglobin (Mb). To ensure destruction of *E. coli* O157:H7, USDA recommends cooking beef to an internal temperature of 71°C [1]. Consumers generally do not use meat thermometers and often rely on dull-brown color in the interior of cooked beef as an indicator of doneness. However, the denaturation temperature for Mb is not constant, and therefore, the relative dull-brown color of cooked beef interiors is not a reliable indicator that product has reached a temperature sufficient to inactivate foodborne pathogens. [2].

Premature browning (PMB) is a condition in cooked beef products where Mb denaturation occurs at a temperature lower than what is necessary to inactivate foodborne pathogens, and thus falsely conveys that thermal pasteurization has been achieved. Myoglobin's redox state governs its resistance against cooking-induced denaturation, and the resistance of Mb redox forms against heat-induced denaturation is in the order - metmyoglobin (MetMb) < oxymyoglobin (OxyMb) < deoxymyoglobin (DeoxyMb) [3]. This suggests that at a specific internal cooking temperature, beef with predominantly DeoxyMb is less susceptible to PMB than beef containing a high proportion of MetMb and OxyMb [4, 5]. Different endogenous and exogenous factors influencing Mb redox state and raw color stability also impact PMB [6].

Retailing fresh beef in high-oxygen modified atmosphere packaging (MAP) has increased significantly because this case-ready system promotes formation of consumer-desirable bright cherry-red OxyMb pigment on meat surfaces [7]. However, the tendency of beef to exhibit PMB is greater when stored in high-oxygen MAP (80% oxygen) than in aerobic packaging [8-12].

Individual beef muscles differ significantly in biochemistry and color stability attributes [13-16]. Longissimus lumborum (LL) is a color-stable muscle [17], which has been widely investigated relative to fresh color stability [14-16]. While previous research examined the effects of high-oxygen MAP on PMB in beef muscles with intermediate color stability [9, 10], the effect of high-oxygen MAP on PMB in color-stable beef muscles has not been explored thoroughly. Determining the tendency of color-stable beef muscles to exhibit PMB during storage in high-oxygen MAP will aid in development of muscle-specific packaging strategies to minimize the occurrence of PMB. Therefore, the objective of the present study was to determine the impact of high-oxygen MAP on the tendency of color-stable beef LL steaks to demonstrate PMB.

II. MATERIALS AND METHODS

Beef packaging and storage

Sixteen USDA Select grade LL (IMPS #180) muscles [18] were obtained from a commercial packing plant. From each muscle, four steaks (1.92-cm thick) were sliced, and two steaks were assigned to each of two packaging treatments - vacuum packaging (VP) and high-oxygen MAP (HIOX; 80% O_2 + 20% CO_2). Steaks were packaged individually in Prime Source pouches (4 ml, Koch Supplies, Kansas City, MO, USA) and were stored at 2°C in darkness for 9 days.

Cooking

At the conclusion of refrigerated storage, one of the two steaks from each packaging was cooked to internal temperatures of either 66°C or 71°C using a George Foreman clam-shell grill (Salton Inc., Columbia, MO, USA) heated to a surface temperature of 180°C [12, 19, 20]. Internal temperature of the steaks was continuously monitored using a handheld probe thermometer inserted into the geometric center. Cooked steaks were removed from the grill when the internal temperature reached 66°C or 71°C, placed into a pouch (4 ml, Prime Source, Koch Supplies, Kansas City, MO, USA), and immediately submerged in slushed ice to minimize any post-cooking temperature rise.

Instrumental color analysis

Cooked steaks were sliced parallel to the grilled surface, and instrumental color (CIE *L**, *a**, and *b** values) was measured at three random locations on the interior with a HunterLab MiniScan XE Plus spectrophotometer (HunterLab Associates, Reston, VA, USA) using a 2.54-cm diameter aperture, illuminant A, and 10° standard observer [21].

Statistical analysis

The experimental design was a Randomized Complete Block, where each LL muscle served as a block and steaks served as experimental units. Data were analyzed using the Mixed Procedure [22]. Least square means for protected F-tests were separated and were considered significant at $P < 0.05$ level.

III. RESULTS AND DISCUSSION

*L** (lightness) and *b** (yellowness) values of cooked LL steaks were not influenced ($P > 0.05$) by packaging systems. In contrast, there was a significant packaging x endpoint temperature interaction ($P < 0.05$) for the internal *a** values (redness) of cooked steaks (Figure 1). LL steaks stored in HIOX exhibited lower ($P < 0.05$) *a** values than those in VP. Furthermore, VP steaks cooked to 66°C had greater *a** values than those cooked to 71°C, indicating that VP was effective in preventing PMB. However, cooking temperature had no effect ($P > 0.05$) on internal *a** values of HIOX steaks. Internal *a** values of HIOX steaks cooked to 66°C did not differ from those cooked to 71°C, and thus HIOX steaks exhibited PMB. High-oxygen (80%) MAP saturates DeoxyMb to OxyMb, which is responsible for consumer-desirable cherry-red color of beef. However, denaturation of OxyMb at a temperature lower than DeoxyMb [3, 23] could lead to PMB in LL steaks stored in HIOX. The results of the present study are in agreement with earlier reports that HIOX predisposed whole-muscle beef steaks of intermediate color stability [9, 10] to PMB.

VP prevents exposure of meat to oxygen and maintains Mb in its purplish-red DeoxyMb redox state. The observed greater internal redness in cooked VP steaks than HIOX steaks could be attributed to the greater thermostability of DeoxyMb than OxyMb [3, 23]. In support, previous investigations reported that the tendency of ground beef to demonstrate PMB could be minimized by VP [8]. Our findings, as well as those of others, indicated that the incidence of PMB could be minimized by packaging beef in VP rather than in HIOX.

IV. CONCLUSION

High-oxygen MAP is increasingly used in beef retailing because it improves red color stability. However, our findings demonstrated that color-stable LL steaks packaged in HIOX are more susceptible to PMB than those in VP. Cooked LL steaks in VP demonstrated greater interior redness than those in HIOX. Cooked steaks having red interiors are, in general, considered less thoroughly cooked, and consumers would cook them for longer time, thus ensuring destruction of foodborne pathogens. Although HIOX MAP promotes development of consumer-desirable cherry-red color on fresh beef surfaces, it also increases the tendency of whole-muscle beef cuts to undergo PMB. On the other hand, VP prevents PMB in color-stable beef muscle. The beef industry could utilize VP as packaging strategy to minimize PMB and thus improve microbiological safety of cooked beef products.

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Figure 1: Influence of modified atmosphere packaging systems on the internal cooked *a** values of beef Longissimus lumborum steaks cooked to different endpoint temperatures.
HIOX = 80% O_2 + 20% CO_2 MAP; VP = Vacuum packaging
Standard error for packaging comparisons = 0.5.
Standard error for endpoint temperature comparisons = 0.6.
a-c Means without a common letter are different ($P < 0.05$).