PHYSIOLOGICAL AGING INCREASES OXIDATIVE SUSCEPTIBILITY OF POST-MORTEM MUSCLES FROM MATURE COWS

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Introduction

Mature cows that are removed from the dairy herd for one reason or another represent a significant source of meat for the beef industry. Although it is recognized that toughness of meat increases with animal age, little is known about other quality attributes of meat from mature cows. Boccard et al. (1979) reported that increasing chronological age in cattle resulted in a darker color of meat, but the post-mortem stability of muscle pigments was not clear. Lipid oxidation, which readily occurs in post-mortem muscle, can be a main impediment to the successful marketing of cow meat, including ground beef and comminuted products. Likewise, discoloration resulting from myoglobin oxidation could negatively impact the utility of cow meat.

While literature is scant about the animal age influence on the oxidative stability of beef, biochemical studies with small laboratory animals or on humans indicate increased susceptibility of muscle cells to oxidizing agents as the age progresses (Stadtman, 2006). In fact, aging of animals is part of the consequence of lipid and protein oxidation occurring in the cell. It may be speculated that age-related weakening of the redox state exists in cows, and deficiencies of cellular antioxidants could negatively impact the oxidative stability of post-mortem muscle. The objective of the present study was to investigate the influence of cow age on the oxidative stability of lipid and myoglobin in two different ground beef muscles stored under a retail display condition.

Materials and Methods

Semitendinosus (ST) and *Semimembranosus* (SM) muscles were obtained from 24-h post-mortem carcasses of nine cows (n = 9) of similar genetic background (Angus-Simmental), which represented three physiological age groups (3 in each) (2-4 yr, 6-8 yr, and 10-12 yr). The muscles were ground through a 4.5-cm orifice plate, shaped into 2-cm thick patties, and subsequently stored aerobically at 3±1°C on a retail display shelf under fluorescent lighting. Patties were measured for surface color and analyzed for myoglobin and lipid oxidation daily for a total of 7 days.

Surface color of raw ST and SM patties stored for different days was measured with a Hunterlab colorimeter to determine lightness (L*), redness (a*) and yellowness (b*). Furthermore, total myoglobin (Mb) and metmyoglobin (MMb) in ST and SM raw patties were determined according to Krzywicki (1982) using a 40 mM phosphate extraction buffer (pH 6.8). Lipid oxidation in ST and SM patties was measured before and after cooking (70°C internal temperature) by means of the thiobarbituric acid (TBA) method, and was expressed as TBA-reactive substances or TBARS (mg/kg of muscle) (Sinnhuber and Yu, 1977).

Each animal within the same age group was treated as a replicate. Data from the three replicated trials were analyzed using the General Linear Procedure, and two-way analysis of variance (ANOVA) was performed to determine the significance of the effect of animal age and muscle post-mortem storage time. The ANOVA tables obtained were further analyzed for the comparison of means by Least Significant Difference procedures.

Results and Discussion

Color and pigment of raw patties. There were no significant differences between the 2-4, 6-8, and 10-12 yr age groups for either ST or SM patties before storage or during storage for all the surface color parameters (L*, a*, and b*), although numerically, the L*-values of raw patties of the 10-12 yr age group tended to be slightly lower (but nonsignificantly) and appeared darker when compared with the other two age groups. Hence, the respective colorimetric values were pooled to obtain the means. Overall, the change in the L*-value during storage was inconsistent, but both a*- and b*-values decreased ($P < 0.05$) after 7 d for both muscle types (Table 1). The most noticeable decrease in the a*-value was seen between day 0 and day 1. Comparison of ST and SM patties showed that the former was consistently lighter (L*) but less red (a*) ($P < 0.05$) than the latter. Kirchofer et al. (2002) reported 24.3, 26.0, and 49.7%, respectively, β-red, α-red, and α-white fibers in beef ST, compared to 26.3, 28.6, and 45.1% in beef SM.

Total myoglobin content (3.15±0.55 mg/g muscle) was similar ($P > 0.05$) between ST and SM samples, and it was not influenced ($P > 0.05$) by animal age. During storage, much of the Mb pigments was converted to MMb, with the most rapid conversion occurring during the first day; by day 7, MMb accounted for almost 70% of the total pigment (data not shown). This followed the trend in decreasing the a*-values during storage (Table 1). Similar findings were previously reported (Demos and Mandigo, 1996).

Table 1. Hunter colorimetry of raw *Semitendinosus* (ST) and *Semimembranosus* (SM) patties stored at 3°C

Sample	Param.	Storage Time (d)							
		0	1	2	3	4	5	6	7
ST	L*	38.87^{a}	36.87^{a}	37.15^{a}	37.70^{a}	37.62^{a}	38.06^{a}	37.77^{a}	37.89^{a}
	a*	24.66^{a}	21.24^{b}	19.32^{c}	18.11^{d}	17.22^{d}	15.57^{e}	15.20^{e}	14.96^{e}
	b*	13.48^{a}	11.65^{b}	11.19^{bc}	10.60^{c}	10.37^{c}	10.38^{c}	10.37^{c}	10.61^{c}
SM	L*	34.76^{a}	32.49^{b}	32.24^{b}	32.27^{b}	32.64^{b}	32.62^{b}	33.20^{ab}	33.16^{ab}
	a*	26.00^{a}	22.51^{b}	21.28^{c}	20.38^{cd}	19.69^{de}	18.86^{ef}	17.83^{f}	17.90^{f}
	b*	12.40^{a}	10.64^{b}	10.13^{bc}	9.72^{c}	9.47^{c}	9.52^{c}	9.32^{c}	9.44^{c}

[a–f] Means in the same row without a common superscript letter differ significantly ($P < 0.05$).

Lipid oxidation. The TBARS analysis revealed marked differences in rate and extent of lipid oxidation between the three age groups of cows as well as between ST and SM muscles during refrigerated retail display ($P < 0.05$). Raw patties of both ST and SM from the 10-12 yr cows were most susceptible to lipid oxidation, followed by the 6-8 yr age group, when compared with the 2-4 yr group (Figure 1). The animal age-associated variation in lipid oxidation as well as the difference between muscle types cannot be attributed to the lipid content, as proximate analysis showed no significant difference between all the muscle samples. While there is no literature report on age-related changes in the redox potential of post-mortem meat, it is suggested that the endogenous antioxidants could be lower in the 10-12 yr cow muscle than in muscle from younger groups, thus, enhancing the oxidative susceptibility of lipids. It has been reported that in humans, total plasma antioxidants decreased with age (Rizvi et al., 2006). The rate and extent of TBARS generation were significantly greater ($P < 0.05$) for ST than for SM. It is plausible that the ST muscle was deficient in endogenous antioxidants when compared with the SM muscle. Cooking slightly increased the TBARS production; however, it did not change the difference between muscle types or animal ages as seen in raw patty samples (result not shown).

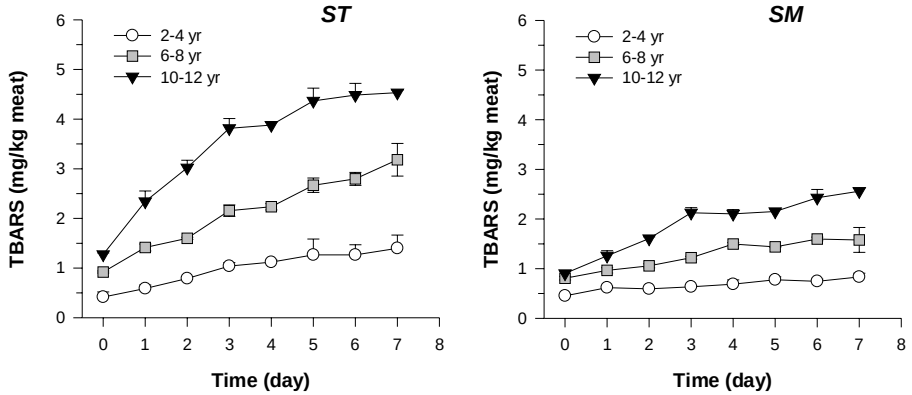

Figure 1. TBARS content in raw beef patties stored at 3°C for various days. Patties were prepared from *Semitendinosus* (ST) and *Semimembranosus* (SM) muscles of cows from different age groups.

Conclusions

The findings validated the hypothesis that oxidative stability of lipids in post-mortem muscle decreased with the age of mature cows, and substantiated the general notion that the overall quality of beef is reduced with the age of cattle. The results indicated the need of antioxidative strategies to maximize the quality and marketability of beef obtained from this particular group of cattle.

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