

Effect of modified atmosphere packaging and potassium lactate injection-enhancement on beef steak surface redness

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Abstract

Our objective was to assess the effects of lactate enhancement in combination with different packaging systems (vacuum; high-oxygen, 80% O₂ + 20% CO₂; or 0.4% CO, 30% CO₂ + 69.4% N₂) on beef *Longissimus lumborum* and *Psoas major* steak redness. Subprimals (n = 16) were divided in half and randomly assigned to 1 of 4 injection treatments (non-injected control, water-injected control, 1.25% lactate, and 2.5% lactate in the finished product; pumped to 110%). Muscles were cut into steaks, each of which was assigned to 1 of 6 packaging x storage time (5 or 9 days at 1°C) combinations. Initial *a** values also were measured prior to packaging and storage. On days 5 and 9 of storage, surface *a** values were measured immediately after each steak was removed from its respective package. Lactate increased the redness of steaks packaged in high-oxygen, but not steaks in vacuum or CO. Compared with the *Psoas*, steaks from the *Longissimus* had greater *a** values in high-oxygen packaging. However, CO packaging resulted in greater *a** values for the *Psoas*. Regardless of muscle type, CO packaging improved color stability compared with high-oxygen packaging.

Introduction

Myoglobin can exist in 4 redox states: deoxymyoglobin, oxymyoglobin, carboxymyoglobin, and metmyoglobin (Mancini & Hunt, 2005). Central packaging of case-ready meat products can increase color life via the use of both modified atmosphere packaging and injection-enhancement technologies. In particular, the use of carbon monoxide (CO) in packaging has become increasingly relevant for the US meat industry since its approval for use at a level of 0.4% in red meat modified atmosphere packaging systems. In addition, lactate is a commonly used injection-enhancement ingredient that stabilizes the color of beef products by minimizing surface discoloration during retail storage and display (Kim *et al.*, 2006; Knock *et al.*, 2006; Seyfert *et al.*, 2007).

Carbon monoxide (CO) binds to myoglobin and forms a bright cherry-red color (carboxymyoglobin), resulting in significant improvements in beef color stability (Jayasingh *et al.*, 2001; Hunt *et al.*, 2004; John *et al.*, 2005). The ability of carbon monoxide to produce a bright cherry-red color may further enhance lactate's color stabilizing effect.

Research has evaluated the effects of lactate and carbon monoxide separately. However, published results from experiments combining both CO packaging and lactate are limited. Therefore, the objective of this study was to assess the effects of lactate enhancement in combination with different packaging systems (vacuum; high-oxygen, 80% O₂ + 20% CO₂; or 0.4% CO, 30% CO₂ + 69.4% N₂) on beef *Longissimus lumborum* and *Psoas major* steak redness.

Materials and methods

Sixteen USDA Select beef strip loins (*Longissimus lumborum*) and tenderloins (*Psoas major*) were divided into two equal-length sections, and 1 of 4 injection treatments (1 = non-enhanced control; 2 = distilled water-enhanced positive control; 3 = 1.25% lactate; and 4 = 2.5% lactate) was assigned randomly to each section within a muscle. Positive controls and lactate-enhanced sections were pumped to 110% of green weight using a multi-needle injector with either distilled water or a solution containing water and potassium lactate, respectively. Finished product lactate concentration was either 1.25 or 2.5%. From each section, seven 2.54-cm thick steaks were cut and one steak from each section was assigned to d 0 redness analyses (no packaging or storage time). The fresh-cut surface of each d 0 steak was scanned 30 min after fabrication (bloom at 1 °C). The remaining 6 steaks were individually packaged in either vacuum, high-oxygen (80% O₂ + 20% CO₂), or 0.4% CO (0.4% CO + 30% CO₂ + 69.6% N₂) and were stored at 1 °C prior to color analyses.

On d 5 and 9 of storage, redness on the surface was measured immediately after each steak was removed from its respective packaging using a HunterLab MiniScan XE Plus spectrophotometer (Model 45/0 LAV, 2.54-

cm diameter aperture, illuminant A, 10° observer). For each steak, a^* values were measured in triplicate and subsamples were averaged for statistical analyses.

The combined effects of lactate enhancement, modified atmosphere packaging, and muscle source were evaluated using a split-split-plot. Within the whole plot, *Longissimus* and *Psoas* muscles were considered experimental units ($n = 16$ for each muscle; $N = 32$ total subprimals). Within the subplot, each one of the 2 experimental units within a subprimal was assigned to 1 of 4 injection treatments, each of which was replicated $n = 8$ times per muscle using a balanced incomplete block. Within the sub-sub-plot, each subprimal half was fabricated into 7 steaks and each steak was assigned to a packaging x storage time combination: (1) Initial d 0 (prior to packaging and storage), (2) 5 d of storage in vacuum, (3) 5 d of storage in high-oxygen, (4) 5 d of storage in 0.4% CO, (5) 9 d of storage in vacuum, (6) 9 d of storage in high-oxygen, and (7) 9 d of storage in 0.4% CO. Type-3 tests of fixed effects for muscle, injection, packaging, storage time, and their interactions were performed using the MIXED procedure of SAS (2007). Least square means for protected F -tests ($P < 0.05$) were separated by using the diff option and were considered significant at $P < 0.05$.

Results and discussion

There was a significant packaging x storage time interaction for a^* values. The a^* values of steaks in high-oxygen decreased ($P < 0.05$) between d 5 and 9 of storage whereas CO packaging increased ($P < 0.05$) and maintained redness during storage. As a result, a^* values of steaks in CO were not affected ($P > 0.05$) by increasing storage time from d 5 to 9. The a^* values of steaks in vacuum were stable during storage (no change from d 5 to 9; $P > 0.05$), but less ($P < 0.05$) than initial values. Overall, steaks packaged in CO, regardless of injection treatment, were more red ($P < 0.05$) than steaks in high-oxygen and vacuum packaging (**Table 1**). The effect of carbon monoxide on color stability in the current study agreed with previous research (Jayasingh *et al.*, 2001; Hunt *et al.*, 2004; John *et al.*, 2005).

There was a significant injection x packaging interaction because lactate increased ($P < 0.05$) the redness of steaks packaged in high-oxygen but had no effect ($P > 0.05$) on the redness of steaks in vacuum and CO (Table 1). Injection had no effect ($P = 0.95$) when comparing *Longissimus* and *Psoas* a^* values.

Table 1. Effects of packaging ¹, injection ², and muscle on the surface a^* values of raw beef steaks stored at 1°C

Muscle	Injection	Packaging		
		Vacuum	High-oxygen	0.4% CO
<i>Longissimus</i>	Non-enhanced	23.2	27.2	34.2
	Water-enhanced	21.9	25.6	33.5
	1.25% lactate	22.2	28.7	33.6
	2.5% lactate	21.6	29.8	32.7
<i>Psoas</i>	Non-enhanced	25.0	24.8	37.0
	Water-enhanced	23.7	24.6	35.3
	1.25% lactate	24.3	25.9	36.1
	2.5% lactate	23.9	27.3	35.3

¹ High-oxygen = 80% O₂ + 20% CO₂; 0.4% CO = 0.4% CO + 30% CO₂ + 69.4% N₂.

² Samples were injected to 110% of green weight with either distilled water (water-enhanced) or a solution containing water and potassium lactate (1.25 and 2.5% in the final product).

LSD for injection comparisons = 1.6; packaging type comparisons = 1.1; and muscle comparisons = 1.0.

In our current study, lactate improved the redness of both the *Longissimus* and *Psoas* steaks when packaged in high-oxygen (Table 1). These results are in agreement with Kim *et al.* (2006) and Seyfert *et al.* (2007), who suggested that lactate's role in color stability is associated with increased metmyoglobin reducing activity via ingredient-induced lactate dehydrogenase activity. Other research has produced similar results for the *Longissimus* (Knock *et al.*, 2006) and ground beef (Eckert, *et al.*, 1997).

Differences in color stability between the *Longissimus* and *Psoas* have been attributed to intrinsic muscle-to-muscle variation in metmyoglobin reducing activity and oxygen consumption (Ledward, 1985; McKenna *et al.*, 2005). As a result, the effects of CO packaging can be muscle-dependent (Claus *et al.*, 2005). For example, Hunt *et al.* (2004) reported that CO resulted in greater improvements in color shelf-life for the *Psoas* and inside

semimembranosus steaks compared with the *Longissimus* and outside *semimembranosus*. In the current project, muscle effects on color stability were dependent on packaging type (Table 1). Compared with the color-labile *Psoas*, steaks from the *Longissimus* were more red ($P < 0.05$) in high-oxygen packaging. However, CO packaging had more effect on the *Psoas* than the *Longissimus* (*Psoas* significantly more red than *Longissimus* in CO packaging).

Conclusions

Injecting beef *Longissimus lumborum* and *Psoas major* subprimals with 2.5% lactate will improve the redness of steaks packaged in high-oxygen. Adding 0.4% carbon monoxide to packages will significantly increase color shelf-life compared with high-oxygen packaging.

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