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ASCORBIC ACID AND ORIGANOX™ IN DIFFERENT PACKAGING SYSTEMS TO PREVENT THE INCIDENCE OF PORK LUMBAR VERTEBRAE DISCOLORATION

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Introduction

Meat color is widely recognized to be one of the most influencing characteristics for fresh meat purchasing decisions. Understandably, bone color of bone-in fresh meats can serve in a similar role as an indicator of wholesomeness to consumers (Gill, 1996). Innovations such as modified atmosphere packaging (MAP), and standard packaging such as polyvinyl chloride (PVC) film overwrap, are ways to maintain desirable red color in case ready meats; however, bone discoloration is problematic.

Recent research has addressed beef bone blackening by evaluating various interventions in preventing this problem. Mancini et al. (2004) found the application of 2.5% ascorbic acid (AA) minimized beef lumbar vertebrae discoloration. Similarly, Grobbel et al., (2005) indicated that 2.5% AA or ultra-low oxygen (ULOx) MAP effectively reduced beef bone discoloration.

Gill (1996) suggested that bone darkening occurs when hemoglobin is disrupted and accumulates at the cut bone surface where oxyhemoglobin darkens to methemoglobin. It should be considered that oxidation-reduction potential is higher for bone marrow than for muscle because bone marrow contains more pro-oxidative iron (Calhoun et al., 1998). Accordingly, Grobbel et al. (2005) showed that beef bone marrow containing more total iron and hemoglobin is more prone to discoloration.

Objectives

Investigations exploring interventions to the ‘black-bone’ problem have primarily focused on beef bones. This condition can be a problem in bone-in fresh pork, and our objective was to investigate means to prevent it. Topical antioxidants including ascorbic acid (AA) and Origanox™ (OG), a natural antioxidant, were used as possible interventions, along with high-oxygen (HiOx) MAP, ULOx MAP, and PVC packaging systems.

Methodology

Forty-eight pork backbones were obtained from a commercial abattoir, from which six 2.54 cm thick cross-sections of lumbar vertebra were cut at 6 d postmortem. Cut sections from each backbone were treated with a 0.5 ml aliquot of 1 of 5 antioxidant treatments: 1.25%, 1,875%, and 2.5% AA; combination treatments of 0.15% OG + 0.30% AA and 0.225% OG + 0.45% AA; and control with no treatment applied. Both Grobbel et al. (2004) and Mancini et al. (2004) identified that 2.5% AA prevented darkening of beef bones. We used lower AA concentrations because pork marrow has lower oxidation-reduction potential than beef (Calhoun et al., 1998).

Vertebrae were packaged such that 6 vertebral sections in 1 package came from 1 backbone and represented all 6 treatments. Three packaging systems were used: 1) HiOx MAP (80% O_2, 20% CO_2); 2) ULOx MAP (70% N_2, 30% CO_2) with an activated oxygen scavenger; and 3) PVC overwrap film on foam trays.

Packages were displayed under continuous fluorescent lighting (2153 lux, 3000K, CRI 85) for 8 d at 2°C in an open retail display case and rotated twice daily to maintain random placement.

Six trained panelists scored porous marrow of the cut surface once daily on 6 d: from d 0 to d 5 and once on d 8 of display. A seven-point scale was used for HiOx MAP and PVC packages: 1) bright reddish-pink to red, 2) dull reddish-pink, 3) slightly grayish-pink or –red, 4) grayish-pink or –red, 5) moderately gray, 6) all gray or grayish-black, and 7) black discoloration. ULOx MAP samples were evaluated using a different seven-point scale: 1) bright purplish-red or –pink, 2) dull purplish-red or –pink, 3) slightly grayish-purple or –pink, 4) grayish-purple or –red, 5) moderately gray, 6) all gray or grayish-black, and 7) black discoloration.

Duplicate instrumental CIE L*a*b* measurements were taken on each cut vertebral section using a 0.64 cm aperture (Illuminant A) and averaged. These instrumental measurements were taken from all samples on day 0, from 24 opened packages on day 2, and from 24 opened packages on day 8. L* corresponds with lightness, a* with redness, and b* with yellowness. The a*/b* ratio is an indicator of discoloration, with lower ratios indicating more discoloration.

Data were analyzed with SAS PROC MIXED (SAS Institute, Inc., Cary, NC). Pairwise comparisons of least squares means were used to determine significant differences ($P < 0.05$).

Results & Discussion

Because the same visual scale was used, PVC and HiOx MAP packaged bones can be compared (Table 1). Control lumbar vertebra packaged in PVC and HiOx MAP did not exhibit graying ($P < 0.05$) until d 3 and d 4 of display, respectively. From d 2 to d 8, antioxidant treated bones in HiOx MAP had better ($P < 0.05$) visual scores than those packaged in PVC or the HiOx MAP control vertebrae. By d 5 of display, bones packaged in PVC and treated with both OG + AA treatments, or with 1.25% AA exhibited graying ($P < 0.05$). On d 5, the least desirable ($P < 0.05$) lumbar vertebrae were the PVC packaged controls, whereas HiOx MAP antioxidant-treated bones had the most desirable ($P < 0.05$) visual color. On d 8 of display, bones in HiOx MAP treated with 1.875% or 2.5% AA had superior ($P < 0.05$) visual scores compared to both OG + AA treatments, 1.25% AA treated bones were intermediate. All antioxidant treated bones in HiOx MAP had superior visual scores on d 8 compared to all bones in PVC and the HiOx control bones. Among PVC packaged bones, 1.875% and 2.5% AA resulted in more desirable d 8 visual scores.

An antioxidant effect was not observed ($P > 0.05$) for bones in ULOx MAP; however, a day effect was observed ($P < 0.05$; Table 2). Visual color scores declined ($P < 0.05$) from d 0 to d 3, maintained ($P > 0.05$) from d 3 to d 5, and declined again from d 5 to d 8 ($P < 0.05$).

The HiOx MAP bones increased in L* from d 0 to d 2, and decreased from day 2 to d 8 ($P < 0.05$; Table 3). The PVC bones underwent a similar decline. The L* values declined for antioxidant treated bones in ULOx MAP from d 2 to d 8 ($P < 0.05$). By d 8, control HiOx MAP bones had the lowest L* values, and PVC bones treated with either 1.875% or 2.5% AA had the highest ($P < 0.05$) L* values. Among antioxidant treated bones in HiOx MAP, those treated with 1.875% AA had the highest ($P < 0.05$) L* values. Nominal differences in d 8 L* value were observed among ULOx bones.

We observed a marked increase ($P < 0.05$) in a* values (more red) for HiOx MAP antioxidant-treated bones from d 0 to d 8 (Table 4). For HiOx control bones, however, a* decreased ($P < 0.05$) from d 2 to d 8, and also for bones packaged in PVC and treated with 0.15% OG + 0.30% AA, 1.25% AA, and the control. Other antioxidant treated bones in PVC underwent an increase ($P < 0.05$) in a* from d 0 to d 2, but did not change ($P > 0.05$) from d 2 to d 8. All bones packaged in ULOx MAP increased ($P < 0.05$) in a* from d 2 to d 8, although the increase was not as great as that observed for HiOx MAP antioxidant treated bones. The HiOX MAP bones treated with 2.5% AA had the highest ($P < 0.05$) d 8 a* values.

Antioxidant treated bones in HiOx MAP had higher ($P < 0.05$) a*/b* ratios than all PVC packaged bones (Table 5). Among antioxidants used in HiOx MAP, the highest a*/b* ratio was observed for 0.225% OG + 0.40% AA; ratios of those treated with 0.15% OG + 0.30% AA, 1.25% and 2.5% AA were the lowest; and 1.875% AA was intermediate. All PVC packaged bones and HiOX MAP control bones had lower ratios. The lowest ratio ($P < 0.05$) for PVC bones was observed for those treated with 1.875% AA. The ULOx MAP bones treated with either 1.875% or 2.5% AA had the least a*/b* discoloration.

Conclusions

Our experiment utilized antioxidants at varying levels coupled with different packaging systems to evaluate their effectiveness at preventing pork bone discoloration. Visual and instrumental values indicated that bones packaged in HiOx MAP benefit from the application of an antioxidant, with higher concentrations of ascorbic acid (1.875% and 2.5%) generally yielding more desirable results. The ULOx MAP appeared to be an effective means to prevent bone discoloration and, according to instrumental measures, also benefits from the application from a higher concentration of ascorbic acid. Origanox™ combined with ascorbic acid was not as effective as the ascorbic acid-only treatments. The application of a topical antioxidant appears to reduce bone discoloration and may be of value for use in bone-in fresh pork cuts.

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Tables and Figures

Table 1. Visual color scores[a] of pork lumbar vertebrae packaged in high-oxygen MAP and PVC overwrap treated with antioxidants and displayed 8 d

Packaging	Antioxidant	Day						
		0	1	2	3	4	5	8
HiOx	0.15% OG+0.30% AA	1.36^{b,u}	1.54^{c,uv}	1.75^{de,vw}	1.94^{d,wx}	2.13^{e,xy}	2.25^{f,y}	2.76^{f,z}
HiOx	0.225% OG+0.45% AA	1.37^{b,v}	1.53^{c,vw}	1.72^{e,w}	1.98^{d,x}	2.14^{e,xy}	2.29^{f,y}	2.72^{f,z}
HiOx	1.25% AA	1.35^{b,v}	1.51^{c,vw}	1.70^{e,wx}	1.95^{d,xy}	2.07^{e,y}	2.18^{f,y}	2.59^{fg,z}
HiOx	1.875% AA	1.34^{b,v}	1.48^{c,wv}	1.74^{de,w}	2.01^{d,x}	2.07^{e,xy}	2.19^{f,y}	2.39^{g,z}
HiOx	2.5% AA	1.37^{b,v}	1.50^{c,vw}	1.68^{e,wx}	1.94^{d,xy}	2.03^{e,yz}	2.07^{f,yz}	2.24^{g,z}
HiOx	Control	1.23^{b,t}	1.65^{bc,u}	2.05^{cd,v}	2.60^{c,w}	3.17^{c,x}	3.76^{c,y}	4.79^{b,z}
PVC	0.15% OG+0.30% AA	1.45^{b,t}	1.80^{bc,u}	2.29^{bc,v}	2.59^{c,w}	3.08^{c,x}	3.43^{cd,y}	3.77^{d,z}
PVC	0.225% OG+0.45% AA	1.38^{b,t}	1.83^{bc,u}	2.33^{bc,v}	2.68^{c,w}	3.13^{c,x}	3.42^{cd,y}	3.90^{d,z}
PVC	1.25% AA	1.32^{b,t}	1.67^{bc,u}	2.18^{bc,v}	2.45^{c,w}	2.86^{cd,x}	3.26^{d,y}	3.75^{d,z}
PVC	1.875% AA	1.30^{b,v}	1.67^{bc,w}	2.20^{bc,x}	2.44^{c,x}	2.75^{d,y}	2.81^{e,y}	3.24^{e,z}
PVC	2.5% AA	1.42^{b,v}	1.84^{bc,w}	2.29^{bc,x}	2.48^{c,x}	2.77^{d,y}	2.90^{e,y}	3.39^{e,z}
PVC	Control	1.44^{b,u}	1.92^{b,v}	2.48^{c,w}	3.24^{b,x}	3.81^{b,y}	4.30^{b,z}	4.31^{c,z}

[a] 1=bright reddish-pink to red, 2=dull reddish-pink, 3=slightly grayish-pink or –red, 4=grayish-pink or –red, 5=moderately gray, 6=all gray or grayish-black, and 7=black discoloration

[b,c,d,e ,f,g] Means with different superscript letters within columns differ ($P < 0.05$)

[t,u,v,w,x,y,z] Means with different superscript letters within rows differ ($P < 0.05$)

Table 2. Visual color scores[a] of pork lumbar vertebrae packaged in ultra-low-oxygen MAP displayed 8 d pooled across treatments

	Day						
	0	1	2	3	4	5	8
Score	1.95^{b}	2.32^{c}	2.80^{d}	3.13^{e}	3.41^{e}	3.51^{e}	3.74^{f}

[a]1=bright purplish-red -pink, 2=dull purplish or -pink, 3=slightly grayish-purple or –pink, 4=grayish -purple or –red, 5=moderately gray, 6=all gray or grayish-black, and 7=black discoloration

[b,c,d,e,f]Means with different superscript letters differ ($P < 0.05$)

Table 3. L* values of pork lumbar vertebrae treated with different antioxidants and displayed 8 d

Packaging	Antioxidant	Day 0	Day 2	Day 8
HiOx	0.15% OG+0.30% AA	48.87^{cd,y}	52.71^{abc,z}	44.22^{ghi,x}
HiOx	0.225% OG+0.45% AA	49.39^{bcd,y}	51.30^{abcd,z}	42.36^{hi,x}
HiOx	1.25% AA	49.42^{bcd,y}	53.33^{ab,z}	45.30^{efg,x}
HiOx	1.875% AA	48.79^{cd,y}	52.69^{abc,z}	48.62^{bc,y}
HiOx	2.5% AA	48.69^{d,y}	53.81^{a,z}	45.77^{efg,x}
HiOx	Control	48.60^{d,y}	51.49^{abcd,z}	41.09^{i,x}
PVC	0.15% OG+0.30% AA	49.53^{abcd,y}	51.31^{abcd,z}	47.15^{cde,x}
PVC	0.225% OG+0.45% AA	48.61^{d,z}	49.50^{defg,z}	46.85^{def,y}
PVC	1.25% AA	48.54^{d,y}	50.71^{cde,z}	49.42^{ab,yz}
PVC	1.875% AA	49.04^{cd,y}	50.67^{cdef,z}	50.73^{a,z}
PVC	2.5% AA	49.45^{abcd,z}	51.07^{bcde,z}	50.02^{ab,z}
PVC	Control	48.73^{cd,y}	50.56^{cdef,z}	48.83^{bc,y}
ULOx	0.15% OG+0.30% AA	50.10^{abc,y}	48.03^{g,y}	44.17^{ghi,z}
ULOx	0.225% OG+0.45% AA	51.34^{a,y}	48.30^{fg,y}	43.89^{ghi,z}
ULOx	1.25% AA	50.59^{abc,y}	49.85^{defg,y}	44.20^{ghi,z}
ULOx	1.875% AA	51.06^{ab,y}	50.71^{cde,y}	45.67^{efg,z}
ULOx	2.5% AA	50.67^{ab,y}	49.51^{defg,y}	44.28^{fg,z}
ULOx	Control	51.20^{ab,y}	49.15^{efg,y}	45.12^{efg,y}

^{a,b,c,d,e,f} Means with different letters within a column differ ($P < 0.05$)
^{x,y,z} Means with different letters within a row differ ($P < 0.05$)

Table 4. a* values of pork lumbar vertebrae treated with different antioxidants and displayed 8 d

Packaging	Antioxidant	Day 0	Day 2	Day 8
HiOx	0.15% OG+0.30% AA	$23.09^{abc,x}$	$28.91^{a,y}$	$36.19^{b,z}$
HiOx	0.225% OG+0.45% AA	$22.70^{abc,x}$	$29.42^{a,y}$	$37.34^{b,z}$
HiOx	1.25% AA	$23.40^{ab,x}$	$29.89^{a,y}$	$37.21^{b,z}$
HiOx	1.875% AA	$23.61^{ab,x}$	$29.86^{a,y}$	$36.07^{b,z}$
HiOx	2.5% AA	$23.14^{abc,x}$	$29.03^{a,y}$	$39.66^{a,z}$
HiOx	Control	$22.64^{abc,y}$	$30.84^{a,y}$	$26.97^{de,z}$
PVC	0.15% OG+0.30% AA	$22.27^{bc,x}$	$29.01^{a,z}$	$26.72^{ef,y}$
PVC	0.225% OG+0.45% AA	$22.90^{abc,y}$	$28.76^{a,z}$	$27.10^{de,z}$
PVC	1.25% AA	$23.47^{ab,x}$	$29.47^{a,z}$	$25.73^{ef,y}$
PVC	1.875% AA	$22.50^{abc,y}$	$29.00^{a,z}$	$29.09^{cd,z}$
PVC	2.5% AA	$22.37^{abc,y}$	$29.01^{a,z}$	$28.29^{cde,z}$
PVC	Control	$23.82^{a,x}$	$29.37^{a,z}$	$25.91^{ef,y}$
ULOx	0.15% OG+0.30% AA	$22.68^{abc,y}$	$19.79^{cd,x}$	$27.49^{de,z}$
ULOx	0.225% OG+0.45% AA	$21.98^{abc,y}$	$20.66^{bc,y}$	$28.38^{cde,z}$
ULOx	1.25% AA	$22.76^{abc,y}$	$20.34^{c,x}$	$29.43^{c,z}$
ULOx	1.875% AA	$22.22^{bc,y}$	$17.91^{d,x}$	$24.29^{f,z}$
ULOx	2.5% AA	$21.52^{c,y}$	$18.74^{cd,x}$	$28.14^{cde,z}$
ULOx	Control	$22.25^{bc,y}$	$21.27^{b,y}$	$28.91^{cde,z}$

^{a,b,c,d,e,f} Means with different letters within a column differ (P <0.05)

^{x,y,z} Means with different letters within a row differ (P <0.05)

Table 5. a*/b* values of pork lumbar vertebrae treated with different antioxidants and displayed 8 d

Packaging	Antioxidant	Day		
		0	2	8
HiOx	0.15% OG+0.30% AA	$1.26^{a,z}$	$1.25^{ab,z}$	$1.14^{d,y}$
HiOx	0.225% OG+0.45% AA	$1.25^{ab,z}$	$1.24^{abc,z}$	$1.24^{abc,z}$
HiOx	1.25% AA	$1.25^{ab,z}$	$1.25^{ab,z}$	$1.16^{d,y}$
HiOx	1.875% AA	$1.26^{a,z}$	$1.25^{ab,z}$	$1.20^{cd,y}$
HiOx	2.5% AA	$1.26^{a,z}$	$1.23^{abc,z}$	$1.15^{d,y}$
HiOx	Control	$1.27^{a,z}$	$1.28^{a,z}$	$1.02^{ef,y}$
PVC	0.15% OG+0.30% AA	$1.24^{ab,z}$	$1.21^{bcd,z}$	$1.03^{ef,y}$
PVC	0.225% OG+0.45% AA	$1.26^{a,z}$	$1.21^{bcd,z}$	$1.02^{ef,y}$
PVC	1.25% AA	$1.20^{bc,z}$	$1.23^{abc,z}$	$0.99^{f,y}$
PVC	1.875% AA	$1.25^{ab,z}$	$1.23^{abc,z}$	$1.07^{e,y}$
PVC	2.5% AA	$1.24^{a,z}$	$1.21^{bcd,z}$	$1.04^{ef,y}$
PVC	Control	$1.26^{a,z}$	$1.26^{a,z}$	$1.02^{ef,z}$
ULOx	0.15% OG+0.30% AA	$1.22^{ab,y}$	$1.14^{de,x}$	$1.27^{ab,z}$
ULOx	0.225% OG+0.45% AA	$1.19^{c,z}$	$1.13^{e,y}$	$1.20^{cd,z}$
ULOx	1.25% AA	$1.22^{ab,z}$	$1.14^{de,y}$	$1.23^{bc,z}$
ULOx	1.875% AA	$1.21^{bc,y}$	$1.12^{e,x}$	$1.31^{a,z}$
ULOx	2.5% AA	$1.21^{bc,y}$	$1.14^{de,x}$	$1.30^{a,z}$
ULOx	Control	$1.19^{c,z}$	$1.18^{cde,z}$	$1.23^{bc,z}$

^{a,b,c,d,e,f} Means with different superscript letters in column differ ($P < 0.05$)
^{x,y,z} Means with different superscript letters in row differ ($P < 0.05$)