K-STATE Research and Extension

CATTLEMEN'S DAY 2026

Determining the Effect of Electromagnetic Field-assisted Freezing on Shelf-stability of Beef Striploins

J.T. Looper, S.R. Hene, S.D. Lee, B.N. Flanders, T.G. O'Quinn, M.D. Zumbaugh, and M.D. Chao

Abstract

The objective of this study was to determine the effect of electromagnetic (EM) field-assisted freezing on beef color stability during the display of previously frozen beef striploins. Striploins were collected from both sides of 12 USDA Choice carcasses and halved into two equal parts (n = 48). Halves were randomly assigned to 0, 2, 4, or 8 kV of EM field and frozen under the designated treatment in a walk-in -4°F freezer for 24 hours. Following treatment, striploin halves were thawed for 72 hours to at least 32°F, fabricated into steaks, and one 1-in. steak and four ½-in. steaks from each portion were overwrapped and subjected to a 10-day simulated display. Instrumental and descriptive color measurements were taken daily. Representative steaks from each portion were frozen and powdered for lipid oxidation and antioxidant capacity analysis on days 0, 4, 7, and 10. During the display period, 4 kV samples showed less discoloration than those from 0, 2, or 8 kV treatments on days 9 and 10. For instrumental color, a^* (redness) and b^* (yellowness) were the highest ($P < 0.01$) in 4 kV samples, followed by 0 kV and 2 kV, with samples from 8 kV having the lowest values ($P < 0.01$). On the other hand, L^* (lightness) values for 0 kV and 2 kV samples were higher ($P < 0.01$) than values from 4 kV and 8 kV. A treatment effect was found for hydrophilic, lipophilic, and total antioxidant capacity values, with the 4 kV treatment having the highest hydrophilic antioxidant capacity, and the 0 kV treatment being highest for the lipophilic portion ($P < 0.01$). However, no treatment effect was found for the lipid oxidation measurement ($P > 0.10$). The improvement in post-thaw color stability and antioxidant capacity from 4 kV could be due to an EM field treatment that resulted in less cellular damage during freezing; however, further research is needed to investigate the mechanisms causing increased antioxidant capacity.

Introduction

Freezing beef has become an increasingly important practice for packers due to fluctuating beef prices. While freezing is one of the few preservation methods that retains most of the fresh product quality, freezing is well documented to negatively affect the overall quality of meat. The formation of ice crystals can tear through and disrupt the structural and cellular components of muscle tissue; thus, previously frozen beef products tend to discolor more quickly than their fresh, never frozen counterparts, decreasing consumer acceptance and product shelf-life. As meat products are frozen more slowly, these negative qualities become more pronounced due to ice crystals

forming from the creation of one nucleus that has the ability to attract more water molecules and thus create larger ice crystals, resulting in greater structural damage.

To address the negative effects of slow freezing, processing aids such as the incorporation of an electromagnetic (EM) field during the freezing process have been investigated. Previous studies have reported EM fields as a promising intervention for cellular damage control and ice crystal reduction. However, many of these studies overlooked the potential of this technology to extend the shelf life of beef. Thus, the objective of this study was to determine the effect of EM field assisted freezing on beef color stability and lipid oxidation during the retail display of previously frozen beef striploins.

Experimental Procedures

Striploins (SL) were collected from both sides of 12 USDA Choice carcasses at a commercial processing facility in Kansas over a four-day period. Whole SLs were processed on-site, vacuum packaged, and transported to the Kansas State University Meat Laboratory. On each day of collection, six striploins were halved, and each half was randomly assigned to one of four freezing treatments: 0 kV, 2 kV, 4 kV, or 8 kV. Halves were then frozen for 24 hours in a walk-in freezer at -4°F under the designated continuous EM field treatment. Following treatment, SLs were vacuum packaged and stored in the same freezer for 8 days before thawing in a walk-in cooler set at 36°F for 72 hours. All samples were thawed to at least 32°F in the geometric center, purge was collected from the vacuum package, and swabs were taken from an approximate 4 × 4 in. square for aerobic plate count (APC). The SL halves were immediately fabricated into steaks, and one 1-in. steak and four ½-in. steaks from each portion were overwrapped and subjected to a 10-day simulated retail display under continuous fluorescent lighting. Instrumental L^* (lightness), a^* (redness), and b^* (yellowness) color measurements were taken using a HunterLab MiniScan EZ spectrophotometer on each day of display. Subjective color (percent discoloration) was also determined daily by trained panelists. Following days 0, 4, 7, and 10, one ½-in. steak from each portion was frozen with liquid nitrogen, powdered, and stored at -112°F for further analysis. These powdered samples were used to measure thiobarbituric acid reactive substances (TBARS) to determine lipid oxidation, and oxygen radical absorbance capacity (ORAC) to determine hydrophilic and lipophilic antioxidant capacity.

Results and Discussion

During the display period, an interaction between display day and EM field treatment was observed for percent discoloration ($P < 0.05$). All treatments maintained a similar level of discoloration until days 9 and 10, in which the 4 kV samples exhibited less discoloration than the 0, 2, and 8 kV treatments ($P < 0.05$; Figure 1). Main effects for treatment and display were found for L^*, a^*, and b^* ($P < 0.01$). For the display effect, overall a^* and b^* decreased steadily throughout the 10-day display while samples became increasingly lighter until day 4 and then remained constant throughout the remainder of display for all treatments ($P < 0.01$). For the treatment effect, a^* and b^* were the highest in the 4 kV group, followed by 0 and 2 kV, while the 8 kV group had the lowest values ($P < 0.01$; Table 1). The L^* values for 0 and 2 kV groups were higher than values from the 4 and 8 kV treatments ($P < 0.01$; Table 1). Finally, no differences in APC for swabs and purge were observed among the EM field treatments ($P > 0.05$). A day effect was found for antioxidant capacity and lipid oxidation values, with lipid oxidation and antioxidant capacity increasing over time ($P < 0.01$; Table 1). Interestingly, a treatment effect was found for hydrophilic, lipophilic, and total antioxidant capacity ($P < 0.01$).

The 4 kV treatment had a higher antioxidant capacity for the hydrophilic portion than those from the 0, 2, and 8 kV treatments ($P < 0.01$; Table 1). For the lipophilic portion, the 0 kV treatment measured higher antioxidant capacity than those from the 2, 4, and 8 kV treatments ($P < 0.01$; Table 1). As a result, total antioxidant capacity for the 4 kV treatment was higher ($P < 0.01$) than those from 2 and 8 kV but was not different from those for the 0 kV treatment (Table 1).

The data showed that the 4 kV treatment appeared to increase hydrophilic antioxidant capacity in the sarcoplasm through an unknown mechanism, and this increase in hydrophilic antioxidants was capable of further delaying myoglobin oxidation. It is possible that the 4 kV treatment was most effective in decreasing the overall ice crystal size, thus reducing structural damage and preventing the leakage of reactive oxygen species out of various cellular compartments.

Implications

The 4 kV group showed better color stability objectively and subjectively throughout the display period, and differences in visual shelf life could not be attributed to microbial load differences. The 4 kV treatment provided a higher level of hydrophilic antioxidant capacity throughout the display. This retention in color stability provides economic incentives for beef processors; however, it is unclear as to what mechanisms caused an increase antioxidant capacity in the 4 kV treatment. Further research is needed to investigate the mechanisms that could affect color retention and antioxidant capacity in EM field-assisted frozen beef.

Acknowledgments

This research was funded by the National Cattlemen's Beef Association, a contractor to the Beef Checkoff.

Table 1. Main effect of electromagnetic field treatments on instrumental color, oxygen radical absorbance capacity (ORAC), and lipid oxidation assay of beef striploins

	0 kV	2 kV	4 kV	8 kV	SEM[1]	*P*-value[2]
*L** value	38.36^{a}	38.43^{a}	37.34^{b}	37.67^{b}	0.20	<0.01
*a** value	16.60^{b}	16.28^{bc}	17.17^{a}	16.15^{c}	0.15	<0.01
*b** value	16.18^{b}	16.02^{bc}	16.56^{a}	15.77^{c}	0.16	<0.01
Lipophilic ORAC (TE[3]/g meat)	0.54^{a}	0.31^{b}	0.36^{b}	0.35^{b}	0.04	<0.01
Hydrophilic ORAC (TE/g meat)	10.28^{b}	10.10^{b}	11.87^{a}	9.19^{b}	0.67	<0.01
Total ORAC (TE/g meat)	10.82^{ab}	10.41^{b}	12.23^{a}	9.54^{b}	0.68	<0.01
Lipid oxidation (mg MDA[4]/kg meat)	1.39	1.63	1.39	1.54	0.12	0.10

[1]SEM = standard error of least-squares means.
[2]Least-square means within a row without common superscripts differ ($P < 0.05$).
[3]TE = Trolox equivalent.
[4]MDA = malondialdehyde.

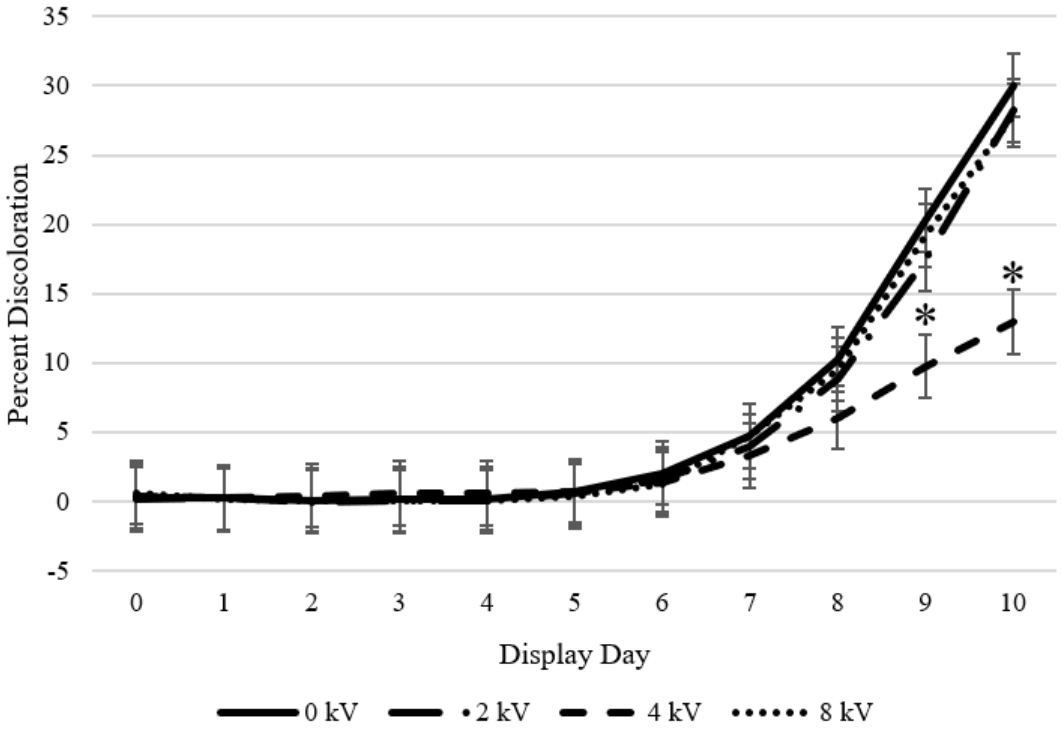

Figure 1. Interaction of display day and electromagnetic field-assisted freezing voltages on the percentage of beef striploin discoloration. The * indicate days (9 and 10) where there were significant differences in discoloration percentage in which samples from 4 kV have a lower percent discoloration compared to those from the other treatments ($P < 0.05$).